Annual Report 2005

Computer Science Department
of the
Faculty for Mathematics, Computer Science,
and Natural Sciences
at
RWTH Aachen University
Preface

One of the virtues of being the speaker of the Computer Science Department is the honor to write the preface for our annual report. This is indeed a very satisfying duty since this document contains a summary of all the scientific and non-scientific activities that our department performed during last year. The delight emerges from the fact that the year 2005 was, again, very successful in terms of scientific merits as well as teaching success and the completion of cooperations and projects.

With a team of now 24 professors, some 185 scientific staff (140 of them funded by third party grants), 42 non-scientific staff (some of them in part-time) and about 2000 students on the graduate and under-graduate level, our department constitutes one of larger units within the RWTH Aachen University. In addition to that, members of the department are actively cooperating with other research groups and industry companies at the local, national, and international level. All this amounts to a considerable outreach and impact of our work.

The successful completion of scientific research projects is well documented by the number of international publications (339) and the amount of money raised for research projects (6 million Euro), the major sources for our research funding being the German Science Foundation (DFG), the European Union, the Federal Ministry of Education and Research as well as various partners from industry. Beyond these “countable” achievements, members of the department have been involved in the organization of quite a number of international workshops and conferences, e.g., by chairing program committees or by hosting an event in Aachen, like

- 3rd MPEG-7 Community Workshop, MPEG-7 and Multimedia Metadata
- SEUH 2005, workshop together with the GI and the German Chapter of the ACM
- 2nd GI-Workshop on Virtual & Augmented Reality

Other highlights were the positive evaluation of our existing DFG Graduate College “Software for Communication Systems” as well as the installation of a new DFG Graduate College “Algorithmic Synthesis of Reactive and Discrete-Continuous Systems”. Moreover, some groups of the department are participating in other Graduate Colleges and Collaborative Research Centers, like SFB 476 “Computer Support for Cross-Company Development Processes in Chemical Engineering”, SFB 540 “Model-based Experimental Analysis of Kinetic Phenomena in Fluid Multi-phase Reactive Systems”, and SFB 401 “Modulation of flow and fluid-structure interaction at airplane wings”.

Several international scientific awards were won by members of the department (see later sections of this report), one prominent example being the honorary doctorate received by our colleague Prof. Wolfgang Thomas from the Ecole Normale Supérieure de Cachan (ENSC). Moreover, with Prof. Matthias Jarke being in office as the president of the German Computer
Society (GI) and Prof. Manfred Nagl being elected as the new chair of the Fakultätentag Informatik, members of our department are prominently involved in shaping the future of the field on the national level.

In our teaching programs, we started to prepare the switch from our established Diploma program to the Bologna-compatible Bachelor and Master programs, which is scheduled for fall 2006. Here we could exploit the experiences that we already made with our international Master programs, which we introduced in previous years. On the one hand, we are somewhat sentimental because our Diplom program was the result of many years of optimization of our teaching curricula and it yielded a large number of well qualified graduates who made their career in academia and industry. On the other hand, we consider this switch also as a good opportunity to re-think our established structures and to introduce an intermediate level of qualification. Our Bachelor graduates will be well prepared to work in the IT-industry, e.g. as a software developer, and will have the foundational knowledge to continue their training on the job or return to the university after some years of practical experiences. Future Master graduates, will still receive the same breadth and depth in their education as our current Diploma students.

As in most years we also had new colleagues joining the department and others leaving to take on new challenges elsewhere. In 2005, two new faculty members on the junior level, Prof. Heiko Mantel and Dr. Matthias Westermann, moved to Aachen, while Prof. Felix Freiling (successful introducer of the “hacker” competition at the RWTH) left to the University of Mannheim. One of our colleagues of the first hour, Prof. Klaus Indermark, retired this year. We would all like to thank him for his important role in shaping the department. A one-day honorary colloquium was organised for his farewell. We hope that he will continue to actively participate in the department life as an emeritus. Last but not least, our colleague Prof. Otto Spaniol had his 60th birthday, which was celebrated with a colloquium by the whole department.

With this short summary I would like to invite you to browse through the following pages where many more interesting and inspiring details are given about our activities. If you want to deepen the discussion about one or the other topic or project, please feel free to contact the corresponding person in charge. We are looking forward to your feedback!

Leif Kobbelt
Chair of the Computer Science Department
Aachen, May 2006
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Faculty Life
Tag der Informatik - Day of Computer Science 2005

The Tag der Informatik is a yearly event that generates awareness of the computer science department. Each chair, accompanied by industry partners, gathers for a one day symposium that presents recent research and teaching activities. Via talks, posters, software demonstrations, and hardware exhibits, participants acquire insight and understanding of the department’s activities. On December 2nd, the Chair of Computer Science 10 (Media Computing Group) organized and hosted this event.

The opening addresses were given by the Dean, Prof. Dr. W. Thomas, and Prof. Dr. Leif Kobbelt of the computer science department. Following this, new faculty members presented an overview of their research fields. This included Prof. Dr. Ir. J.-P Katoen (Lehrstuhl Informatik 2, Softwaremodellierung und -verifikation), Prof. Dr. H. Mantel (Arbeitsgruppe Informatik 4, Entwurf und Analysis sicherer Softwaresysteme), Prof. Dr. Th. Rose (Fraunhofer FIT, Medienprozesse), and Dr. M. Westermann (Arbeitsgruppe Informatik 1, Flexible Online-Algorithmen).

The first technical session was lead by Apple Computer’s Dr. Rafael Kobylinski. He explored the theme “Blick über den Tellerrand (Look Beyond your Nose)” and discussed the beneficial coexistence between Open Source and Apple. The second technical session explored the research of the computer science department. Research Assistants, from various chairs, held talks: David Holman (Informatik 10, “PaperWindows: Interaction Techniques for Digital Paper”), Dipl.-Math. Philipp Rohde (Informatik 7, “Erreichbarkeitsprobleme über sabotierten Netzwerken”), Dipl.-Inform. Darko Pavic (Informatik 8, “Interaktive Bildverarbeitung”), Dipl.-Inform. Ira Assent (Informatik 9, “Schnelle Multimedia-Ähnlichkeitssuche basierend auf der Earth Mover’s Distance”), and Dipl.-Inform. Bodo Kraft (Informatik 3, “Semantische Unterstützung des Gebäudeentwurfs”). Finally, the technical sessions ended with a closing talk by IBM’s Gunter Dueck, entitled “Der Informatiker in artgerechter Haltung.”

Following the end of the technical session, Jan Buchholz’s introduced the theme of this year’s software prize: “Jerry Potter.” Motivated by the wizardry of Harry Potter, contestants tested their magical skills in a game involving sorcery, spells, and gesture recognition. Hufflepuff, the winning group, dressed as wizards and accepted the award from SUN microsystem’s representatives Dr. Wilfried Stüttingen and Thorsten Maier.

The afternoon session ended with the student graduation ceremony. This included Prof. Dr. Klaus Indermark’s speech to the graduates and Prof. Dr. Leif Kobbelt’s presentation of diplomas to recent graduates.

With the official part of the day over, the evening banquet took place. The Jonathan Klein Trio provided live jazz during the banquet. This get-together was a chance for family, current students, and alumni to relax and celebrate. The building was packed – many participants enjoyed the food, drink, and music of this successful event. Later in the evening, DJ Stick Dojah thrilled the crowd with his live mixing of funk, house, and hip hop. The celebration, lasting late into the night, ended another successful and exciting Tag der Informatik. Thank you to all who participated.
Figure 1: (Left) David Holman presents “PaperWindows: Interaction Techniques for Digital Paper.” (Right) Posters, hardware, and software demonstrations take place throughout the day.

Figure 2: (Left) Team Hufflepuff, the winners of the Jerry Potter software prize. (Right) The student graduation ceremony takes place.

Figure 3: (Left) The Jonathan Klein Trio. (Right) The celebration lasted late into the night.
Sommerfest der Informatik – Computer Science Summer Party 2005

Each year, in the mid of the summer term, the Computer Science Department organises a summer party for the ceremonial presentation of diploma certificates to the graduates of the first half of the year. This year, the location of the event was the Computer Science Center. The summer party 2005 took place on Friday, June 3rd, 2005.

At the beginning of the summer party, Prof. Dr.-Ing. M. Nagl opened the event with an introductory talk, followed by a ceremonial talk given by Prof. em. Dr. W. Oberschelp. The official part ended with the ceremonial presentation of the diploma certificates, moderated by Prof. Dr.-Ing. S. Kowalewski. About 50 students have received their diplomas at this summer party.

After the official graduation celebration, the informal part of the summer party was started with a small buffet and several kinds of drinks. This year, the acoustic band Beets ‘n’ Berries accompanied the event with music for about three hours. About five hundred people have attended to this event, including the graduates and their families, current students, most of the staff of the computer science department, and several guests from other departments.
Informal part of the summer party. The acoustic band Beets ’n’ Berries.

The financing of the event was possible by the support of some sponsors, namely Ericsson, sd&m, and Kirchhof Software. Some of them had set out information stands to give interested students the chance to talk about job opportunities. With the help of this sponsoring, the summer party had gone on till late evening.
**Doctor honoris causa for Professor W. Thomas**

In November 2005, Prof. W. Thomas was awarded the honorary doctoral degree by the Ecole Normale Supérieure de Cachan (ENSC). The ENSC is one of the schools of excellence in the region of Paris, founded early in the last century and focussing on subjects in science and technology. Computer science is represented by the internationally highly reputed “Laboratoire de Spécification et Verification” (LSV), which has taken the initiative in the award procedure.

The ceremony on 18th November was preceded by a two days workshop under the title *Perspectives in Verification*. It was attended by about 100 participants from France, Germany, and other countries. After the opening by Philippe Schnoebelen, currently director of LSV, a series of invited talks gave a fascinating overview over the results and challenges in the field:

- Wolfgang Thomas (Aachen): Perspectives of algorithmic model theory
- Anca Muscholl (Paris): First-order logic with infinite alphabets
- Martin Grohe (Berlin): Law enforcement on hypergraphs
- André Arnold (Bordeaux): On simulation theorems in mu-calculi
- Erich Grädel (Aachen): Complexity measures for directed graphs
- Amir Pnueli (Weizmann, Rehovot/New York): Program synthesis in action
- Paul Gastin (Cachan): On the synthesis of distributed controllers
- Igor Walukiewicz (Bordeaux): Pushing the limits of pushdown verification

On the afternoon of the second day, the doctoral award ceremony took place, where Professors D. Chemla (Berkeley, Material Science), H. Fujita (Tokyo, MicroMechatronis), and W. Thomas received honorary doctoral degrees by ENSC.

W. Thomas and C. Dupas, Directrice of ENSC
For each of the laureates, a short presentation was given by a colleague of ENSC, and after the hand-over of the doctoral certificate by the Directrice of ENSC, Prof. C. Dupas, some words of the recipients followed. Antoine Petit from LSV gave a short account of the person and the work of W. Thomas, and the new honorary doctor replied in French with words of thanks, mentioning especially the fruitful bonds of scientific cooperation between Germany and France.

In a reception after the ceremony, many colleagues and young researchers from Paris, Aachen and many other places gathered for pleasant discussions, exchanging personal impressions and scientific ideas.
On Friday, November 4th, the Computer Science Department of RWTH Aachen University invited to a colloquium to the honor of Professor Klaus Indermark, who has retired in October. The programme was opened with greetings by the Dean of the Faculty of Mathematics, Computer Science, and Natural Sciences, Professor Wolfgang Thomas, and by the Speaker of the Computer Science Department, Professor Manfred Nagl. Then one of Professor Indermark’s scholars, Professor Herbert Klaeren from Tübingen University, gave a talk with the title *Wieso LISPeln Programmieren?* Finally the new head of the Chair of Computer Science 2, Professor Joost–Pieter Katoen, introduced his
research area with the lecture *What is Pointing When to Whom? Model Checking Heap–Manipulating Programs.*

For almost 30 years, Professor Indermark headed the Chair of Computer Science 2. Together with Professor Jürgen Merkwitz, who died in 1995, and Professor Walter Oberschelp, who retired in 1998, he is one of the founders of the Diploma Programme in Computer Science. Among students, Professor Indermark is considered to be one of the most popular academic teachers, mainly due to his didactically outstanding lectures. His staff record lists, among others, 26 successful PhD students and six habilitated assistants, eight of whom were later appointed to professorships.

Between 1962 and 1967, Professor Indermark studied Mathematics, Physics and Economic Science at Bonn University. He graduated in Mathematics and, working as a research fellow at the Gesellschaft für Mathematik und Datenverarbeitung (GMD), obtained his PhD in 1970 for a dissertation with the title *Zur Zustandsminimierung nicht–deterministischer Automaten.* Subsequently he lead a research group at the Institute for Automata Theory and Switching Circuits of the GMD.
After becoming a lecturer at the Institute for Applied Mathematics and Computer Science at Bonn University, he habilitated in Computer Science in 1974 and was appointed to a full professorship at the Chair of Computer Science 2 at RWTH Aachen University. Until his retirement he has been serving, among others, as the Dean of the Faculty of Mathematics, Computer Science, and Natural Sciences, as the Speaker of the Computer Science Department, and as the Head of the Examination Committee for the Diploma Programme in Computer Science.

Figure 8: Professor Joost–Pieter Katoen
Colloquium on the Occasion of Prof. Spaniol’s 60th Birthday

“Sechzig Jahre - Und Kein Bisschen Weise” is the title of a song made popular by Curd Jürgens (it would roughly translate to “Sixty and still not the least bit wise”). It might as well have been the motto of the colloquium. This is meant very positively - after all, wisdom is typically associated with old age, reserve, perhaps tranquillity, and none of these attributes would fit. Otto is still young at heart, very outspoken, and quite active. Nonetheless, this birthday clearly was an excellent reason for some celebrations.

The colloquium was held on 15 April. The festivities started rather informally, with some beer in the Informatik 4 seminar room. Eventually, everyone walked down to the foyer, where the guests were arriving. Here, wine and cheese were served slightly less informally.

The colloquium proper was opened by the Dean of the Faculty of Mathematics, Computer Sciences and Natural Sciences, Prof. Wolfgang Thomas, who happens to be a computer scientist as well. This means that he could talk about Prof. Spaniol and his various and varied activities at RWTH and within the Computer Science Group from first hand experience. It was quite surprising to see how much you can achieve if you really set your mind to it - the ‘Graduiertenkollegs’, the ‘Forum Informatik’, the list went on.

His remarks were followed by a speech by the Chairman of the Computer Science Group, Prof. Manfred Nagl. He recalled Prof. Spaniol’s career that led him from Saarbrcken to Aachen via Bonn and Frankfurt, and his numerous achievements in research and in science policy - German representative to, and twice chairman of, IFIP TC6, Head Evaluator (practical computer science) of the German Research Association (DFG) and, perhaps most importantly, member of the high-level German Research Council (‘Wissenschaftsrat’). On behalf of the CoSc
group he also unveiled one of Otto’s private interests - although not strictly a local, he’s a big fan of Alemannia Aachen (the local football club).

After these presentations the organisers clearly had felt that one can have too much of a good thing. Thus, the Laudatory Speech, which was delivered by Dr. Rolf Hager, an Alumnus of the Chair Informatik 4 and now a director with T-Mobile, showed a slightly different side of Otto Spaniol - the one you may get to see as a member of his group. Rolf took the audience on a journey through time. During this trip, it turned out that some classical figures are bearing an uncanny resemblance to Otto. The audience was fascinated.

The ’Keynote Speech’ was also a bit out of the ordinary. The name of the speaker was something of a mystery; at least, it was not included in the programme. He turned out to be Wendelin Haverkamp, a well-known cabaret artist from Aachen. He presented part of his programme, parts of which he had adapted to fit the occasion. It was to be expected - the birthday boy insisted on a speech. This presentation revealed Otto’s passion for poems in
the tradition of Ernst Jandl. Apparently, though, the poet himself felt that this required some form of refreshment.....

Following the colloquium, some (quite a few, really) of Prof. Spaniol’s friends and colleagues, and his staff were invited for dinner at the ‘Ratskeller’, located, as the name suggests, underneath the Town Hall. Rumour has it that some stayed rather long, and had eventually to be ushered out by the tired restaurant staff.

All in all, it was a highly successful, instructive, and entertaining event.
1 New Professors

In 2005, two new colleagues joint our department: Heiko Mantel and Matthias Westermann.

In the following the new colleagues introduces themselves with a brief description of their research fields and some biographical information.

1.1 Heiko Mantel

In August 2005, I joined the Computer Science department of the RWTH Aachen as a Juniorprofessor in Security Engineering leading a research group in the Computer Science Action Program (Aktionsplan Informatik) of the German Research Foundation (DFG).

Before moving to Aachen, I spent almost two years as a postdoctoral researcher in David Basin’s information security group at the ETH Zürich. Earlier in my life, I enjoyed studying Computer Science at the TU Darmstadt and at the University of Colorado at Boulder. After my studies, I worked for several years as a researcher at the German Research Center for Artificial Intelligence (DFKI GmbH) in Saarbrücken where I gained valuable experiences in applying and in improving formal methods. During this time, I also spent extended research stays at Chalmers University in Gothenborg and at Cornell University in Ithaca. In July 2003, I obtained my PhD from Saarland University.

My research is driven by the question how we can improve the quality of software-based systems. My contributions include formal analysis techniques for verifying that systems satisfy given requirements, development principles for reliable systems, automated tools for supporting system development and analysis, and their application in the analysis and construction of critical software systems. In recent years, my focus has been mainly on
non-functional requirements, in particular, on aspects of information security. The high frequency and the persistence of security problems despite many technological advances support my opinion that there are fundamental, conceptual difficulties in this area that need to be overcome. Obtaining a deeper understanding of security requirements themselves, was one of my original goals in developing the MAKS, a formal framework for analyzing security properties. Later, the MAKS turned out to also be a suitable basis for security analysis techniques. Currently, the framework is used in the derivation of sound security engineering principles and in the model-based analysis of information systems. Another focal research interest is the development of language-based analysis techniques that allow one to automatically analyze the security of applications before running them. This appears an attractive solution for sanitizing code downloaded from the Internet or obtained from other untrusted sources. Pushing this technology forward towards applicability in the context of mobile devices is one of the current goals of my group.

At this point, I would like to thank my colleagues in the department for the very nice welcome and for providing support. This has been rather helpful in making it a very positive experience to pioneer the concept of a Juniorprofessor in the Computer Science department.

1.2 Matthias Westermann

In January 2005, I joined the Computer Science Department at RWTH Aachen University as head of the DFG research group Flexible Online Algorithms. Matthias Englert and Helge Bals accompanied me as PhD students from Dortmund University.

From 1989 till 1995, I studied computer science at Paderborn University. During the last terms, I became very enthusiastic about algorithms and other topics of theoretical computer science. As a consequence, I joined the research group “Theoretical Computer Science” headed by Friedhelm Meyer auf der Heide at Heinz Nixdorf Institute and Paderborn University. In 2000, I finished my PhD dealing with distributed randomized algorithms for data management in large computer networks. After staying for eleven years in Paderborn, I joined the “Algorithms Group” headed by Richard Karp at the International Computer Science Institute in Berkeley, California, in 2001. This one year postdoc scholarship was funded by the DAAD. In 2002, I joined the research group “Parallel and Distributed Computing” headed by Susanne Albers at Feiburg University. Right after my return to Germany, my research group “Flexible Online Algorithms” got funded by the DFG. The first two years, this research group was located at Dortmund University.

Our research is centered around the design and theoretical analysis of algorithms. The main focus lies on system algorithms characterized best by the fact that they have in practice an infinite running time, and, during the running time of these algorithms, new jobs are permanently generated, e.g., requests to data distributed in a computer network. The research is highly motivated by problems and questions appearing in practice. Besides tackling concrete practical problems, the aim is also to understand basic questions and, by using this knowledge, to design new algorithmic concepts for these basic questions. In this context,
probabilistic methods play a major role, since without these methods an efficient solution is often not possible.

The focus of the DFG research group lies on flexible online algorithms. Online algorithms studied in theory are characterized by the fact that they do not have knowledge about the whole input sequence of jobs in advance. Instead, the input sequence is generated job by job, and a new job is not issued until the previous one is handled by the online algorithm. In real applications, jobs can usually be delayed for a short amount of time, and hence the input sequence of jobs can be rearranged in a limited fashion to optimize the performance. This flexible online scenario occurs in many applications in computer science and economics, e.g., in computer graphics: A rendering system displays a sequence of primitives. The number of state changes of such a system is a significant factor for the performance. State changes occur when two consecutively rendered primitives differ in their attribute values, e.g., in their texture. With the help of a reordering buffer that can buffer primitives, the sequence of primitives can be reordered online in such a way that the number of the state changes is reduced. Challenges of the DFG research group are to identify fundamental problems in the flexible online scenario and to design and analyze algorithms for them.
Teaching
Description of the contents and curriculum of the

*Computer Science (Diploma) - program*

at RWTH Aachen University

**Short description:**

Computer science is the research field dealing with the analysis, the conceptual planning, the implementation, and the application of information processing systems. This requires the study of the basic ideas and fundamental terms like algorithm, process, language, knowledge, complexity, simulation, and communication. Theoretical computer science clarifies these terms, investigates the limits between the possible and the impossible and studies the complexity of algorithms.

Applied computer science is a problem-oriented engineering science – just like other engineering disciplines. The only difference is that a computer engineer’s tools are *algorithms* and the material is *information* instead of metal or silicon. Applied computer science offers and develops a variety of methods and techniques for programming languages, software development, information systems, communication systems, language- and image processing, computer graphics, and high performance computing. Many applications involve complex systems which consist of *agents*, communicating with each other and with the environment. Those “agents” can be software modules, but also machines. Other applications focus on finding efficient, scalable, and robust algorithmic solutions for a given problem with well-defined input and output data. As a consequence, computer science techniques enter almost all natural and engineering sciences as well as many areas of everyday life. So, computer science is a highly interdisciplinary science cooperating with various fields of application.

**Degree:** Diploma

**Standard period of study:** 9 semester (average duration: 12 semester)

**Registered students:** 2039 (total number in fall term 2005)

**Female rate:** approx. 13.5 %

**Required qualifications**

Multifaceted methods concerning the structuring, modeling, analysis and solution of problems are utilized within computer science. In fact, these go far beyond mere programming. Therefore, good mathematical knowledge is recommended (major high school course
favoured) while no deeper knowledge of a specific programming language or industrial experiences are required. During the study, good English knowledge is essential.

Overall structure

The curriculum is split into two parts. Stage I (Vordiplom) covers semesters 1 to 4 while stage II (Hauptdiplom) covers semesters 5 to 9.

Stage I (Vordiplom)

The technical and methodical basic knowledge in computer science is taught over approx. 80 semester hours in total. The pre-degree examination, which extends over five individual exams, is passed study-attendant and comprises the topics computer science I (programming, data structure), computer science II (computer structures, system programming), computer science III (theoretical computer science), mathematics I and II as well as one subsidiary subject. Practical course or practical training certificates are the precondition to an examination allowance. Normally, the examination is done in the form of a written test.

Stage II (Hauptdiplom)

Advanced knowledge concerning computer science and the subsidiary subject is acquired over approx. 75 semester hours. A specialization is necessary into one post-graduate study. Together with the theoretical and the practical computer science as well as the subsidiary subject it builds the four majors of the oral examination. In addition, four practical course or practical training certificates are to be provided and a written diploma thesis is to be made.

Study courses

The study courses can be chosen among: business administration, biology, chemistry, electrical engineering, production engineering, mathematics, medicine, physics and psychology. Other study courses, if offered at the RWTH Aachen, may be chosen upon approval by the examination committee.

Post-graduate studies

These correspond to the main research directions in the computer science department. Possible topics are amongst others: parallel algorithms, programming languages, software techniques, data communication and distributed systems, databases and information systems,
knowledge-representations and cognitive robotics, sample- and language detection, as well as computer graphics and high performance computing.

**Foreign study offer**

Here, we primarily mention the european SOCRATES-programs within which an exchange of students is possible between the respective participating universities. A temporary stay abroad should comprise a minimum of one semester, better two semester and is recommended right after the diploma pre-examination. The acceptance of study- and examination performance, obtained abroad, is possible.

**Subject-related specialty**

One specialty of studying computer science at the RWTH Aachen is the multifaceted cooperation between the computer science especially with the engineering science and the regional computer science industry, which makes professional experiences possible to the students early within their studies.

**Professional areas**

Computer Scientists may find employment in many different professional areas which all bear upon information technology. For example chip producers, telecommunication companies, software companies, consulting firms, and users of administration systems (banks, insurances, public service etc.) or automation technology (producing industry, automotive and airplane industry). Because of the increasing use of computer systems in all areas, presently the career opportunities of computer science graduates are excellent!
Description of the contents and curriculum of

**Principles of Computer Science**

as second major of the

**Technik-Kommunikation (Magister/Magistra Artium) - program**

at the RWTH Aachen University

Short description

*Technik-Kommunikation* is an interdisciplinary study major consisting of two main subjects. The compulsory first main subject is *Communication Science*. The second main subject is an eligible technical subject. Technical subjects currently offered are *Principles of Computer Science, Principles of Electrical Engineering and Information Technology, Technical Principles of Mechanical Engineering*, as well as *Technical Principles of Mining, Metallurgy, and Earth Sciences*. *Technik-Kommunikation* is coordinated by the education and research area *Textlinguistik* headed by Prof. Eva-Maria Jakobs located in the Philosophical Faculty of the RWTH Aachen.

The first main subject *Communication Science* combines educational offers of several disciplines of the humanities at the Philosophical Faculty at the RWTH Aachen. The main focus of *Communication Science* is to mediate competencies in communication, transfer, legislation/standards, document testing, creativity, rhetoric, technical terminology, media/multimedia, sociology, psychology, foreign languages, and further training.

The second main subject *Principles of Computer Science* offered by the Computer Science Department of the RWTH Aachen aims at qualifying students to follow the development of computer science and its applications in breadth. Furthermore, an eligible specialization direction is intended to provide a training example for getting acquainted with a specific field of computer science. For example, this will be vital for cooperation in concrete projects of computer science (e.g. for system or user documentation, or the moderation of design processes), or during concentrated journalistic investigation in new areas of computer science.

As indicated by the statistics below, more than half the students matriculated for *Technik-Kommunikation* have chosen *Principles of Computer Science* as their second main subject.

**Degree:** Magister/Magistra Artium

**Standard period of study:** 9 semester (offered since winter semester 1999/2000)
Required Qualifications

Besides a general technical interest, and the requirements for the first main subject Communication Science which comprise communicative skills in speech and writing, the second main subject Principles of Computer Science requires good mathematical knowledge, whereas knowledge of a specific programming language or industrial experiences are not required. During the study, good English knowledge is essential.

Overall Structure

The curriculum of the second main subject Principles of Computer Science is split into two parts. Stage I covers semesters 1 up to 4 while stage II covers semesters 5 to 9.

Stage I

The technical and methodical principles of computer science are taught over approx. 41 semester hours in total. The intermediate examination (Zwischenprüfung), which extends over four individual exams, is passed study-attendant and comprises the topics Computer Science I (Programming, Application Software and Internet, Algorithms and Data Structures, Software Development), Computer Science II (Computability and Complexity, Computer Organization), and Mathematics (Linear Algebra, Differential and Integral Calculus). Practical courses or practical training certificates are prerequisite to an examination allowance. Examinations usually are performed in the form of a written test. In addition to the courses already mentioned, a course electronics in computer science and a software practical have to be undertaken.

Stage II

Advanced and exemplary specialization knowledge of computer science is acquired over approx. 40 semester hours. This stage is threefold into the Compulsory Eligible Subject, Central Computer Science (a set of eligible courses making up 14 semester hours), and the Computer Science Specialization (Stage II includes System Programming, Automata Theory and Formal Languages, a mathematical course depending on the choice of specialization direction, and a choice of courses offered by the Department of Computer Science). For the second main subject Principles of Computer Science, Central Computer Science and the Computer Science Specialization will make up the two majors of the oral examination to obtain the Magister/Magistra Artium degree. In addition, one practical training and one seminar certificate have to be performed successfully.

Professional Areas

Graduates of Technik-Kommunikation with second main subject Principles of Computer Science will be able to find employment in a diversity of professional areas. The main focus
will always be on knowledge transfer - possible areas are: documentation, presentation, public relations, corporate communication, technical writing, media management, information management, interface design, usability testing, concept development, as well as further training.
Secondary School Teachers’ Curriculum in Computer Science

The subject of computer science at school

The aim of this curriculum is to give future teachers (in secondary school education) a firm basis for the school subject of computer science. This curriculum has been established a response to the growing importance of computer science in all branches of science and society. A central issue in the school education of computer science is its broad understanding of computer science as a discipline which provides concepts and tools for the analysis and construction of information processing systems - a scope which clearly transcends ”programming” and the ability to run software systems.

Pupils should acquire fundamental concepts and some essential methods of computer science at school, thus looking beyond the superficial use of computer games and internet functions as every young person experiences them today.

The computer science curriculum for teachers is offered since the fall of 2000. The subject can (and must) be combined with another subject of study, like mathematics, physics, chemistry, biology, or any other subject, e.g., German or a foreign language. A smaller part (about one fifth) of the total curriculum has to be devoted to pedagogical studies.

An overview of the curriculum

Within the computer science curriculum, the first two years are concerned with basic foundations. The following courses have to be passed (each of them accompanied by practical exercises): Introduction to Programming, Computer Structures, Data Structures and Algorithms, System Programming, and Automata and Formal Languages. In addition, a software practicum and a proseminar are obligatory.

In the second phase, the third and fourth year of studies, a collection of more special subjects are to be chosen which have to cover a prescribed range of areas: Theoretical science, practical computer science, mathematical methods of computer science, and didactics of computer science. Five tracks of courses (and/or seminars) have to be selected such that all mentioned four major areas are represented. Final exams are to be passed in all chosen tracks. Also a thesis has to be prepared (in one of the subjects of study, though not necessarily in computer science).

The essential prequisites for a successful study of computer science are similar as for the diploma curriculum: a certain acquaintanse with abstract methods and constructions as they are learned and trained in mathematics. Moreover, the ability to communicate with others (and of course, in particular with children) is a necessary condition for future success as a teacher.
In 2000, the Computer Science Department launched the two-year Master programme *Software Systems Engineering*. It is primarily intended for international students holding a Bachelor degree in Computer Science, Computer Engineering, or a closely related field from an internationally recognized university-level institution. The programme aims to attract very good, if not the best students from all over the world in pursuit of a Master degree in Computer Science. In order to make the programme as attractive as possible to non-German speaking students, courses are offered entirely in English. To successfully complete the programme, students are required to earn 120 ECTS credits, including 30 credits for the Master thesis and 10 for German language classes. At present, about 80 students from 20 countries are enrolled in the programme.

Building on the strengths of our department, the programme focuses on the design and implementation of complex software systems, including their embedding in technical and socio-technical systems. The degree programme consists of a core curriculum and an area of specialization.

The core curriculum spans both Theoretical Computer Science (for example, Complexity Theory, Logic, Theory of Parallel Processes, Compiler Construction) and Practical Computer Science (for example, Programming Languages, Communication and Distributed Systems, Information Systems, Artificial Intelligence, Speech and Image Processing, Computer Graphics and Multi Media, Embedded Systems). The student is required to cover both subfields in sufficient breadth, which typically means taking three courses in each of the two subfields. In addition, a course on the management of large software system engineering projects is mandatory.

The area of specialization, which consists of courses combined with a seminar and a Master Thesis, can be any of the research areas of the Computer Science faculty members. The Master Thesis typically occupies the final six months of the programme and can be undertaken in cooperation with industry.

Since September 2004, Software Systems Engineering is also part of the *Erasmus Mundus* programme *European Master in Informatics*, which is offered together with the University of Edinburgh and the University of Trento. Participating students receive a two-year scholarship and spend the middle two semesters at one of the partner universities. At the end of the programme, they receive a double degree.
Media Informatics
Master Programm of RWTH Aachen University

Goals of the Programme

Whilst a Bachelor degree in Computer Science typically qualifies a person to participate in large software projects, the Master degree provides the skills needed for leadership. Graduates of the programme Media Informatics can be expected to be technically innovative, to work as system architects, and to manage large projects. Students who excel during their Master’s programme will also have the necessary qualifications to pursue a doctoral degree.

Formal Entrance Requirements

A candidate should have a recognised first degree (Bachelor of Science or Engineering) in Computer Science, Computer Engineering, Informatics, or other closely related discipline, awarded by an internationally recognised university-level institution. Candidates should have also performed above average in their undergraduate studies. The Graduate Record Examination (GRE) is also strongly recommended. For English-taught programmes candidates must be able to speak and write fluently in English (TOEFL 550 paper-based /213 computer-based or IELTS 6.0). English-speaking students attend a basic German language course that will start in August, two months prior to the beginning of the master programme. See English Language Requirements for RWTH Master Programmes and How to apply to RWTH Master Programmes for further information.

Special Entrance Requirements

The candidate should have a substantial background in computer science and mathematics. Typically this would include previously taken courses in the following areas: Calculus, Linear Algebra, Discrete Mathematics and Logic, Numerics, Probability Theory, Fundamentals of Computer Programming, Computer Architecture, Data Structures, Analysis of Algorithms, Programming Languages, Automata Theory, Computability and Complexity Theory. In addition, an applicant should have at least two advanced undergraduate courses on specialised topics such as Distributed Systems, Information Systems, Operating Systems or Multimedia Techniques.
General Description of the Programme

The international Master Programme in Media Informatics was introduced in 2002 at the Bonn-Aachen International Center for Information Technology (B-IT). Media Informatics is offered by RWTH Aachen University and the University of Bonn in co-operation with the Fraunhofer Institutes at Sankt Augustin near Bonn. This interdisciplinary programme will educate the participant to successfully master the novel technical and economic challenges at the crossroads of computer science, software engineering, next-generation communication systems, and media. The programme is distinguished by its international orientation, its focus on IT competence, and its high level of integration of research and teaching. The master’s programme in Media Informatics consists of three main blocks: computer science and mathematical foundations, basic principles in media science and business, media informatics. The programme is characterised by a significant proportion of research lab courses embedded in both basic and applied research of the participating Fraunhofer Institutes of Applied Information Technology (FIT), and Media Communication (IMK). Major topics include: digital interactive media, internet infrastructures, management of information, communication and security, knowledge management, visualisation, and virtual engineering on the basis of augmented reality. Special courses on modelling of spatial and mobile aspects, and on usage, annotation, and retrieval of spatial data provide for a special focus in the important application domain of Geographical Information Systems. The programme of study also includes methodological aspects of designing media informatics systems from the perspectives of software engineering, usability, media design, and business requirements. The final six months of the programme are dedicated to the master thesis which can be done in co-operation with industry. The course contents is structured according to the ECTS (European Credit Transfer System).

Career Opportunities

Computer scientists with an applied focus have been in great demand in the past, and this trend is expected to continue for the foreseeable future. With an M.Sc. degree in Media Informatics you will be well-prepared for the typical challenges faced when working in computer systems engineering and for creative work with audio-visual media. The ABCD region (Aachen, Bonn, Cologne; Düsseldorf) is home to many prospective employers, including global players such as Philips, Deutsche Telekom, Vodafone, Bertelsmann Group, as well as many television stations such as WDR, VIVA, etc.

Language of Instruction

The Programme will be taught completely in English

Duration of the Programme

Two years
Beginning of the Programme
October

Deadline for application:
March 1st the same year the programme starts

Further information
For further general information please check the RWTH webpages. If you have specific questions on course content please contact:

RWTH Aachen University
Department of Computer Science 4
Media Informatics Team
52056 Aachen, Germany

E-Mail: msc-mi@b-it-center.de
Webpage: http://mi.b-it-center.de/
The Girls’ Day is organized nationwide once a year. It provides an opportunity for 10- to 16-year-old female pupils to get to know professions especially in technical areas and in the domain of science. In 2005, two different computer science workshops were offered by computer scientists from RWTH Aachen. In total, they were attended by about 34 pupils.

One workshop was organized in collaboration of several computer science chairs. It was a full-day workshop consisting of a practical part and a theoretical part. In the morning, the pupils had the chance to experiment themselves with a tool that gives an understanding of the basic elements of programming. A robot can be controlled by small programs to accomplish simple tasks like moving items over a field. Using this environment, it is possible to solve more complex tasks like the addition of binary numbers.

In the afternoon, the pupils visited different institutions of the Computer Science Faculty. The Computer Science Library gave an overview of their work and the services they offer. The media computing group (i10) demonstrated two of their research systems: the “Personal Orchestra” system which recognizes gestures and allows the user to conduct world-famous orchestras, and a system which controls large displays via handycams. The chair for pattern recognition and human language technologies (i6) presented a speech translation system. The system recognizes German speech and automatically translates it into English. Afterwards, the English sentences are uttered via a speech synthesis component.

In the second workshop, a music video was produced with the girls both as actors and editors. Using an electric guitar, a DJ turntable and a giant wig among many other things, they turned the computer science building into a video clip scenery. Two groups produced a music video for some of their favorite tracks using a digital video camera and a computer-based video editing system while a third group created their own track using a loop-based music software. The girls could take the results of their work home with them on CD.
The Schnupperstudium is organized by RWTH once a year. It provides female pupils an opportunity to get to know programmes of study with a low ratio of female students – such as computer science.

In 2005, two computer science workshops were offered by female computer scientists from RWTH Aachen. In both groups of 18 pupils each, scientists gave an impression of the variety of research activities the computer science departments are engaged in.

The study programme at RWTH was introduced by two computer science students. They presented the organizational and technical aspects of the studies as well as their personal experiences. The pupils got an impression of life at university and the personal skills necessary for studying computer science. Furthermore, several professions in the area of computer science were presented.

The pupils of age 16 to 19 had the chance to get their own impression of computer science by learning a little bit about programming accompanied by some theoretical aspects. They enjoyed getting an opportunity to put this into practice by actually programming in a computer science lab.

The Markt der Möglichkeiten, a fair organized for the pupils, gave an overview of different programmes of study and offered information about central institutions such as Fächschaften, Studienberatung, and Berufsberatung.
1 Courses in Summer term (Sommersemester 05)

1.1 Undergraduate Courses 2nd semester

Freiling
Rechnerstrukturen (Computer Organisation)

Kobbelt
Datenstrukturen und Algorithmen (Data structures and algorithms)

Esser
Differentialgleichungen und Numerik (Differential Equations and Numerics)

Triesch
Diskrete Strukturen (Discrete structures)

1.2 Undergraduate Courses 4th semester

Rossmanith
Automatentheorie und Formale Sprachen (Automata Theory and Formal Languages)

Kamps
Einführung in die Stochastik für Informatiker (Introduction to Stochastics for Computer Scientists)

Noll
Hardware-Praktikum (f. Informatiker 4. Semester)

Schumacher, Fieger
Elektronische Grundlagen für Informatiker

Vöcking, Bongartz, Franke
Proseminar: Algorithmen und Datenstrukturen (Data structures and algorithms)

Rossmanith, Richter, Mölle
Proseminar: Insel der Zahlen (Surreal Numbers)

Giesl, Schneider-Kamp, Thiemann
Proseminar: Fortgeschrittene Programmierkonzepte in Java, Haskell und Prolog (Advanced Programming Concepts in Java, Haskell, and Prolog)

Nagl, Kirchhof, Wörzberger
Proseminar: Objektorientierte Softwareentwicklung in Eiffel

Freiling, Mink, Dornseif
Proseminar: Die 10 wichtigsten Veröffentlichungen im Bereich IT-Sicherheit (The top ten most important papers in computer security)

Berlage
Proseminar: Elementare Bioinformatik

Lakemeyer
Proseminar: Logische und Stochastische Methoden der Künstlichen Intelligenz (Logical and Stochastical Methods in Artificial Intelligence)
1.3 Graduate Courses

Vöcking, Röglin, Fischer  
**Optimierung und Spieltheorie**

Unger, Bongartz  
**Parallele Algorithmen**

Westermann  
**Online Algorithmen**

Indermark  
**Compilerbau (Compiler Construction)**

Katoen  
**Probabilistische Modelle für Verteilte Systeme (Probabilistic Models of Concurrency)**
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<td>Software-Qualitätssicherung und Projektmanagement (Software Quality Assurance and Project Management)</td>
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Formale Methoden für eingebettete Systeme

Kowalewski, Klünder, Wilking  
Entwurf eingebetteter Software (Embedded Software Design)

Bischof  
Rechnergestütztes Differenzieren (Computational Differentiation)

Bücker  
Parallele Algorithmen zur Vorkonditionierung linearer Systeme (Parallel Preconditioning Techniques for Linear Systems)

Naumann  
Kombinatorische Probleme im Wissenschaftlichen Rechnen (Combinatorial Problems in Scientific Computing)

Kraiss  
Mensch-Maschine Systeme II (Human Machine Systems II)

Walke  
Kommunikationsnetze II (Communication Networks II)

Rokitansky  
Stochastische Simulation II

Bemmerl  
Betriebssysteme II (Operating Systems II)

Niebert  
Vermittlungssysteme (Switching Systems)

Vöcking, Röglin, Newman  
Seminar: Combinatorial Optimization

Vöcking  
Lehrstuhlseminar Effiziente Algorithmen

Vöcking, Bongartz  
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Unger, Newman  
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Westermann, Franke  
Seminar: Online Algorithmen

Rossmanith, Richter, Mölle  
Seminar: Helping Donald Knuth

Indermark, Katoen, Noll  
Seminar: Modelling, Analysis, and Optimization of Object-Based Systems

Indermark, Giesl, Katoen  
Lehrstuhlseminar

Giesl, Thiemann, Schneider-Kamp  
Seminar: Verifikationsverfahren (Seminar: Verification Techniques)

Thomas, Löding, Rohde, Wöhrle  
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Grädel  
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Freiling, Mink, Dornseif, Pimenidis  Hacker-Praktikum (Hacker Lab)

Jarke, Oppermann  User-oriented system design and personalized information services for nomadic information and e-learning systems

Ney  Praktikum Data Mining Cup (Practical Course Data Mining Cup)

Kobbelt, Habbecke  Hauptpraktikum: Spezialeffekte (Practical Course: Special Effects)

Schroeder, Breuer, Giani  eLearning: Werkzeuge und Technologien

Kowalewski  Praktikum: Programmierung Eingebetteter Hardware (Programming embedded hardware)

Kraiss, Kuhlen  Praktikum: Virtuelle Realität (Laboratory on Virtual Reality)

Jarke, Quix, Kensche, Chatti  Model Management Lab

Dornseif  PenTest


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Giesel, Thiemann, Schneider-Kamp  Arbeitsgemeinschaft: Programmverifikation

Grädel, Thomas  Arbeitsgemeinschaft: Logik und Automaten

Nagl  Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge

Wallbaum, Spaniol  Arbeitsgemeinschaft: Mobilkommunikation (Study Group: Mobile Communications)

Seipold, Kritzner, Spaniol  Arbeitsgemeinschaft: Multimediakommunikation (Study Group: Multimedia Communication)

Imhoff, Thißen, Diepolder, Spaniol, Freiling  Arbeitsgemeinschaft: Verteilte Systeme (Study Group: Distributed Systems)

Kesdogan, Spaniol, Freiling  Arbeitsgemeinschaft: Privacy Enhancing Techniques (Study Group: Privacy Enhancing Techniques)

Jarke, Quix  Arbeitsgemeinschaft: Model Management (Working Group Model Management)

Jarke, Schlüter  Arbeitsgemeinschaft: Verfahrenstechnische Informationssysteme

Jarke, Klamma  Arbeitsgemeinschaft: Deduktive Objektbanken (Working group deductive object bases)

Lakemeyer  Arbeitsgemeinschaft: Kognitive Robotik (Working Group Cognitive Robotics)

Ney  Arbeitsgemeinschaft: Bilderkennung (Study Group Image Recognition)

Ney  Arbeitsgemeinschaft: Spracherkennung (Study Group Speech Recognition)

Ney  Arbeitsgemeinschaft: Sprachübersetzung (Study Group Machine Translation)

Kobbelt  Arbeitsgemeinschaft: Geometrische Modellierung (Study Group Geometric Modelling)

Spaniol  Graduiertenkolleg Software für Kommunikationssysteme (Graduate School Software for Communication Systems)

Nagl  Regionalgruppe Informatik Aachen

Freiling, Mink, Dornseif  Summerschool Applied IT Security 2005

Borchers  CHI Club

Grädel  Informatik-Kolloquium

Courses for Other Curricula (“Service Courses”)

Naumann  Software-Entwicklung

Jarke, Quix  Algorithmen & Datenstrukturen

Borchers, Ballaga, Lee  Designing Interactive Systems II

Spaniol, Thißen  Multimedia Systems
2 Courses in Winter term (Wintersemester 05/06)

2.1 Undergraduate Courses 1st semester

Giesl
Informatik I - Programmierung (Programming Concepts)[Prog]

Jongen
Analysis für Informatiker (Analysis for Computer Scientists)[MathIn]

Hiß
Lineare Algebra (Linear Algebra)[VLAI]

2.2 Undergraduate Courses 3rd semester

Ney
Systemprogrammierung (System Programming)

Grädel
Mathematische Logik (Mathematical Logic)

Vöcking
Berechenbarkeit und Komplexität (Computability and Complexity)

Aach
Elektronische Grundlagen für Informatiker

Vöcking, Röglin
Proseminar: Algorithmen Design

Katoen, Bohnenkamp, Rieger
Proseminar: Programmiersprachen

Thißen, Spaniol
Internet-Technologie (Internet Technology)

Jarke, Klamma
Netzwerkanalyse

Ney, Schlüter
Proseminar Datenkompression (Seminar Data Compression)

Seidl
Proseminar Methoden und Werkzeuge

Nagl, Kraft, Wörzberger
Software-Praktikum: Webbasiertes Koordinationssystem für verteilte Arbeitsprozesse

Jarke, Quix, Kensche
Praktikum: Entwicklung eines graphischen Editors für UML-Klassendiagramme in Java

Kobbelt, Hornung
Softwarepraktikum Computer Graphics (Basic practical course Computergraphics)

Borchers, Buchholz, Ballagas, Spelmezan, Lee
Softwarepraktikum: Multimodal Media Madness (Practical Course: Multimodal Media Madness)
### 2.3 Graduate Courses

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<tr>
<th>Instructor</th>
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<tr>
<td>Unger</td>
<td>Algorithmische Graphentheorie (Algorithmic Graph Theory)</td>
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<tr>
<td>Rossmanith</td>
<td>Analyse von Algorithmen (Analysis of Algorithms)</td>
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<tr>
<td>Katoen</td>
<td>Model Checking</td>
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<tr>
<td>Noll</td>
<td>Modellierung nebenläufiger Systeme (Modeling Concurrent Systems)</td>
</tr>
<tr>
<td>Thomas</td>
<td>Automata on Infinite Words</td>
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<tr>
<td>Löding, Thomas</td>
<td>Unendliche Spiele</td>
</tr>
<tr>
<td>Grädel</td>
<td>Endliche Modelltheorie und deskriptive Komplexität (Finite Model Theory and Descriptive Complexity)</td>
</tr>
<tr>
<td>Mathar</td>
<td>Kryptographie II (Cryptography II)</td>
</tr>
<tr>
<td>Nagl, Haase, Heller</td>
<td>Einführung in die Softwaretechnik (Introduction to Software Engineering)</td>
</tr>
<tr>
<td>Lichter</td>
<td>Objektorientierte Software-Konstruktion (Object-Oriented Software Construction)</td>
</tr>
<tr>
<td>Lichter, Weiler, von der Maßen, Nyßen, Schackmann</td>
<td>Software-Produktlinienentwicklung (Software Product Line Development)</td>
</tr>
<tr>
<td>Thißen, Spaniol, Wienzek</td>
<td>Datenkommunikation und Internet-Technologie (Data Communication and Internet Technology)</td>
</tr>
<tr>
<td>Kesdogan, Spaniol</td>
<td>Introduction to Security and Privacy</td>
</tr>
<tr>
<td>Thißen, Spaniol</td>
<td>Mobilkommunikation (Mobile Communications)</td>
</tr>
<tr>
<td>Jarke, Quix, Lübbers</td>
<td>Introduction to Database Systems</td>
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<tr>
<td>Jarke, Klamma, Chatti, Spaniol</td>
<td>Unternehmensgründung und neue Medien (Entrepreneurship and new Media)</td>
</tr>
<tr>
<td>Berlage</td>
<td>Einführung in die Bioinformatik (Introduction to Bioinformatics)</td>
</tr>
</tbody>
</table>
Broll
Virtual and augmented Reality

Ney
Statistical Methods in Natural Language Processing

Kobbelt
Computergraphik I (Computergraphics I)

Kobbelt
Geometrische Modellierung I (Geometric Modelling I)

Seidl
Indexstrukturen für Datenbanken

Schroeder, Giani
Web Engineering

Borchers
HCI Design Patterns

Borchers, Spelmezan, Holman
Designing Interactive Systems I

Kowalewski, Klünder
Dynamische Systeme für Informatiker

Kowalewski, Salewski
Introduction to embedded systems

Bischof
Einführung in High-Performance Computing (Introduction to High-Performance Computing)

Kuhlen
Virtuelle Realität (Virtual Reality)

Naumann
Adjungierte per Quellcodetransformation (Adjoints by Source Transformation)

Kraiss
Mensch-Maschine Systeme I (Human Machine Systems I)

Walke
Grundgebiete der Informatik 3 (Basics of Computer Science 3)

Habetha, Walke
Kommunikationsnetze I (Communication Networks I)

Rokitansky, Einhaus, Walke
Stochastische Simulation I

Vöcking
Lehrstuhlseminar: Effiziente Algorithmen

Vöcking, Fischer
Seminar: Algorithmische Spieltheorie

Unger, Bongartz, Vöcking
Seminar: Parallele Algorithmen

Westermann, Englert, Vöcking
Seminar: Randomisierte Algorithmen (Randomized Algorithms)

Rossmanith, Richter, Möller
Seminar: Exakte Algorithmen für NP-schwere Probleme (Exact Algorithms for NP-hard Problems)

Katoen, Kern, Noll
Seminar: Global Computing
Katoen, Giesl | **Lehrstuhlseminar**

Giesl, Thiemann, Schneider-Kamp | **Seminar: Automatische Terminierungsanalyse (Automated Termination Analysis)**

Thomas, Löding | **Seminar Automatentheorie**

Grädel | **Seminar: Entscheidbare Theorien (Decidable Theories)**

Mathar | **Seminar zur Kommunikationstheorie**

Nagl, Ranger, Armac | Visuelle Spezifikationssprachen und ihre Anwendung in eHome-Systemen (Visual Specification Languages and their Application in eHome Systems)

Lichter | **Lehrgebietsseminar**

Thißen, Spaniol | **Seminar Ubiquitous Computing**

Freiling, Mink, Dornseif | **Lehrgebietsseminar (Laboratory Seminar)**

Freiling, Mink, Dornseif | Konferenzseminar Verlässliche Verteilte Systeme (Conference Seminar on Dependable Distributed Systems)

Jarke, Claßen | **Logic-based Knowledge Representation**

Jarke, Lakemeyer | **Lehrstuhlseminar**

Jarke, Lakemeyer | **Doktorandenseminar**

Jarke, Berlage, Quix | Data Integration in Life Science Informatics

Lakemeyer | Diplomandenseminar (graduand seminar)

Ney | Seminar Speech Recognition and Natural Language Processing

Ney | Lehrstuhlseminar Fortgeschrittene Methoden in der Sprachverarbeitung (Lehrstuhlseminar Advanced Topics in Speech and Language Processing)

Kobbelt, Habbecke | Seminar 3D Reconstruction of Complex Real-World Objects

Kobbelt | Diplomanden- und Doktorandenseminar

Seidl | **Seminar: Aktuelle Entwicklungen des Data Mining (Seminar: Recent Developments in Data Mining)**

Seidl | **Lehrstuhlseminar**

Borchers, Ballagas, Spelmezan, Buchholz | **Seminar: Post-Desktop User Interfaces**
<table>
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<tr>
<th>Kowalewski, Wilking</th>
<th>Methoden der empirischen Softwaretechnik (Methods of empirical software engineering)</th>
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<tr>
<td>Kuhlen, Bischof</td>
<td>Seminar: aktuelle Themen der Virtuellen Realität</td>
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<tr>
<td>Naumann</td>
<td>Seminar: Kombinatorische Probleme im Wissenschaftlichen Rechnen (Combinatorial Problems in Scientific Computing)</td>
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<tr>
<td>Mantel</td>
<td>Current Topics in Information Security</td>
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<tr>
<td>Mantel</td>
<td>Network Security</td>
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<tr>
<td>Katoen, Weber, Rieger, Stolz</td>
<td>Praktikum Compilerbau</td>
</tr>
<tr>
<td>Nagl, Fuß, Nosler</td>
<td>Praktikum: Model-Driven Engineering von eingebetteten Systemen (Model-Driven Engineering of Embedded Systems)</td>
</tr>
<tr>
<td>Lichter, Schackmann</td>
<td>Praktikum Software-Konstruktion</td>
</tr>
<tr>
<td>Freiling, Mink, Dornseif</td>
<td>Building Walled Cities</td>
</tr>
<tr>
<td>Jarke, Oppermann</td>
<td>User-oriented system design and personalized information services for normadic information and e-learning systems</td>
</tr>
<tr>
<td>Jarke, Klamma, Chatti, Spaniol</td>
<td>Projektpraktikum Unternehmensgründung und neue Medien (Lab Hightech entrepreneurship and new media)</td>
</tr>
<tr>
<td>Lakemeyer, Claßen</td>
<td>Roboterpraktikum (Moblie Robot Lab)</td>
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<tr>
<td>Ney</td>
<td>Praktikum Sprach- und Bildverarbeitung (Laboratory Course Speech and Image Recognition)</td>
</tr>
<tr>
<td>Schroeder, Giani</td>
<td>eLearning Praktikum (eLearning Engineering Praktikum)</td>
</tr>
<tr>
<td>Kowalewski, Salewski, Wilking</td>
<td>Programmierung Eingebetteter Hardware (Programming embedded hardware)</td>
</tr>
<tr>
<td>Bücker, Vehrschild</td>
<td>Praktikum: Einführung in MPI (Introduction to MPI)</td>
</tr>
<tr>
<td>Diepolder, Thißen, Spaniol</td>
<td>Praktikum Verteilte Systeme (Labwork Distributed Systems)</td>
</tr>
<tr>
<td>Giesl, Thiemann, Schneider-Kamp</td>
<td>Arbeitsgemeinschaft: Programmverifikation (Wokring Group: Modelling Concurrent Systems)</td>
</tr>
<tr>
<td>Grädel, Thomas</td>
<td>Arbeitsgemeinschaft: Logik und Automaten (Working Group on Logic in Computer Science)</td>
</tr>
</tbody>
</table>
Nagl
Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge

Nagl
Anleitung zum selbst. wissenschaftlichen Arbeiten

Wallbaum, Spaniol
Arbeitsgemeinschaft: Mobilkommunikation (Study Group: Mobile Communication)

Seipold, Spaniol
Arbeitsgemeinschaft: Multimediakommunikation (Study Group: Multimedia Communication)

Kesdogan, Wienzek, Spaniol, Freiling, Mink, Dornseif
Arbeitsgemeinschaft: Sicherheit in der Kommunikationstechnik (Study Group: Security in Communication Systems)

Imhoff, Thiessen, Diepolder, Spaniol, Freiling, Mink, Dornseif
Arbeitsgemeinschaft: Verteilte Systeme (Study group: Distributed Systems)

Kesdogan, Spaniol
Arbeitsgemeinschaft: Privacy Enhancing Techniques (Study group: Privacy Enhancing Techniques)

Jarke, Klamma
Arbeitsgemeinschaft: Deduktive Objektbanken (Working group deductive object bases)

Jarke, Quix
Arbeitsgemeinschaft Model Management (Working Group Model Management)

Jarke, Schlüter
Arbeitsgemeinschaft Verfahrenstechnische Informationssysteme

Lakemeyer, Claßen
Arbeitsgemeinschaft Kognitive Robotik (Working Group Cognitive Robotics)

Ney
Arbeitsgemeinschaft Bilderkennung (Working Group Image Recognition)

Ney
Arbeitsgemeinschaft Sprachübersetzung (Working Group Machine Translation)

Ney
Arbeitsgemeinschaft Spracherkennung (Working Group Speech Recognition)

Kobbelt
Arbeitsgemeinschaft: Geometrische Modellierung (Working Group Geometric Modelling)

Schroeder, Giani
Arbeitsgemeinschaft Didaktik der Informatik (Computer Science Didactics)

Schroeder, Giani
Arbeitsgemeinschaft eLearning
Spaniol  
Graduiertenkolleg: Software für Kommunikationssysteme (Graduate school. Software for Communication Systems)

Prinz  
Kooperationsunterstützende Systeme - Neue Architekturen und Anwendungen (Computer Supported Cooperative Work (CSCW) - New Architectures and Applications)

2.4 Other courses

Kobbelt, Ney, Oberschelp, Repges, Spitzer, Lehmann  
Ringvorlesung Medizinische Bildverarbeitung (Medical Image Processing)

Grädel  
Informatik-Kolloquium (Computer Science Colloquium)

Luksch, Stoffel, Vorländer, Fels, Schnakenberg, Seidl, Lakemeyer, Offenhäuser  
Bionik I

Alles, Beiss, Blümunich, Bohn, Esser, Heinen, Jakobs, Kneer, Kugeler, Nebe, Mayer, Pischinger, Schreoder, Seidl  
Ringvorlesung: Faszination Technik

Courses for Other Curricula (“Service Courses”)

Thomas  
Automaten, Sprachen und Komplexität

Seidl  
Programmierung für Alle (Java)

Bücker  
Anwendungsssoftware und Internet

Borchers, Spelmezan, Holman  
Designing Interactive Systems I

Rose  
eBusiness Applications, architecture and standards

Rose  
Process Management

Linz, Jäger, Jarke  
Theories of Verbal and Pictorial Human Communication
3 Talks within the Computer Science Colloquium

January, 10    Prof. Dr. Artur Czumaj, New Jersey Institute of Technology, Newark
                Sublinear-time Approximation Algorithms

January, 13    Prof. Maurice Herlihy, Brown University, 2004 Gödel Prize Winner
                Distributed Computing and Combinatorial Topology

January, 17    Dr. Heiko Mantel, ETH Zürich
                Analysis of Secure Systems

January, 20    Alfred Hermes
                Thema: Fachdidaktik Informatik

January, 27    Prof. Dr. Bernt Schiele, Multimodal Interactive Systems Group, TU
                Darmstadt
                Multi-Sensor Context Awareness for Ubiquitous and Wearable Computing

April, 14      Prof. Dr. May Mühlhäuser, Telekooperation, TU Darmstadt
                Endgeräte und Infrastrukturen für Ubiquitous Computing

May, 12        Prof. Dr. Igor Walukiewicz, CNRS, LaBRI, Universite Bordeaux-1
                Games in verification and synthesis

May, 19        Dr. Torsten Kühlen, Rechen- und Kommunikationszentrum der RWTH
                Methodik und technisch-wissenschaftliche Anwendungen der Virtuellen
                Realität

June, 2        Prof. Dr. Deepak Kapur, University of New Mexico, Albuquerque, USA
                Can Algebraic Geometry Rescue Program Verification?

June, 9        Dr. Felix Wolf, Dept. of Computer Science, University of Tennesse,
                Knoxville
                Automatic Performance Analysis of Parallel Applications

June, 16       Prof. Sukumar Ghosh, The University of Iowa, USA
                The many faces of stabilization in distributed systems

June, 20       Dr. Heiko Mantel, Information Security, ETH Zürich
                Information Flow Security: Modeling and Analysis

June, 30       Prof. Ursula Sury, HSW Luzern, Schweiz
                Pervasive Computing und Recht

July, 14       Dr. Roman Englert, T-Lab der Deutschen Telekom, Berlin

November, 4    Fachgruppe Informatik
                Festkolloquium anlässlich der Emeritierung von Prof. Dr. Klaus
                Indermark

November, 21   Dr. Utz Rödig, University College Cork (Irland)
                Leistungskontrolle von drahtlosen Sensornetzen

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November, 21  Dr. Markus Fidler, NTNU Trondheim (Norwegen)
Probabilistic Network Calculus. Eine Systemtheorie für das Internet

November, 21  Dr. Christian Becker, Uni Stuttgart
Systemsoftware für Pervasive Computing

November, 21  Dr. Klaus Wehrle, Uni Tübingen
Flexible Nutzung und Kopplung von Overlay-basierten Diensten

November, 22  Dr. Frank Fitzek, Uni Aalborg
Cooperation in distributed wireless networks: the evolutionary step towards real G4

November, 22  Dr. Manfred Hauswirth, EPFL Lausanne
Efficient, self-contained handling of identity in peer-to-peer systems

November, 22  Dr. Thomas Fuhrmann, Uni Karlsruhe
Peer-to-Peer und Selbstorganisation

November, 24  Dr. Felix Wolf, FZ Zürich
Scalability of Trace-based Performance Analysis

December, 1  Thorsten Reinsch, Gymnasium Odenkirchen, Mönchengladbach
Herausforderungen & Chancen des Schulfachs Informatik durch die Schulzeitverkürzung in NRW

December, 8  Prof. Dr. Johan van Benthem, University of Amsterdam and Stanford University
Rational Dynamics: Game Solution Procedures in Dynamic-Epistemic Logic

December, 12 Dr. Gerald Lüttgen, University of York
Structured Symbolic Model Checking of Asynchronous Systems

December, 19 Dr. Erika ÁbrahámAlbert-Ludwigs-Universität, Freiburg
Bounded Model Checking for Linear Hybrid Systems
4 Diploma and Master Theses

4.1 Diploma

Akhoundi, Arash  Distributed Automatic Deployment of eHome Configurations (Nagl, Spaniol)

Altmann, André  Lattice Rescoring and Log-Linear System Combination (Ney, Lakemeyer)

Apel, Thomas  Generating Fingerprints of Netware Servers and their use in Honeypots (Freiling, Spaniol)

Armac, Ibrahim  Process Support in eHome Systems (Nagl, Spaniol)

Berenzon, Vladimir  Representation and Extraction of Rules in Geographic Information Systems (Jarke, Azzam)

Bierbaum, Boris  Implementation of a Multi-Device-Architecture for MetaMPICH (Bemmerl, Bischof)

Blecher, Wolf  Interactive Visualization of three Dimensional MR-Data (Kobbelt, Blümich)

Bodden, Eric  I-Lo - A Tool for Runtime-Verifying Temporal Assertions (Indermark, Mezini)

Braun, Matthias  Anonymous Location Based Services (Spaniol, Nagl)

Buchholz, Jan  A System for Computer-Assisted Jazz Improvisation (Borchers, Lichter)

Buchner, Dimitri  Development of Cooperation-Platform for a Regional Social Network (Henning, Schroeder)

Camen, Eric  Concepts for Region-Based Similarity Search in Image Databases by Using the Earth Mover’s Distance (Seidl, Lakemeyer)

Cao, Yiwei  Open Standards an Architectures for community Information Systems in cultural Heritage Management - For Afghan Sites and Monuments Database (Jarke, Jansen)

Cholewinski, Peter  Evasive Data Storage in Sensor Networks (Gärtner, Spaniol)

Claßen, Jens  Knowledge-Based Programming with Sensing in the Logic ES (Lakemeyer, Jarke)

Conrad, Carsten  Movement Inspired Storytelling (MIST) (Jarke, Schönert)
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<td>Performance Evaluation of a Multi-Mode Capable Data Link Lager for Relay Enhanced Cells in 4th Generation Mobile Radio Networks (Walke, Freiling)</td>
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<td>Decker, Bernd</td>
<td>Development of a Software Module for Automated Analysis of UML Class Diagrams in a Distributed Assessment Environment (Schroeder, Lichter)</td>
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<td>Dohmen, Lars</td>
<td>Dynamic Simulation of Nonconvex Rigid Bodies with Friction (Kobbelt, Bischof)</td>
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<td>Dreuw, Philippe</td>
<td>Appearance Based Gesture Recognition (Ney, Seidl)</td>
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<td>Egerland, Matthias</td>
<td>Semi-Automatic Videosegmentation (Kobbelt, Bischof)</td>
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<tr>
<td>Eggert, Patrick</td>
<td>Integration of Text Mining and Structured Database Queries for Customer Relationship Management (Jarke, Seidl)</td>
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<tr>
<td>Eickvonder, Björn</td>
<td>Encapsulation and Representation of Learning Objects in Learning Environments (Schroeder, Lichter)</td>
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<tr>
<td>El Isbihani, Anas</td>
<td>Development of a Model for the Integration of Hybrid Geodata with an Example of Groundwater Vulnerability Assessment (Jarke, Azzam)</td>
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<tr>
<td>Eßer, Hans-Georg</td>
<td>Exploiting Covert Channels Using a Web-Server (Gärtner, Rossmanith)</td>
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<tr>
<td>Fliegen, Ingo</td>
<td>Improved Priority Dropping for Wireless Video Streaming (Spaniol, Nagl)</td>
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<td>Ganzow, Tobias</td>
<td>Order-invariant definability (Grädel, Thomas)</td>
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<tr>
<td>Geilmann, Kathrin</td>
<td>View-based Cooperation in a Process Management System for Dynamic Development Processes (Nagl, Spaniol)</td>
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<tr>
<td>Gerhards, Konrad</td>
<td>Conception and Realization of an Experimental Vehicle for Automotive Software (Kowalewski, Lichter)</td>
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<tr>
<td>Glavic, Boris</td>
<td>Subspace Clustering for Sequences of Ordered Categorical Data (Seidl, Nacken)</td>
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<tr>
<td>Greco, Roberto Sante</td>
<td>A Translation of UML-Class Diagrams into Description Logics (Baader, Lakemeyer)</td>
</tr>
<tr>
<td>Grosse-Plankermann, Holger</td>
<td>Design and Implementation of an Infrastructure-Model for Browser-Located Applications in the Domain of Process-Control Engineering (Eppe, Lichter)</td>
</tr>
</tbody>
</table>
Gu, Xin  
*Development and Evaluation of a Priority Dropping System for Video Streaming over Channels with Limited Bandwidth* (Spaniol, Nagl)

Haferkamp, Lars  
*Discriminative Acoustic Modelling in Speech Recognition* (Ney, Seidl)

Hartmann, Thomas  
*Alias free Geometry Images by Geometric Feature Alignment of the Parameterization* (Kobbelt, Bischof)

Hentschel, Achim  
*Toolpath Generation* (Kobbelt, Bischof)

Herold, Sebastian  
*A Framework for Graph-Based Integration Tools* (Nagl, Spaniol)

Herr, Paul  
*Tool-Supported Feature-Modeling in the Automotive-Industry* (Lichter, Kowalewski)

Hink, Gregor  
*Path-Oriented Automata and Logics over Trees* (Thomas, Katoen)

Holz, Thorsten  
*New Fields of Application for Honeynets* (Freiling, Spaniol)

Ifller, Lutz  
*Implementation and Graphical Declaration of Object-Oriented Views* (Spitzer, Lichter)

Jacobs, Stefan  
*Applying Readylog to Agent Programming in Interactive Computer Games* (Lakemeyer, Kobbelt)

Jansen, Christian  
*Multi-Resolution Approaches for Post-Processing of CFD Datasets in Virtual Environments* (Bischof, Kobbelt)

Jogmin, Markus  
*Interference Investigations for Realistic Macro Cellular Scenarios of PMR Systems* (Walke, Gärnter)

Kaiser, Boris  
*A Mapping and Validation Concept for Data Exchange in E-Business Applications* (Seidl, Lakemeyer)

Kampa, Adam  
*Konzeption und Entwicklung einer webbasierten Benutzungs Oberfläche für das Prozessmanagementssystem AHEAD* (Nagl, Spaniol)

Kanithasen, Waratat  
*Development and Evaluation of an OFDMA Medium Access Control for WLAN Systems with Data Rates up to 1 Gbit/s.* (Walke, Nagl)

Karakas, Gökhan  
*Automatic generation of web-based and user-friendly hospital information pages from an object-oriented database* (Spitzer, Jarke)
Kariantso, Wong  Parikh Automata with Pushdown Stack (Thomas, Indermark)

Karrer, Thorsten  PhaVoRIT - a Phase Vocoder for Real-Time Interactive Time-Stretching (Borchers, Vary)

Käunicke, Christian  Automatic Termination Analysis of Logic Programs (Giesl, Indermark)

Kern, Carsten  MSCan, an Analysis Tool for Message Sequence Charts (Indermark, Katoen)

Kessel, James  Automatic Generation of Shape Models for Feature-Based Registration of Medical Image Data (Kobbelt Bischof)

Kesselner, Klaus  Automated Kinematics Derivation from Finite Element Computation Results in Virtual Reality (Bischof Brecher)

Kirmizi, Askin  Optimization of the Sequencing of Cutting Tools for Cutting 2D-Components (Sebastian, Rossmanith)

Klein, Jonathan  A Pattern-Based Software Framework for Computer-Aided Jazz Improvisation (Borchers, Prinz)

Kneis, Joachim  Parameterized Complexity of Variants of the Satisfiability Problem (Rossmanith, Hromkovic)

Kreienbrink, Ingo  Classification and Search Strategies in eHome-Scenarios (Nagl, Spaniol)

Leusch, Gregor  Evaluation Measures in Machine Translation (Ney, Seidl)

Malik, Adam  Information Acquisition for Automatic Deployment of EHome Systems (Nagl, Spaniol)

Mausberg, Niklar  Using Reinforcement Learning Methods for Action Selection in Dynamic Domains (Lakemeyer, Seidl)

Mauser, Arne  Improved Word Alignment and Phrase Extraction for Statistical Machine Translation (Ney, Lakemeyer)

Max, Gustaf Sebastian  IEEE 802.11s - Ad hoc Gigabit Mesh WLAN - Development and Evaluation of an Interference aware Mesh WLAN MAC Protocol for the Support of Coexistence (Walke, Freiling)

Mertens, Martin  Modularity, Strategies and Proof Management in Automated Program Verification (Giesl, Indermark)

Mitschning, Ralf  Evaluation of a CASE Tool for Embedded Software (Kowalewski, Seidl)
Müller, Octavian
Ontology-Based Integration of Semistructured Data (Jarke, Lakemeyer)

Nasserian, Samad
“Oblivious Signature Based Envelopes (OSBE)”, their Efficiency and their Applications (Tsudik, Freiling)

Neuhäußer, Martin
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O, Chang Pae
Development and Evaluation of an Innovative Multihop ARQ Concept (Spaniol, Nagl)

Offermann, Steffen
Design and Implementation of a Cache Mechanism for the Service Location Protocol to Support Efficient Service Hand-over in Mobile Ad-hoc Networks (Spaniol, Nagl)

Ostwald, Leonid
Interactive Visualization of Dynamic 3D-Contact-Data in Multibodysystems (Bischof, Pischinger)

Pabst, Rafael
Collection and Comparison of Design Principles with Respect to Technology Independent Modelling (Kowalewski, Lichter)

Peger, Daniel
Binaural Sound Source Localisation using Interaural Level Differences (Lakemeyer, Wagner)

Peter, Michael
Design, Implementation, and Assessment of a Situated Learning Environment to Support Universitary Education in the Subject of Dimensional Metrology Refering to the Measurement Process (Schroeder, Pfeiffer)

Peters, Volker
Prediction-based Evaluation of Communication Path Availability of Mobile Ad-Hoc Networks (Spaniol, Nagl)

Plum, Christoph
Adaptive wireless Multimedia Streaming based on Bitstream-Switching (Spaniol, Nagl)

Retkowitz, Daniel
Rule-Based Knowledge Definition and Analysis for Conceptual Design Support (Nagl, Spaniol)

Rieger, Stefan
Analysis and Optimisation of Linear Code (Indermark, Noll)

Sar Dessai, Sandip
Normalization and Parameterization of Motion Captured Data (Kobbelt, Bischof)

Sarholz, Samuel
Parallelisation of CFD Post-Processing exploiting the NUMA Architecture of current High Performance Computers (Bischof, Bemmerl)
Schiffer, Stefan  
*Readyworld - A Qualitative World Model for Autonomous Soccer Agents in the Readylog Framework* (Lakemeyer, Seidl)

Scharrenbach, Thomas  
*Investigations on Minimum Bates Risk for String Classification* (Ney, Seidl)

Schlosser, Jochen  
*Stream-Based Processing of Interval Joins* (Seidl, Jarke)

Schlosser, Achim  
*Single index based interval management in relational databases* (Seidl, Jarke)

Schlüttter, Markus  
*Generation of typed process skeletons from Message Sequence Charts* (Indermark, Lichter)

Schmidt Borredà, Marcel  
*Classification methods for region extraction on hierarchically decomposed image series in medical applications* (Lehmann, Seidl)

Schmitz, Arne  
*Efficient and realistic image synthesis with photon mapping* (Kobbelt, Bischof)

Schoenemann, Thomas  
*Model-based Confidence Measures for Statistical Machine Translation* (Ney, Seidl)

Schultchen, Erhard  
*Distributed Graph Transformations in Fujaba-Prototypes* (Nagl, Spaniol)

Schulte Althoff, Christoph  
*Construction of Deterministic W-Automata: A Comparative Analysis of the Algorithms by Safra and Muller/Schupp* (Thomas, Indermark)

Schürmans, Stefan  
*A Compiler and Virtual Machine for State Space Generation* (Indermark, Noll)

Specht, Oliver  
*Synchronization of Multimedia Annotations for Interactive Recordings* (Schroeder, Lichter)

Sperber, Falk  
*Experimental Studies of Probabilistic Instances of the Knapsack Problem* (Vöcking, Rossmanith)

Stark, Jörg  
*Improvement of immersion in virtual environments by different feedback methods and their combination* (Prinz, Bischof)

Stein, Daniel  
*Morpho-syntax Based Statistical Methods for Sign Languages Translation* (Ney, Seidl)

Thyssen, Marcus  
*Development of a query language for the graph-oriented DBMS Gras/GXL* (Nagl, Spaniol)
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<td>Design and implementation of a real-time simulation of musculature for virtual environments (Bischof, Borchers)</td>
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<td>Interface Design in Business Intelligence Applications-Analysis and Optimization of ETL Functionalities in an Internet-based Database Application (Jarke, Lakemeyer)</td>
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### 4.2 Master Thesis

#### 4.2.1 Software Systems Engineering

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<td>Emotion Expression of Virtual Humanoids by Facial Animation and the Influence on Presence in Virtual Environment (Bischof, Kraiss)</td>
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<td>Enabling Power Awareness, Addressing and Clustering in Generie Sensor Networks (Mähonen, Spaniol)</td>
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<td>Automatic Generation of MATLAB Gateway Functions for Coupling AD Tools and Tuning Applications (PD Dr. Bücker, Katoen)</td>
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<td>Er-Jongmanee, Tassanee</td>
<td>XML-Driven Device Independent User Interface - Build Rich Client Application Using XML (Jarke, Stetter)</td>
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<td>Erkoc, Münevver</td>
<td>Adaptive Overlay Networks for Mobile Environments (Walke, Freiling)</td>
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<td>He, Ning</td>
<td>Develop Cross Platform Application with Pattern Based Service Oriented Architecture (Jarke, Prinz)</td>
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<td>Kaur, Harsimran</td>
<td>Seamless and Dynamic Linking of Web Services (Prinz, Rose)</td>
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<td>Koh, John Cher Ping</td>
<td>Meeting follow up tool for BSCW (Prinz, Rose)</td>
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<td>Li, Yu</td>
<td>Ellipse Detection and Stereo Circle Reconstruction (Ney, Jiang)</td>
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<td>Reusing and Sharing Learning Resources (Jarke, Lake-meyer)</td>
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<td>Manolescu, Liviana</td>
<td>Rule Patterns and Conflict Detection in eHome Systems (Nagl, Spaniol)</td>
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<td>Panchenko, Andriy</td>
<td>Preference-Based Scheduling of Operation Theatres (Spaniol, Nagl)</td>
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<td>Ramar, Sridharan</td>
<td>Development and Performance Evaluation of Wireless Routing Protocols for W-CHAMB (Walke, Kowalewski)</td>
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Roy, Banani  
*Dynamic Subchannel Allocation in a Multi-Cellular OFDMA System based on Interference Measurements and Traffic Situation* (Walke, Spaniol)

Salumaa, Priit  
*Model Transformations in Ehome Systems* (Nagl, Spaniol)

Savev, Stefan  
*Language Modeling Based on Latend Semantic Analysis* (Ney, Lakemeyer)

Sriprasarn, Kingkarn  
*Realization Strategies for Rich Clients by Web Services* (Jarke, Stetter)

Tawiah, Paul  
*Modelling Core Erlang in PI-Calculus* (PD Dr. Noll, Indermark)

Ünver, Olcay  
*Exposing Heterogeneous Service Discovery Protocols in an Ad-Hoc Ubiquitous Environment with a Web Services Architecture* (Walke, Prinz)

Villar, Jase Alberto Mejia  
*Decision Algorithms for the Bisimulation Problem of Finite-State Processes* (PD Dr. Noll, Indermark)

Vilsy, Vicky  
*Decodability based Priority Generation for Adaptive Video Streaming* (Spaniol, Nagl)

Wang, Qi  
*Ranking in Parallel Electronic Business to Business Negotiations* (Jarke, Lakemeyer)

Wang, Xida  
*RSS-basierte Contend Syndication für ein Groupware System* (Prinz, Berlage)

Xiang, Jinghui  
*A Data and Interaction Model for Storage and Usage of Related Structured and Unstructured Data* (Jarke, Lakemeyer)

Yeboah, Frederick  
*Anonymity Through Mixes: A Performance Study* (Spaniol, Nagl)

Zaman, Baber c/o Sluman Shahid  
*Shared Workspaces Mining Using Ontologies* (Jarke, Prinz)

4.2.2 Media Informatics

Stojadinovic, Predrag  
*Interactive Path Planning and real-time Motion Synthesis for articulated humanoid Characters in virtual Environments* (Bischof, Kraiss)
### Statistics

The following table gives the total number of students enrolled in the “Computer Science” course, sorted by their semester count in the respective winter term.

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*13 or more terms
*2 number of PhD students
The following table gives the total number of students enrolled in the “Computer Science” course, split into male and female students in the respective winter term. Moreover it lists the total number of intermediate ("Vordiplom") and postgraduate examinations ("Diplom") for both the winter and the subsequent summer term.

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Research Reports
Algorithms and Complexity

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  Dr. Matthias Westermann (DFG Research Group)
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• Researchers:
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  Dipl. Inform. Helge Bals
  Dr. Hans-Joachim Böckenhauer (until February 2005)
  Dipl. Inform. Dirk Bongartz
  Dipl. Inform. Matthias Englert (DFG Research Group)
  Dipl. Inform. Simon Fischer
  Dipl. Inform. Thomas Franke
  Dr. (PhD) Alantha Newman (until August 2005)
  Dr. Harald Räcke (July – August 2005)
  Dipl. Inform. Heiko Röglin

• Guests:
  Nir Ailon (Princeton University)
  Artur Czumaj (NJIT Newark)
  Prahladh Harsha (TTI Chicago)
  Matthias Ruhl (Google, California)

• Technical Staff:
  Viktor Keil

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Overview

The group focusses both in research and teaching on following topics:

- randomized algorithms
- approximation and online algorithms
- algorithms for interconnection networks
- probabilistic analysis of algorithms
- algorithmic game theory

Approaches for the design of algorithmic solutions to hard problems are manifold. For optimization problems, a very suitable concept is that of approximation algorithms, where one tries to obtain provably good solutions for the problem, in the sense that the cost of the computed solution is at most a fraction apart from the cost of the optimal one. Another approach is to apply randomized algorithms, which are designed to give an optimal (or good approximative) solution with high probability. Besides positive results as in the design of algorithms, also the according hardness results with respect to the particular concepts are of high interest, since they guide the way for appropriate algorithmic approaches.

In many applications the input data for a given optimization problem is not completely given in advance, but is revealed step by step. Nevertheless, the algorithm must already make decisions based on the partial input only. Typical problems in this area include for instance elevator movement planning and paging strategies. These algorithms are referred to as online algorithms and their performance can be evaluated by comparing their solutions to an optimal offline strategy, i.e., a strategy for which the complete input for the problem is assumed to be known in advance.

In particular, the merge of economic game theory and algorithmics for modelling problems arising for instance in today’s networks opens a completely new field of algorithmic research and received a lot of attention in recent years. Here, one focus is on the comparison between the cost of optimal solutions obtained by globally coordinated operators on one hand and the cost of equilibria yielded by selfish agents on the other hand. Another focus is the design of algorithms for optimization problems, where the input data is not necessarily reliable, as it is given by selfish agents. In this setting, the goal is to design algorithms solving the optimization problem and additionally forcing the agents to “reveal” the true input data — “algorithms” of these types are usually denoted as mechanisms. In this context, the analysis and design of auctions, and in particular of combinatorial auctions, reveals interesting insights.

Besides classes concerning the above mentioned topics, the department regularly offers courses on algorithmic cryptography and parallel algorithms.
Online algorithms studied in theory are characterized by the fact that they do not have knowledge about the whole input sequence of jobs in advance. Instead, the input sequence is generated job by job, and a new job is not issued until the previous one is handled by the online algorithm. In real applications, jobs can usually be delayed for a short amount of time, and hence the input sequence of jobs can be rearranged in a limited fashion to optimize the performance. This flexible online scenario occurs in many applications in computer science and economics, e.g., in computer graphics: A rendering system displays a sequence of primitives. The number of state changes of such a system are a significant factor for the performance. State changes occur when two consecutively rendered primitives differ in their attribute values, e.g., in their texture or shader program. With the help of a reordering buffer in which primitives can be buffered the sequence of primitives can be reordered online in such a way that the number of the state changes is reduced.

According to the above described research topic, the group offers in particular regular courses and seminars on design and analysis of algorithms.

This project deals with dynamic routing algorithms in large networks like the Internet. The goal is to improve our understanding of communication patterns as well as to design algorithms routing the data in such a way that the communication load is as evenly distributed over the available resources as possible. This gives us the opportunity to avoid congestion on the one hand and to guarantee a fair treatment of all participating users on the other hand. In particular, we aim at the design of algorithms for allocating streams of data on web servers as well as for performing intra-domain routing in networks. The resulting research problems will be tackled theoretically, practically, and experimentally. The project is part of the DFG research program “Algorithmik großer und komplexer Netzwerke”. We closely cooperate with
the networking group of the TU München headed by Anja Feldmann. Our particular focus in this cooperation is mainly on the theoretical part.

DELIS: Dynamically Evolving Large Scale Information Systems

S. Fischer, A. Newman, B. Vöcking
(funded by European Union, Integrated Project)

Most of the existing and foreseen complex networks are built, operated and used by a multitude of diverse economic interests. A prime example is the Internet, perhaps the most complex computational artifact of our times. The (possibly) selfish nature of the participating entities calls for a deeper understanding of the network dynamics in order to efficiently achieve their cooperation, by possibly considering bounded rationality aspects. In the past few years, there has been a flourishing amount of work in the border of Computer Science, Economics, Game Theory and Biology that has started to address the above issues. For example, (a) selfish network routing (and flows) were addressed in a number of recent research papers, (b) mechanism design for algorithmic cooperation of selfish users was proposed by many authors, (c) evolutionary economics addresses the dynamics of self-organization in large networks, and (d) the issues of bounded rationality of machines versus their ability for game playing were examined by several research groups, among them the Nobel-prized Economists work of 2001 and 2002.

Activities within the project can be grouped into two main classes:

Basic Research: basic research to understand the dynamics of the network and the effect of concepts like self-organization, selfishness and bounded rationalism as well as the structure of equilibria (and the form of dynamics) in such systems.

Efficient Algorithms: design of mechanisms and algorithms that efficiently achieve the cooperation between the involved selfish entities, possibly applying results from evolutionary models.

Probabilistic Analysis of Discrete Optimization Problems

H. Röglin, B. Vöcking
(funded by the DFG)

Many algorithmic problems are hard from a worst-case point of view but can be solved quite well on typical inputs by heuristic approaches. Hence, worst-case complexity does not seem to be an appropriate measure for the complexity of these problems. This
research project deals with the probabilistic analysis of such problems and heuristics in order to narrow the gap between the observations made in practice and the theoretical understanding of these problems.

For many problems, average-case analyses do not provide much insight either since inputs which occur in practice usually possess certain properties and a certain structure which cannot be reflected by an average-case analysis alone as it is not clear how to choose the underlying probability distribution over the set of possible inputs. In this project, we turn our attention to more general probabilistic input models like, e.g., the model of smoothed analysis. The semi-random input model used in a smoothed analysis consists of two stages. First an adversary chooses an input, then this input is randomly perturbed in the second step. In particular, the adversary can specify a worst-case input with certain properties which is only slightly perturbed in the second stage.

The focus of our research are problems which can be expressed in the form of integer linear programs. In our previous analyses we have characterized the class of integer optimization problems with polynomial smoothed complexity. The algorithms with polynomial smoothed complexity we designed, however, are clearly outperformed by common heuristics used in practice, like, e.g., Branch and Bound and Branch and Cut approaches. One of the main goals of this research project is the probabilistic analysis of these heuristics in order to understand why they perform so extraordinary well in practice. Our approach consists of two steps: First structural parameters like, e.g., the number of Pareto optimal solutions or the integrality gap, are analyzed. Then the running time of the heuristics is analyzed in terms of these parameters.

**GRAAL: Graphs and Algorithms in Communication Networks**

*W. Unger*  
*funded by European Science Foundation, Cost Action*

The main objective of this Action is to create a discussion space between applied communities and theorists in the context of communication networks in which models and assumptions can be reviewed and formalized into the appropriate language.

Inside the context of communication networks, the Action focusses on, but is not restricted to the following specific fields:

1. **QoS networks**: Quality of Service (QoS) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on traffic transmission. Elements of network performance within the scope of QoS include availability (uptime), bandwidth (throughput), latency (delay), delay jitter, and error rate.
2. **Optimization in optical networks**: Optical networks using light paths in optical fibers as communication media induce a number of problems that cannot be directly resolved by using standard solutions from electronic networks, but require new approaches and techniques, instead. These problems include routing techniques, wavelength assignment on switches and cross connects, signalling, topologies design, and path recovery (backup) for protection and restoration.

3. **Optimization in wireless networks**: Wireless networks were traditionally related with voice and telephony. Nowadays, packet networks are also supported in mobile, such as in GPRS and UMTS technologies. Trends on wireless networks include QoS for multimedia transmission and backup paths. Therefore, problems for static networks are moving to wireless, such as delay minimization, traffic engineering, frequency assignment and localization. But there are several additional challenges for wireless networks, one is for instance the coordination of the single uncontrolled agents participation in the network.

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**Algorithmics in Computational Biology**

*D. Bongartz*

This project is devoted to the study of algorithmic problems arising in the area of molecular biology. Most of these problems are computationally hard and therefore may be approached by various algorithmic techniques as for instance approximation algorithms. Special focus is given to the design and analysis of algorithms for problems arising in the area of protein folding. One of the basic tasks here, and in bioinformatics in general, is to first model the problem in a mathematically suitable way. Our focus is in particular on modelling protein folding as a special kind of embedding problem.

Further interests include problems arising in genome analysis and comparison. One example are the haplotyping problems, where the goal is to reassign DNA sequencing data to paternal and maternal chromosomes, respectively. During DNA sequencing this information gets lost and has to be regained, for instance to improve the understanding of genetic diseases.

To analyze the similarity between species on the level of genes (and not on the level of DNA), one searches for the minimum number of genome rearrangements needed to transform one genome into the other one. Several types of rearrangements were introduced in the literature, here we focus on reversal and transposition operations.
Other Activities

Courses

Our group offered the following lectures and seminars:

Summer semester 2005

- Lecture on *Optimization and Game Theory*
- Lecture on *Parallel Algorithms*
- Lecture on *Online Algorithms*
- Seminar on *Auctions, Games, Algorithms — Algorithmic Game Theory and the Internet*
- Seminar on *Combinatorial Optimization*
- Seminar on *Algorithmic Cryptography*
- Seminar on *Online Algorithms*
- Proseminar on *Algorithms and Datastructures*

Winter semester 2005/06

- Lecture on *Computability and Complexity*
- Lecture on *Algorithmic Graph Theory*
- Seminar on *Algorithmic Game Theory*
- Seminar on *Parallel Algorithms*
- Seminar on *Randomized Algorithms*
- Proseminar on *Algorithm Design*

PC Memberships

B. Vöcking was active as a PC member for the following conferences:

- 13th Annual European Symposium on Algorithms (ESA 2005)
- Third Workshop on Approximation and Online Algorithms (WAOA 2005)
Talks and Publications

Talks

Heiner Ackermann: *Decision Making Based on Approximate and Smoothed Pareto Curves*, Invited by Prof. Dr. Eckart Zitzler, ETH Zurich, Switzerland, December 02, 2005.

Heiner Ackermann: *Decision Making Based on Approximate and Smoothed Pareto Curves*, 16th International Symposium on Algorithms and Computation (ISAAC 2005), Sanya, China, December 19-21, 2005.


Heiko Röglin: *Smoothed Analysis of Integer Programming*, 11th International IPCO Conference (IPCO 2005), Berlin, Germany, June 8-10, 2005.


**Publications**


Staff

- Faculty:
  Prof. Dr. Peter Rossmanith

- Secretary:
  Valentina Elsner

- Research Assistants:
  Dipl.-Inform. Joachim Kneis
  Dipl.-Inform. Daniel Mölle
  Dipl.-Inform. Stefan Richter

- Student Assistants:
  Alexander Langer

- Technical Staff:
  Sami Okasha
Overview
Our teaching and research profile consists mainly of

- Efficient Algorithms
- Parameterized Algorithms
- Complexity Theory
- Formalizing Mathematics
- Analysis of Algorithms
- Algorithmic Learning Theory

with an emphasis on the design and analysis of efficient algorithms.

We are particularly interested in solving hard problems, i.e., NP-hard ones. Many practically relevant problems are in this category, often solved by inexact methods that do not give the truly optimal solution. In the case of approximation algorithms, there is at least a guarantee of how close the computed solution is to the exact one. While approximation algorithms are often very useful, they frequently have a very large running time even for rather bad approximation ratios. On the other hand, we sometimes need an exact solution, and we concentrate on such exact algorithms.

While the NP-hardness implies an exponential worst-case running time, practical instances can be solved quite efficiently surprisingly often. In the paradigm of parameterized complexity, for instance, the hardness of a problem is measured by some parameter k. An algorithm with a running time of, e.g., $O(2^k n^2)$ is quite efficient in practice if k is small. Practical instances can be easy to solve for other reasons that are not so obvious—in some way, they have a “simple structure.”

To exemplify this view, consider the problem connected vertex cover: Given a graph G and a number k, is there a set of at most k nodes in G inducing a connected subgraph and covering every edge? It turns out that this problem, although NP-hard, can be solved in $O(3.2361^k \cdot poly(n))$ steps.
When developing exact, non-parameterized algorithms for NP-hard problems, we cannot expect anything better than exponential running times. Hence, we are interested in deriving exponential bounds with at least a small base. One way of analyzing the resulting algorithms lies in investigating the local complexity of their branching behavior (see Figure 9).

**Research Projects**

**Algorithms with Refined Worst-Case Analysis via Suitable Notions of Hardness**

*Daniel Mölle, Stefan Richter, Peter Rossmanith*

In theoretical computer science, the most common way to analyze the running time of an algorithm is the classical worst case analysis, which gives an upper bound on the required computing time as a function of the size of the input. However, the analysis of algorithms is usually a difficult task, and, in practice, the worst case may hardly ever appear at all. Hence, there is usually a huge gap between the best known (mathematically proved) upper bound and the running times observed in realistic applications of an algorithm.

This leads to the question whether we might be able to identify realistic instances in order to exploit their properties when designing exact algorithms for the respective problem. For
instance, consider the problem 3-colorability: Given an undirected graph, can we assign one of three colors to every vertex such that no two adjacent vertices share the same color? The best known algorithm by Eppstein solves this problem in time \( O(1.3289^n) \), where \( n \) is the number of vertices. A rough interpretation of this bound is that the running time doubles every time we add about 2.35 vertices, which is extremely pessimistic—and not quite what we observe in practice. But why is that?

In practice, an algorithm for 3-colorability would not be applied to arbitrary or random graphs, but to graphs used as models of communication networks, transport chains and similar structures. These, again, often happen to have small dominating sets; that is, there is a small subset of vertices such that every vertex in the graph is either in this subset or a neighbor of a vertex in this subset. There are fast ways to find nearly-minimal dominating sets. Finally, if we have a dominating set \( D \), testing the graph for 3-colorability takes time \( O(3^{|D|} \cdot n^c) \) for a small constant \( c \), which, for small values of \(|D|\) (like, \(|D| \leq \frac{n}{4}\)), yields an algorithm with a better running time than the one by Eppstein.

The key idea of this project is to find similar useful properties of realistic instances for various important problems and design fast exact algorithms accordingly. As a bonus, testing instances for these properties could also allow for predicting the running time of such an algorithm.

Let us exemplify our efforts by briefly discussing three of our main results from 2005:

Firstly, we were able to prove that the treewidth of a graph with \( m \) edges is bounded by \( m/5.769 \). This graph-theoretical result is not only interesting by itself—it also implies a lot of new, improved runtime bounds for various important problems such as Dominating Set on cubic graphs, Max-Cut, and Max-2SAT.

Secondly, we investigated the problem of finding unique minimum hitting sets. An algorithm solving this problem can be seen as a means to attack anonymity protocols based on so-called anonymity sets. In particular, we obtained reasonably small bounds on the number of observations (of protocol interactions) required by such algorithms. In many cases, it is thus possible to reveal the identities of the participants.

Thirdly, we developed a new paradigm for the design of algorithms for graph problems, called Enumerate and Expand. It relies on the enumeration of node sets whose removal would yield a very restricted graph, e.g., a graph of maximum degree three. In a second phase, these node sets must then be expanded into solutions of the graph problem at hand. Using this method, new record-breaking runtime bounds for several covering problems were derived.

This project is funded by the DFG under grant RO 927/6-1 (TAPI).
Using the graph-theoretical concept of treewidth, we were able to develop a new approach to solving a plethora of graph and satisfiability problems. The basic idea is to branch recursively only where it seems—at least locally—to be cheap, until only a simple instance of the investigated problem remains.

It can be shown that algorithms based on the above method do not branch too often. In fact, our new approach yields practical algorithms and improved runtime bounds for many important problems. This holds even though the derived algorithms are extremely intuitive, that is, easy to understand, implement, and verify. Nearly all the effort lies in the analysis, and in order to obtain tighter and tighter runtime bounds, we employ more and more complex methods of analysis.

One of the curious facts about this paradigm is that it contrasts with the classical way of developing algorithms, which are usually made more and more complicated (e.g., by case distinctions) in order to ease the analysis.

We have begun to develop programs for the automation of certain parts of the analysis, allowing us to identify and focus on the most critical parts when trying to prove new bounds.

**Other Activities**
Program committee member of SOFSEM'2005

**Talks and Publications**

**Talks**
Daniel Mölle: *Algorithms Based on the Treewidth of Graphs*, WG 2005, Metz, France, June 2005
Peter Rossmanith: *An $O^*((2 + \varepsilon)^k)$-Algorithm for the Steiner Tree Problem*, Dagstuhl Seminar on Exact Algorithms and Fixed-Parameter Tractability, Germany, July 2005
Joachim Kneis: *On the Parameterized Complexity of Exact Satisfiability Problems*, MFCS 2005, Gdansk, Poland, September 2005
Peter Rossmanith: *Design and Analysis of Intuitive Algorithms (invited talk)*, MEMICS 2005, Znojmo, Czech Republic, October 2005
Peter Rossmanith: *Treewidth and Pathwidth of Sparse Graphs*, Workshop on Graph Classes, Width Parameters and Optimization, Prague, Czech Republic, October 2005

**Publications**


Daniel Mölle, Stefan Richter, Peter Rossmanith: A Faster Algorithm for the Steiner Tree Problem, Technical Report AIB-2005-04, Dept. of Computer Science, RWTH Aachen University, March 2005
Software Modeling and Verification

Staff

- Professors:
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  Prof. em. Dr. Klaus Indermark
  http://www-i2.informatik.rwth-aachen.de/

- Secretary:
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- Lecturer:
  Akademischer Oberrat Priv.–Doz. Dr. Thomas Noll

- Researchers:
  Dr. Henrik Bohnenkamp (since Sept. 1st)
  Dr. Benedikt Bollig (until Okt. 1st)
  Dr. Michael Weber (until Nov. 1st)
  Tingting Han, B.Sc. (since Nov. 1st, funded by the NWO)
  Dipl.-Inform. Carsten Kern (since Sept. 1st)
  Dipl.-Inform. Martin Neuhäußer (since Nov. 1st, funded by the NWO)
  Dipl.-Inform. Stefan Rieger (since Sept. 1st)
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- Visiting Scientists:

  Dr. Gerald Lüttgen (Univ. of York, UK)
  Dr. David Jansen (University of Twente, NL)
  Dr. Érika Abrahám (Universität Freiburg, D)
Overview

2005 has been a rather dynamic and evolving year for LS2! Klaus Indermark received his status as emeritus professor on October 1. Since then the chair is led by Joost-Pieter Katoen. As Joost-Pieter already joined the group in December 2004, this change could be accomplished in a co-operative and step-by-step manner. We thank Klaus Indermark for his enormous enthusiasm and dedication with which he has shaped and chaired LS2 over the last 30 years, and hope to welcome him frequently on our floor in good health!

Several changes in the academic staff of the group have taken place in 2005. Benedikt Bollig received his PhD degree in June, and obtained a permanent research position at the ENS Cachan, France. An updated and extended version of his doctoral dissertation will be published by Springer. Michael Weber left in November to the group of Jaco van de Pol in the well-known Dutch research institute CWI (Centrum voor Wiskunde en Informatica, Amsterdam). He received his PhD in January 2006. New group members are: Henrik Bohnenkamp, Tingting Han, Carsten Kern, Martin Neuhäußer, Stefan Rieger and Ivan Zapreev. Welcome to LS2!

As last drastic change in 2005, we mention the enormous renovation of the chair. The newly furnished and equipped chair provides an excellent place to work. We thank all involved people for their support during the renovation.

In August 2005, the chair has been involved in the organization of the workshop “Algebraic Process Calculi: The First Twenty Five Years and Beyond”. This event was a great success, and several pioneers in process algebra such as Robin Milner, Tony Hoare, Matthew Hennessy, Jan-Willem Klop and Stephan Brookes gave their acte-de-presence. It was interesting to listen to their excellent retrospective talks.

The research programme of the Software Modeling and Verification group (MOVES), as the group is called now, is concerned with the study, development and application of formal methods to software design in a broad sense. Our group aims at modeling and verifying thrustworthiness aspects (such as safety, reliability, performance and survivability) of software systems by applying mathematical theories and methods.

Major research topics of interest are:

- modeling formalisms for concurrent systems (such as process algebra, state-charts, message sequence diagrams and mobile process calculi);
- model checking and quantitative extensions thereof (in particular probabilistic model checking, cost bounds, abstractions, scheduling generation and analysis);
- semantics and analysis of modern programming languages (a.o., semantics of Erlang, heap abstractions and pointer analysis, multi-threading);
- probabilistic models for concurrency (i.e., the theory of models, abstraction, refinement etc.);
• testing and run-time verification.

Our research is conducted in the context of several projects that are funded by the NWO (Dutch Research Council), NWO and DFG, and the European Union. We are looking forward to our participation in the forthcoming research training group on the algorithmic synthesis of reactive systems.

Joost-Pieter Katoen

Research Projects

The MoDeST Tool Environment

_H. Bohnenkamp, J.-P. Katoen, H. Hermanns (Univ. d. Saarlandes),
P. R. D’Argenio (Univ. Nacional de Córdoba, AR)_

The specification language MODEST covers a wide spectrum of modelling concepts, ranging from plain labelled transition systems to stochastic systems like Generalised Semi-Markov Decision Processes. MODEST possesses a rigid, process-algebra style semantics, and yet provides modern and flexible specification constructs. MODEST specifications constitute a coherent starting-point to analyse distinct system characteristics with various techniques, e.g., model checking to assess functional correctness and discrete-event simulation to establish the system’s reliability. Analysis results thus refer to the same system specification, rather than to different (and potentially incompatible) specifications of system perspectives like in the UML.

The tool MOTOR (MODEST Tool enViRonment) is aimed to provide the means to analyse and evaluate MODEST specifications. The tool is written in the C++ programming language. The tool provides (i) interfacing capabilities for connection to existing tools for specific projected models, and (ii) also means for enhancement by native algorithms for analysis of (classes) of MODEST specifications. In earlier work, MOTOR has been connected to MÖBIUS, a performance evaluation tool suite that has been developed at the University of Illinois at Urbana-Champaign, US. Currently we are working on a state-space generator for MODEST and aim at connecting MODEST via MOTOR to the PRISM tool, a model-checker for probabilistic timed systems, developed at the University Birmingham, UK. Furthermore, we plan to connect MODEST to the UPPAAL model checker.

Timed Model-Based Testing

_H. Bohnenkamp, A. Belinfante (Univ. Twente, NL), M. Stoelinga (Univ. Twente, NL)_
Testing is one of the most natural, intuitive and effective methods to increase the reliability of software. Formal methods have been employed to analyse and systematise the testing idea in general, and to define notions of correctness of implementations with respect to specifications in particular. The IOCO testing theory reasons about black-box conformance testing of software components. The test-case generation and execution algorithms of IOCO have been implemented in TORX, a testing tool developed at the University of Twente.

We work on an extension of TORX to allow testing of real-time properties: real-time testing. Real-time testing means that the decisions whether an implementation under test has passed or failed a test is not only based on which outputs are observed, given a certain sequence of inputs, but also on when the outputs occur, given a certain sequence of inputs applied at predefined times. We use as input models non-deterministic safety timed automata.

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**Dependable Global Computing**

H. Bohnenkamp, T. Han, J.-P. Katoen, R. De Nicola (U. Florence, I), D. Latella and M. Massink (CNR-ISTI, I)

(funded by the DAAD and CNR-ISTI)

Due to their enormous size—networks typically consist of thousands or even millions of nodes—and their strong reliance on mobility and interaction, performance and dependability issues are of utmost importance for “network-aware computing”. Spontaneous computer crashes may easily lead to failure of remote execution or process movement, while spurious network hick ups may cause loss of code fragments or unpredictable delays. The enormous magnitude of computing devices involved in global computing yields failure rates that no longer can be ignored. The presence of such random phenomena implies that correctness of global computing software and their privacy guarantees are no longer rigid notions like: “either it is safe or it is not” but have a less absolute nature, e.g.: “in 99.7% of the cases, privacy can be ensured”. The intrinsic complexity of global computers, though, complicates the assessment of these issues severely. Systematic methods, techniques and tools—all based on solid mathematical foundations i.e., formal methods, are therefore needed to establish performance and dependability requirements and guarantees.

This project attempts to make a considerable step into this direction by extending a successful programming and specification formalism for global computing, KLAIM, with random delays, and by developing a novel stochastic spatial temporal logic as property specification language for performance and dependability guarantees.
Automata and Logics for Message Sequence Charts

B. Bollig

A message-passing automaton is an abstract model for the implementation of a distributed system whose components communicate via message exchange and thereby define a collection of communication scenarios called message sequence charts. In this project, we study several variants of message-passing automata in a unifying framework. We classify their expressiveness in terms of state-space properties, synchronization behavior, and acceptance mode and also compare them to algebraic characterizations of sets of message sequence charts, among them the classes of recognizable and rational languages.

We then focus on finite-state devices with global acceptance condition that communicate via a priori unbounded channels. We show them to be exactly as expressive as the existential fragment of monadic second-order logic over message sequence charts and to be strictly weaker than full monadic second-order logic. It turns out that message-passing automata cannot be complemented and that they cannot be determinized in general. Those results rely on a new proof technique, which allows to apply graph acceptors as introduced by Thomas to the framework of message sequence charts.

QUPES: Verification of Quantitative Properties of Embedded Software

T. Han, J.-P. Katoen, M. Neuhäußer, D. Willems

(funded by the NWO)

The research challenge faced by the QUPES project is to adapt and enrich model checking, a successful technique for checking the logical correctness of system designs, to meet the requirements of state-of-the-art embedded software engineering. Embedded software typically executes on devices that, first and foremost, are not computers. This imposes high requirements on performance and economical resource usage. Due to its embedded nature, its robustness is of prime importance, and timely reactions to stimuli from its—mostly physical—environment are essential. This project proposes to assess these “non-functional” aspects (e.g., timeliness and robustness) as an integral part of the embedded software validation phase. The aim is to obtain a single framework that supports both the validation of qualitative (i.e., functional) as well as quantitative aspects of embedded software.
To accomplish this, model-checking techniques will be extended with ample means to reason about costs (power consumption, memory usage, and the like), efficiency, and robustness. In particular, we aim to develop verification algorithms for real-time systems that exhibit both (continuous-time) randomness as non-determinism and extend this approach with cost aspects. Furthermore, advances to model checking of stochastic systems will be made by developing aggressive abstraction techniques and methods that effectively exploit the (compositional) structure of embedded software specifications for verification purposes. The latter activities are aimed at making stochastic model checking applicable to state spaces that are several orders of magnitude larger than currently can be handled. Our techniques will be tailored to hierarchical design notations (statechart diagrams) for embedded software.

This project takes place in the context of the DFG-NWO bilateral project VOSS2 (Validation of Stochastic Systems). In this project, we cooperate with the Universities of Bonn (Prof. Christel Baier), Saarland (Prof. Holger Hermanns), Nijmegen (Prof. Frits Vaandrager), Twente (Prof. Boudewijn Haverkort), and Federal Armed Forces Munich (Prof. Markus Siegle).

### Verifying Safety and Liveness in Concurrent Pointer Programs

*J.-P. Katoen, Th. Noll, S. Rieger, A. Rensink (U. Twente, NL) and D. Distefano (Queen Mary College London, UK)*

The incorrect use of pointers is one of the most common source of software errors. Concurrency has a similar characteristic. Proving the correctness of concurrent pointer manipulating programs, let alone algorithmically, is a highly non-trivial task. This project attempts to develop automated verification techniques and accompanying tool-support for concurrent programs that manipulate dynamic, linked data structures. Initially, we focus on linked lists. As verification technique, we investigate the use of automata-based model-checking algorithms. First and second-order (monadic) temporal logics are employed for the specification of properties of such concurrent programs. These logics can easily express the dynamic creation and deletion of data. In our approach, we consider abstractions of linked data structures that are tailored to both the property and the program to be analysed. The main challenge is to achieve a fully automated technique to prove the correctness of concurrent pointer programs such as deadlock avoidance protocols, concurrent garbage collection algorithms and so forth.
Model-based performance evaluation aims at forecasting system behaviour in a quantitative way, starting from an abstract system model. Due to the ever-increasing size and complexity of modern computer and communication systems, performance models that are directly amenable to a numerical solution are often generated from high-level modelling languages, based, e.g., on stochastic Petri nets or stochastic process algebras. For a significant class of systems, these models turn out to be infinite state, and need to be analysed by specific techniques, such as matrix-geometric methods.

Recently, extensions to temporal logics have been developed to ease the specification of important measures-of-interest (like response times, or the probability to reach deadlines) over performance models, and logic-based verification algorithms have been integrated with numerical means to automatically check these properties. This novel approach is, however, still restricted to finite-state systems.

This project aims to establish a cross-fertilization between (i) performance evaluation techniques for infinite-state systems and (ii) logic-based model-checking algorithms for Markov chains. The goal is to develop algorithms and a prototype software tool for the specification and automated evaluation of performance measures for infinite-state Markov chains, and to apply these to case studies with realistic complexity.

This project also takes place as part of the VOSS2 project.

Verification of Erlang Programs

M. Neuhäuser, Th. Noll, L.H. Haß, P. Tawiah, C.K. Roy (Dublin City Univ., IRL)

Software written for telecommunication applications usually has to meet high quality demands. Due to its complexity and its nondeterministic behaviour validation methods which are purely based on testing are generally not sufficient to ensure that the requirements are met. Therefore formal verification methods are highly desirable.

In this project we are developing and studying verification approaches which are tailored to Erlang, a programming language for implementing open, distributed telecommunication software. The complex dynamic and concurrent behaviour of such systems makes standard, finite-state model-checking techniques inapplicable in this setting.

We are tackling this problem from two different sides:
To make Erlang systems amenable to automatic model checking techniques, one thread of our research focuses on abstraction techniques which can be employed to reduce the state space of the system under consideration. More concretely we have developed a formal definition of the syntax and semantics of a core version of Erlang in Rewriting Logic, a unified semantic framework for concurrency which is founded on conditional term rewriting modulo equational theories. In particular, the term rewriting machinery can be employed to model the operational behaviour of programs in terms of transition systems, and equations allow us to define abstraction mappings on the state space.

A prototype version of an Erlang evaluator has been implemented in Maude, which is a specification language supporting the Rewriting Logic framework. The results obtained so far are very promising, inviting to further investigate the benefits of equational abstractions for Erlang programs.

In a second approach we try to benefit from existing work by translating the given Erlang program into a specification language for which analysis and verification methods have been already developed. Due to the dynamic and mobile process and communication structures which are present in many Erlang applications, classical languages such as LOTOS or Promela are not suitable for this purpose. Rather we are using the π-calculus, a name-passing process algebra which allows to describe concurrent systems with a dynamically developing communication topology.

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**Optimization of Straight-Line Code**

*T. Noll, S. Rieger*

We study the effect of an optimizing algorithm for straight-line code which first constructs a directed acyclic graph representing the given program and then generates code from it.

It can be shown that this algorithm produces optimal code with respect to classical optimizing program transformations such as Constant Folding, Common Subexpression Elimination, and Dead Code Elimination. In contrast to the former, the latter are also applicable to iterative code containing loops.

We can show that the graph-based algorithm essentially corresponds to a combination of the three classical optimizations in conjunction with Copy Propagation. Thus, apart from its theoretical importance, this result is relevant for practical compiler design as it allows to exploit the optimization potential of the graph-based algorithm for non-linear code as well.
Runtime Verification
V. Stolz, E. Bodden, R. Theisen

Concurrent programs may contain bugs like deadlocks which are hard to reproduce. Potentially bad behaviour of these programs can be detected through runtime verification where Linear-Time Logic (LTL) formulae are used to express temporal assertions. We implemented LTL-checkers in Haskell and Java, which, driven by annotations in the source program, checks the formulae.

Annotations for Haskell where provided through a wrapper for functions in the standard concurrency library. For Java, we used metaprogramming, that is, treating a program as data and manipulating it, through AspectJ. The temporal properties to verify are extracted via Java 5 Metadata annotations from the source code and stored in a standardised way in the class file. Thus, automatic manipulation of such data no longer depends on pre-processors. We use this scheme to store a combination of LTL formulae and AspectJ expressions.

For checking dynamic systems, a template mechanism allows to instantiate placeholder variables in parameterised formulae which generate new formulae on the fly. If a violation is detected, the trace leading to this situation can be examined.

The results where presented at the Fifth Workshop on Runtime Verification in Edinburgh, UK. Also, two diploma theses where published. For his diploma thesis on the Java version with the title “J-LO - A tool for runtime-checking temporal assertions” Eric Bodden won the first place in the undergraduate category of the Association for Computing Machinery (ACM) Student Research Competition 2005. He and his supervisor Volker Stolz enjoyed a trip to the awards ceremony in San Francisco sponsored by the ACM.

DIVSPIN—A SPIN Compatible Distributed Model Checker
M. Weber, M. Leucker (TU München), L. Brim (Brno, CZ)

The project’s goal is the design and implementation of a parallel and distributed model checker called DIVSPIN.

The benefits of this project are threefold: first, we intend to create a ready-to-use, large-scale distributed state space exploration tool directed at a significant part of the user base of verification tools, as well as providing hardware to run on. Second, the tool enables us to empirically evaluate existing algorithms with regard to their performance and characteristics under controlled conditions, providing useful insight into their
strengths and weaknesses, leading to a more informed way to choose an algorithm depending on a given task. Third, we intend to use the environment as a platform for further development of (and experimentation with) parallel and distributed model checking algorithms.

Further development and evaluation of parallel algorithms deserves special attention, considering recent developments in CPU technology wrt. multi-core “Cell processors”, and the rising interest in grid computing, which foreshadow the near end of Moore’s Law, and consequently the need for well-scaling parallel and distributed algorithms in future verification tools.

Distributed Algorithms Test Bench
M. Weber, M. Rohrbach, E. Bodden

In parallel to the already mentioned DIVSPIN project, work has begun to develop a benchmark environment for distributed algorithms. Complementary to the DIVSPIN project, which aims at producing a practical and competitive model checker, the focus of this project is to provide a language-independent prototyping framework for distributed and parallel algorithms.

The tool is aimed at researchers who want to experiment with algorithms in their programming language of choice, without the distractions of having to implement a distributed data processing framework, distributed termination checks, instrumentation for profiling, data structures, etc.

A Virtual Machine for State Space Generation
M. Weber

We develop formal semantics for a virtual machine which can be used for state space generation.

Common approaches in explicit-state model checking employ modeling languages like CSP, LOTOS or Promela for the description of state spaces. The semantics of these languages are usually non-trivial: besides concepts found in programming languages (scopes, variables, expressions etc.) they often provide features like process abstraction, non-determinism, communication primitives, timers, etc. Implementing the semantics of languages like Promela for use in verification tools is consequently not straight-forward, even more so if the language is described only informally and static and operational semantics are unavailable.
The goal of this on-going work is the definition of formally specified semantics of a small and straight-forwardly implementable byte-code language which incorporates the above mentioned features in a compositional way, so that tool implementors can choose what is needed and leave out the rest.

In a second step, we define faithful translation functions for modeling languages like Promela, π-calculus, and DIVINE language which enables us to compile them into byte-code.
Other Activities

J.-P. Katoen

• Member of the Steering Committee of ETAPS (*European Joint Conferences on Theory and Practice of Software*).
• Member of the Steering Committee of QEST (*Quantitative Evaluation of Systems*).
• Board Member of the Dutch Society on Theoretical Computer Science (NVTI).
• Member of the Program Committee of the following events:
  – Workshop on *Methods for Modalities* (M4M 2005), Berlin.
  – 2nd Int. Conf. on *Quantitative Evaluation of Systems* (QEST 2005), Torino, Italy, 2005.
  – 3rd Int. Conf. on *Formal Modelling and Analysis of Timed Systems* (FORMATS 2005), Uppsala, Sweden, 2005.
  – Conf. on *Component-Oriented Enterprise Applications* (COEA 2005), Erfurt, 2005.
• Member of the IFIP Working Group 1.8 on Concurrency Theory.
• Member of the EPSRC Review College (Engineering and Physical Sciences Research Council).
• Member of the Organization Committee of the Workshop on *Algebraic Process Calculi: The First Twenty Five Years and Beyond*, Bertinoro, August, 2005.
• Member of external PhD committees.

K. Indermark

• Scientific Advisor of the German-Israeli Foundation for Scientific Research and Development (G.I.F.)
• Member of the Editorial Board of
  – *Fundamenta Informaticae*, Annales Societatis Mathematicae Polonae
  – Aachener Beiträge zur Informatik
• Additional member of RWTH Faculty of Electrical Engineering and Information Technology
• Referee for Deutsche Forschungsgemeinschaft (DFG)
• Administrative tasks:
  – assignment of undergraduate courses to the teaching personnel
– student statistics
– head of Committee for Teaching Service

Th. Noll

• Organizer of the 5th Workshop on Language Descriptions, Tools and Applications (ETAPS/LDTA ’05)
• Program committee member of the 21st Annual ACM Symposium on Applied Computing (SAC’06)
• Member of the examination boards for Computer Science and Computational Material Science
• Student advisor for the following subsidiary subjects within CS: Electrical Engineering, Civil Engineering, and Medicine
• Organization of teaching service of CS Department (http://www-i2.informatik.rwth-aachen.de/Teaching/Service/)
• Member of external PhD committees.

B. Bollig

• Reviewer for ICALP 2005, FSTTCS 2005, QEST 2005 and FORMATS 2005

Talks and Publications

Talks

E. Bodden: Temporal Assertions using AspectJ, 22. Workshop der GI-Fachgruppe 2.1.4 Programmiersprachen und Rechenkonzepte, Bad Honnef

H. Bohnenkamp: Timed testing with TorX, 11th Dutch Testing Day, 11. 11. 2005, Enschede, Netherlands


B. Bollig: On the Expressiveness of Asynchronous Cellular Automata, Kolloquium/-Ringvorlesung des Graduiertenkolleg Wissensrepräsentation, Universität Leipzig, Germany, August 2005

B. Bollig: On the Expressiveness of Asynchronous Cellular Automata, TU München, August, 2005

B. Bollig: Automata and Logics for Message Sequence Charts, Informatik-Oberseminar, RWTH Aachen University, March 2005
K. Indermark: *Commemorative Speech for CS Graduates*, RWTH Day of Computer Science, December 2, 2005


J.-P. Katoen: *Are You Still There? - A Lightweight Algorithm to Monitor Node Presence in Self-Configuring Networks*, Int. Conf. on Dependable Systems and Networks (DSN), Yokohama, Japan, June 30, 2005

J.-P. Katoen: *Model Checking Meets Performance Evaluation*, Informatik Kolloquium at the University of Stuttgart, July 12, 2005


J.-P. Katoen: *Applications of Stochastic Model Checking*, Tutorial at the ARTIST2 Summerschool on Component & Modelling, Testing & Verification, and Static Analysis of Embedded Systems, Naesslingen, Sweden, October 2, 2005


J.-P. Katoen: *Who is Pointing When to Whom? Model Checking Concurrent Heap-Manipulating Programs*, Retirement Colloquium of Prof. K. Indermark, RWTH Aachen, November 4, 2005


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Th. Noll: *Modelling Erlang in the π–Calculus*, Computer Science Colloquium, University of Kent at Canterbury, GB, March 25, 2005


V. Stolz: *Temporal Assertions using AspectJ*, RV’05 - Fifth Workshop on Runtime Verification


M. Weber: *DIVSPIN – A SPIN compatible distributed model checker*, PDMC 2005 short presentation, Lisbon, Portugal, July 10,

**Publications**


E. Bodden, V. Stolz: *Temporal Assertions using AspectJ*, RV’05 - Fifth Workshop on Runtime Verification, to be published in ENTCS


B. Bollig: *Automata and Logics for Message Sequence Charts*, Dissertation, Faculty of Mathematics, Computer Sciences and Natural Sciences, RWTH Aachen, Germany, May 2005


Programming Languages and Verification

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  Stephan Swiderski
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  Arnd Gehrmann
Overview
Our research group is concerned with several topics from the area of programming languages and verification. In particular, we are interested in the application of formal methods in order to increase the reliability of programs:

To guarantee the correctness of software, testing is not sufficient, but a formal verification is required. Program verification is a highly relevant aspect of software technology and correctness issues are especially important for safety-critical and distributed applications. However, in general correctness proofs are very expensive and time-consuming. Therefore, program verification should be automated as much as possible.

Thus, a main topic of our research is the development of methods for mechanized analysis and verification of algorithms and systems. For that purpose, we use approaches from areas like term rewriting, automata theory, mathematical logic, computer algebra, and artificial intelligence in order to facilitate the task of correct software development.

A central problem in the design of reliable software is the proof of termination. We have developed the “dependency pair” method, which extends the applicability of classical techniques for automated termination analysis significantly.

Moreover, we work on methods and systems for proving partial correctness of programs. These techniques check if a program meets its specification provided that it terminates. In particular, we are interested in applying such techniques for several types of programming languages and paradigms.

Other important topics of our research are concerned with evaluation strategies, modularity aspects of programs, and formal specification languages.

In 2005, we held the first-year course on Computer Science I – Programming Concepts for almost 500 students and a lecture on Functional Programming. We also offered seminars on Automated Termination Analysis, on Verification Techniques, and on Advanced Programming Concepts in Java, Haskell, and Prolog. Moreover, we organized the 5th TeReSe workshop on Term Rewriting in November (the first TeReSe workshop which took place in Germany).
We are developing a verification environment which allows a fast and easy implementation of new approaches and techniques for program verification. In this way, their practical applicability can be evaluated and experiments can be performed to develop heuristics which increase their degree of automation. The system is designed in a modular way such that the implemented tools can be extended and modified easily.

Our verification framework is also applicable for teaching purposes in courses on formal methods, term rewriting, or program verification. The tool is written in Java and verification can be performed both in fully automated or interactive mode via a graphical user interface.

In particular, we design and implement a powerful automated termination prover within our system AProVE. Experiments on large benchmarks and AProVE’s success at the annual International Competition of Termination Tools show that our system is currently among the most powerful termination provers available. The system can be obtained from

http://aprove.informatik.rwth-aachen.de/
This project is a cooperation with the TU Eindhoven, The Netherlands, which is funded by the DFG. Techniques for automated termination analysis have mainly been developed for term rewriting and for logic programming. However, the connection between the respective techniques from these two fields is not clear. Therefore, our aim is to compare the existing approaches for termination analysis from both areas and to develop new techniques which combine their benefits. In particular, we are working on a new approach to transform logic programs into term rewrite systems such that termination of the resulting term rewrite system implies termination of the logic program. Then all existing techniques and systems for termination analysis of term rewriting can also be used to verify termination of logic programs.

**Termination Analysis for Functional and Imperative Programs**

Jürgen Giesl, René Thiemann, Peter Schneider-Kamp, Stephan Swiderski

The goal of this project (funded by the DFG) is to use the wealth of techniques developed for termination analysis of term rewrite systems in order to perform automated termination analysis for “real” programming languages as well. To this end, programs in these languages have to be translated into term rewrite systems. Then one can prove termination of the resulting term rewrite systems instead. However, it is not trivial to develop translations which yield rewrite systems that are suitable for an automatic analysis. We are working on such techniques for termination analysis of Haskell and (a subset) of Java. We will integrate our results in our system AProVE and evaluate their practical applicability.

**Satisfiability Checking for Termination Analysis**

Jürgen Giesl, Michael Codish, Peter Schneider-Kamp, René Thiemann, Carsten Fuhs

In this project with the Ben-Gurion University, Israel, we work on new efficient algorithms to tackle the search problems arising in automated termination proofs. In particular, our goal is to encode them as SAT-problems in a suitable way and to investigate the use of SAT-solvers in automated termination analysis.

**Process Verification by Term Rewriting Techniques**

Jürgen Giesl, Hans Zantema, Peter Schneider-Kamp, René Thiemann
This joint project with the TU Eindhoven, The Netherlands, is funded by the NWO. The goal is to apply approaches from the area of term rewriting for process verification problems. Our approach is based on an earlier project with Ericsson Telecom, Stockholm, Sweden, where we applied termination techniques in order to verify security aspects of distributed telecommunication processes. We extend this approach to a general method for proving liveness and other properties of infinite-state systems, where standard approaches based on model checking are not directly applicable.

**Combining Program Verification and Decision Procedures**  
*Jürgen Giesl, Deepak Kapur*

This project is concerned with integrating decision procedures and mechanized program verification techniques. Together with the University of New Mexico, USA, we are working on new decision techniques which can be used for verification tasks that could only be tackled by interactive provers up to now. In particular, we develop a “decidable induction prover” which can decide inductive validity of proof obligations of a certain form. Another important topic in this project is the development of techniques for automated lemma generation and generalization within inductive theorem proving. This collaboration is supported by the NSF.

**Program Transformations for Program Verification**  
*Jürgen Giesl, Janis Voigtländer, Armin Kühnemann*

In a project with the Dresden University of Technology (funded by the DFG), our aim is to use transformation techniques to increase verifiability of programs. In particular, our goal is to apply verification systems (e.g., inductive theorem provers) which were designed for functional programs to imperative programs as well. To this end, we develop a procedure to transform imperative programs into functional programs that are especially well suited for verification. In this way, it allows the mechanized verification of imperative programs without the use of loop invariants.

**Other Activities**

J. Giesl:

- Editor of three special issues of the *Journal of Automated Reasoning* on “Tech-
niques for Automated Termination Proofs” (together with Deepak Kapur, University of New Mexico, USA)

- Editor of a special issue of the journal *Information and Computation* devoted to the *16th International Conference on Rewriting Techniques and Applications (RTA ’05)*

- Chair of the Steering Committee of the *International Conference on Rewriting Techniques and Applications (RTA)*

- Member of the *IFIP Working Group 1.6 on Term Rewriting*

- Program Chair of the *16th International Conference on Rewriting Techniques and Applications (RTA ’05)*, Nara, Japan

- Invited Speaker of the *11th International Conference on Logic for Programming, Artificial Intelligence, and Reasoning (LPAR ’04)*, Montevideo, Uruguay

- Invited Speaker of the *CADE 20 – Workshop on Disproving*, Tallinn, Estonia

- PC-member and participant of the *5th International Workshop on Frontiers of Combining Systems (FroCoS ’05)*, Vienna, Austria

- PC-member of the *4th International Workshop on Parallel and Distributed Methods in Verification (PDMC ’05)*, Lisbon, Portugal

- Member of the Steering Committee of the *International School on Rewriting*, scheduled for July 2006

- Reviewer and member of the jury for the habilitation of Claude Marché, Université Paris-Sud, France

- Participant of the Dagstuhl-Seminar on *Deduction and Applications*

- Participant of the *TeReSe* workshops in Eindhoven (The Netherlands) and Aachen

- Participant of the Symposium in honor of Jan Willem Klop’s 60th birthday, CWI, Amsterdam, The Netherlands

- Research visit at the University of New Mexico, Albuquerque, USA

- Research visits at the Technical University Eindhoven, The Netherlands

- Project reviewer for the DFG

- Reviewer for many international journals and conferences
• Member of the committee for the development of the Bachelor- and Master-
curriculum for Computer Science, RWTH Aachen

P. Schneider-Kamp:

• Participant of the 5th International Workshop on Frontiers of Combining Systems
  (FroCoS '05), Vienna, Austria

• Participant of the TeReSe workshops in Eindhoven (The Netherlands) and Aachen

• Research visits at the Technical University Eindhoven, The Netherlands

• Reviewer for several international journals and conferences

R. Thiemann:

• Participant of the Annual German Meeting on Deduction (Deduktionstreffen),
  Koblenz, Germany

• Participant of the 5th International Workshop on Frontiers of Combining Systems
  (FroCoS '05), Vienna, Austria

• Participant of the TeReSe workshops in Eindhoven (The Netherlands) and Aachen

• Research visits at the Technical University Eindhoven, The Netherlands

• Reviewer for several international journals and conferences

Talks and Publications

Talks

J. Giesl: Proving Termination Automatically by Dependency Pairs, Computer Science
  Colloquium, University of New Mexico, Albuquerque, USA, March 2005

J. Giesl: The Dependency Pair Framework: Combining Techniques for Automated
  Termination Proofs, Invited Talk at the 11th International Conference on Logic for
  Programming, Artificial Intelligence, and Reasoning (LPAR '04), Montevideo, Uruguay,
  March 2005

J. Giesl: The Dependency Pair Framework: Combining Techniques for Automated
  Termination Proofs, Annual Meeting of the IFIP Working Group 1.6 on Term Rewrit-
ing, Nara, Japan, April 2005
J. Giesl: *Disproving Termination of Term Rewriting*, Invited Talk at the CADE 20 – Workshop on Disproving, Tallinn, Estonia, July 2005

J. Giesl: *Proving and Disproving Termination in the Dependency Pair Framework*, Dagstuhl-Seminar on Deduction and Applications, Dagstuhl, Germany, October 2005

J. Giesl: *Disproving Termination of Term Rewriting*, TeReSe workshop on Term Rewriting, Aachen, Germany, November 2005

R. Thiemann: *Proving and Disproving Termination of Higher-Order Functions*, Lehrstuhlseminar, RWTH Aachen, June and September 2005

R. Thiemann: *Proving and Disproving Termination of Higher-Order Functions*, TeReSe workshop on Term Rewriting, Eindhoven, The Netherlands, June 2005

R. Thiemann: *Proving and Disproving Termination of TRSs Using the Dependency Pair Framework*, Annual German Meeting on Deduction (Deduktionstreffen), Koblenz, Germany, September 2005

R. Thiemann: *Proving and Disproving Termination of Higher-Order Functions*, 5th International Workshop on Frontiers of Combining Systems (FroCoS ’05), Vienna, Austria, September 2005

C. Käunicke: *Automatische Terminierungsbeweise für Prolog–Programme*, Lehrstuhlseminar, RWTH Aachen, March 2005

M. Mertens: *Modularisierung, Strategien und Beweisverwaltung in der automatisierten Programmverifikation*, Lehrstuhlseminar, RWTH Aachen, March and August 2005

S. Swiderski: *Terminierungsanalyse von Haskell–Programmen*, Lehrstuhlseminar, RWTH Aachen, May and December 2005

D. Kapur: *Can Algebraic Geometry Rescue Program Verification?*, Computer Science Colloquium, RWTH Aachen, June 2005

**Publications**

J. Giesl (ed.): *Proceedings of the 16th International Conference on Rewriting Techniques and Applications (RTA ’05)*, Nara, Japan, Lecture Notes in Computer Science 3467, Springer-Verlag, 517 pages

J. Giesl and D. Kapur (eds.): *Special issue on “Techniques for Automated Termination Proofs”*, Journal of Automated Reasoning, 34(2), Springer-Verlag, 104 pages


J. Giesl, R. Thiemann, P. Schneider-Kamp: *Disproving Termination of Term Rewriting*, Proceedings of the CADE 20 – Workshop on Disproving, Tallinn, Estonia


C. Käunicke: *Automatic Termination Analysis of Logic Programs*, Diploma Thesis, LuFG Informatik 2, RWTH Aachen, Germany


S. Swiderski: *Terminierungsanalyse von Haskell–Programmen*, Diploma Thesis, LuFG Informatik 2, RWTH Aachen, Germany
Software Engineering

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Research Assistants continued:

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Dipl.-Inform. E. Schultchen (since November)
Dipl.-Inform. R. Wörzberger

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J. Hormes (since February)
C. Niewerth (part time 50% CRC 476)
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M. Sehrbrock, A. Simon, M. Thyssen, V. Tuttles,
I. Weisemöller, N. Wilhelms, R. Wittek, Y. Zhang

Overview

The research activities of the group can be described under the title “Languages, Methods, and Tools in Software Engineering and Architectures of Specific Software Systems”. We distinguish between general software engineering for the development and maintenance of arbitrary software systems on one side and specific forms of software engineering for certain application classes, structure classes of systems, project types etc.

Application domains we are facing are software development, chemical process engineering, process control, telecommunication systems, multimedia applications, eHome, conceptual design of buildings, specification systems for visual modeling down to systems programming as e.g. for the non-standard data based system GRAS, underlying our tools.
The structure class the group has worked in for a long time are interactive, intelligent and integrated development systems following either an a-priori or an a-posteriori integration approach. In the last two years we have also studied concurrent and distributed systems in the embedded systems domain. Project types are new development, reengineering, and reuse projects.

Most projects aim at improving general software engineering techniques or facilitating engineering development processes. Internally, the projects apply specific forms of software engineering for constructing tools for various application domains. We have developed an elaborate reuse process for developing tools, which can be applied to general tools on one side and to specific tools and context as well.

Funding of the group is by German Research Foundation (Collaborated Research Centre 476 (in short CRC) with 3 subprojects, Graduate College SCS, and Conceptual Design of Buildings), Ericsson (E-CARES Project). Furthermore, there exists some funding by the European Union (APPLIGRAPH) and A. v. Humboldt Foundation. Finally, some small cooperations with other institutes or with external companies have been carried out.

Link to research activities of the group:
http://www-i3.informatik.rwth-aachen.de/research/index.html

Teaching

The group is engaged in teaching on undergraduate level for computer science students as well as for students in electric engineering and information technology.

On graduate level the group offers courses for the focus “Software Engineering”:
- Introduction to Software-Engineering (L3+E2), every winter semester
- Architectures of Software Systems (L3+E2), summer, every 2nd year
- The SE Programming Language Ada 95 (L3+E2), summer, every 2nd year
- Graduate Practical Training Project in Software Engineering (E2), every semester
- Seminar on “New Topics of Software Engineering”, every semester
- Working group for graduate and postgraduate students, during the whole year

Furthermore the following lectures are given from time to time:
- Visual Programming (L2)
- Software Development Environments (L2)
- Management of (Software) Development Projects (L2)
- Specification of Software Systems (L2)
Research Projects

AHEAD (Adaptable and Human-centered Environment for the Management of Development Processes)

M. Heller, R. Wörzberger, M. Nagl, B. Westfechtel, G. Volkova, Chr. Briem, K. Geilmann, I. Weisemöller, R. Mao

The AHEAD project is part of the CRC 476 IMPROVE and focuses on the management of development processes. In this context, management denotes the coordination of all development activities, the management of all related documents and the administration of all involved development resources.

The process management system AHEAD works on the level of tasks and resulting products and above the level of particular detailed procedures for task fulfillment or the contents of the work results. The management system is reactive, which means it considers the dynamic nature of development processes, which are continuously evolving during enactment. The management model of AHEAD integrates three underlying models for activities, products, and resources. The model is specified in the graph rewriting language PROGRES. The AHEAD system is based on the UPGRADE framework which gives support for graphical user interfaces for graph-based tools.

In 2005, we continued our previous work on support for distributed development processes with AHEAD in several ways.

Firstly, we have integrated AHEAD with several commercial management systems. For example, we coupled AHEAD with MS Project. A project manager can now use the functions offered by MS Project to plan start and end dates for all tasks in a dynamic task net. Documentum management systems, like CVS or the commercial Documentum system, are now used as document repositories to store all documents of the development project. Additionally, developers can interface with AHEAD using their e-mail client (e.g. if they cannot run the traditional developer environment of AHEAD).

Secondly, our work focused on the development of a flexible view-based concept supporting a broader spectrum of cooperation scenarios, so that cross-company cooperation is not constrained to a delegation-based scenario any more. Flexible and dynamically changeable contracts provide a uniform way to couple development processes across enterprises.

In another direction of research we are continuing to develop a concept for the coupling of AHEAD with workflow management systems. While workflows support the execution of well-structured and static parts of a process, the remaining dynamic parts of the overall process are supported within AHEAD. Workflow descriptions are
transformed into dynamic task nets which can be monitored and controlled within the AHEAD system. AHEAD and the workflow system are coupled at runtime and exchange messages using industrial and standardized interfaces.

Furthermore, we started to prepare the transfer of the results achieved so far in the AHEAD project into industry. During the year, we met with our industrial partners (Innotec and AMB-Infomatik) to develop a concept for the construction of new dynamic process management systems based on already existing management systems provided by the industrial partners.

**Authoring Tools**

*F. Gatzemeier, M. Lerch, O. Meyer*

Our efforts in text structuring are twofold: in the CHASID project, on the one hand, we let the author model the semantical structure of his document. The additional structure is used to support an author in document creation. In the aTool project, on the other hand, we semi-automatically derive the structure of a text as it manifests itself in the typographic layout.

Both projects reached their homestretch in 2004. You can read about CHASID’s major results in the dissertations section of the last year’s report. aTool is the topic of a dissertation in 2005.

The aTool project is geared towards direct practical applicability. It enhances MS-Word with XML editing capabilities. It can be used to derive an XML structure for an existing MS-Word document, or to create that structure while writing the text. The author formats the text in the way he is used to and thus creates structural elements. For details see the dissertation’s abstract.

**Conceptual Design in Civil Engineering**

*B. Kraft, M. Nagl, G. Adonakis, T. Heer, T. Kurpick, D. Retkowitz, N. Wilhelms*

The conceptual design phase at the beginning of the building construction process is not adequately supported by any CAD tool. Conceptual design support has to regard two aspects: First, the architect must be able to develop conceptual sketches that provide abstraction from constructive details. Second, conceptually relevant knowledge should be available to check these conceptual sketches.

The aim of the project is to achieve semantics-oriented tool support for computer-aided conceptual design. Therefore, (a) tools for knowledge definition and evaluation
have been realized. The realization is based on graph transformation, specified in the graph rewriting system PROGRES. A visual language for knowledge definition, and a graph-based system implementing this language were developed. Furthermore, (b) an industrial CAD tool was extended to allow architects to design in a conceptual way. Both, the graph-based system and the industrial tool extension were integrated. The architect’s sketch can be checked against defined knowledge by consistency analyses.

In 2005 and corresponding to (a), the visual language for knowledge formalisation, as well as the corresponding consistency analyses were extended to provide and check rule-dependencies. An internal consistency checker identifies conflicts, e.g. contradictions within the set of formalized design rules. The existing visual graph-based editor for knowledge definition was extended to support the knowledge engineer while he inputs domain knowledge.

In (b), new semantical tool functionality to support architects while creating conceptual sketches is elaborated. In 2005, the concepts of top-down decomposition and modularization have been analysed. An extension of ArchiCAD implements new concepts and demonstrates their feasibility.

The project is financed by the German Research Foundation (DFG) within the priority program “Network-based Co-operation in Structural Engineering” (SPP 1103)

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**DRAGOS – A Parameterizable Database For Development Environments**

B. Böhlen, E. Schultchen, M. Breuer, G. Volkova, S. Badral, T. Hermes, T. Lettow, E. Maes, M. Thyssen, in cooperation with the fujaba development group

DRAGOS is a database system which is developed according to the requirements of software systems for special application areas. This includes integrated development environments, CASE tools, re- and reverse engineering tools and other interactive applications using complex object structures. Common to these applications is the necessity to handle different types of objects on different levels efficiently: Coarse- and fine-grained objects, hierarchical and non-hierarchical relations between them, and a vast number of differently sized attributes (chapter numbers and images). DRAGOS offers a rich graph model and an extensible architecture. Features not provided by DRAGOS itself can be realized by extension modules, e.g. graph versioning, undo/redo etc.

In 2005 we completed the development of SUMAGRAM, a tool for specifying specialized graph models as UML diagrams. Based on the UML diagram the code which maps the graph model onto the DRAGOS graph model is generated. The prototypes built with PROGRES and UPGRADE now utilize DRAGOS as their graph storage.
For the prototypes the most apparent benefit is that they are no longer tied to UNIX. For persistent storage, the user now can choose between different database systems.

In 2005 we also completed the DRAGOS plug-in for Fujaba (From UML to Java and back again) and the associated runtime library. In the future additional concepts can be realized in Fujaba based on the features provided by DRAGOS and its extensions. In 2005 we realized two extensions for DRAGOS: incremental attribute evaluation and graph versioning. To support additional graph storages we started the development of a MySQL and Apache Derby based graph storage.

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E-CARES (Ericsson Communication Architecture for Embedded Systems)

C. Mosler, M. Nagl, L. Xu, Y. Zhang, W. Zhao

The subject of study of the E-CARES (Ericsson Communication Architecture for Embedded Systems) research cooperation between Ericsson Eurolab Deutschland GmbH (EED) and the Department of Computer Science 3, RWTH Aachen, is Ericsson’s Mobile-service Switching Center (MSC) called AXE10. The cooperation aims to develop methods, concepts, and tools to support the processes of understanding and restructuring complex legacy telecommunication systems.

In the first phase of the E-CARES reengineering project, our research concerned the reverse engineering of telecommunication software. The project focused on the detection, extraction, and visualization of information on the system’s structure and behaviour. Extraction from static information (code) and from runtime information (traces) was regarded.

The static information is used to build a so-called system structure graph. This graph contains information on a system’s decomposition into different units in different granularity. Furthermore, the system’s control flow and parts of its data flow are represented by the graph as well. Dynamic information is gathered through tracing the execution of traffic scenarios on the AXE10 system emulator. The resulting AXE10 traces are, e.g., used to generate collaboration diagrams or, in combination with multi-layer abstraction and visualization, to reduce the amount of displayed static information according to a certain traffic case.

Current work (Ph.D. work of C. Mosler) concerns restructuring of legacy telecommunication systems including their re-design and re-implementation. The aim is to extend the reverse engineering tool to a functional reengineering tool, allowing the engineers to interactively modify and improve the software architecture.

In 2005, several re-design algorithms improving the software architecture were successfully implemented. New algorithms for improving the runtime performance
of the AXE10 system are being developed. The extensions of the reengineering
tool comprise also facilities for source code modification, by which architectural
changes performed on the structure graph can be automatically propagated to the
implementation level.

**i-caramba: Integrated Component Architecture for Automotive Embedded Applications**

*C. Fuß, M. Nagl, T. Nguyen, V. Tuttlies, R. Wittek*

With up to 80 electronic control units in luxury cars, soon 1 GB of software, and many
non-functional requirements the increasing amount of electronic functionality repre-
sents a big challenge for the automotive industry. In today’s development processes
of embedded systems, numerous models are utilized in parallel to describe one target
system. In order to allow a later integration of the different results of this process many
consistency relations have to be obeyed.

In an effort to tackle the arising problems in automotive electronics the international
AUTOSAR consortium, formed by OEMs, suppliers and tool developers, tries to
develop an open standard for automotive E/E-architectures, easing systems integration
and deployment of standard components. As one of the most innovative car manufac-
turers in Germany, the BMW Group took over the lead in the consortium and strives
for a continuous model-driven development process of automotive electric/electronic
systems based on the evolving AUTOSAR standard. In this process architectural
models of functions, software and hardware play a prominent role.

i-caramba (Integrated Component ARchitecture for Automotive eMBedded Applica-
tions) is a cooperative project of BMW Group and the Department of Computer Sci-
ence 3 (Software Engineering) at RWTH Aachen University, which aims at supporting
the engineers in developing integrated models of functions, hardware and software by
providing concepts and tools.

The conceptual work focuses on developing a component meta-model forming the
common kernel of the above mentioned models, thus also building the greatest com-
mon denominator of all AUTOSAR meta-models. Particular attention is paid to the
following aspects: communication in distributed systems, real-time requirements, vari-
ants in product line development, and foremost model integration.

Tools are developed for editing models separately as well as editors for mappings
between models, e.g. the deployment of software components to hardware units. All
tools are based on the i-caramba meta-model kernel.
Development processes in engineering disciplines are inherently complex. Throughout the development process, different kinds of inter-dependent design documents are created which have to be kept consistent with each other. Ensuring consistency is a difficult task, especially if the documents are handled by heterogeneous tools and/or different developers.

This project, which is part of the CRC 476 IMPROVE, deals with the construction of incremental tools for a-posteriori data integration (integrators). Integrators help keeping documents consistent by offering transformation and incremental change propagation between dependent documents. Integration is controlled by rules. Nevertheless, in general, user interaction is required to choose among different possible options. Integration functionality is realized by establishing and maintaining fine-grained inter-document links between related entities of the documents, which mirror the relationships between the documents’ contents.

In 2005, we completed the semi-formal definition of the semantics of integration rules by specifying the translation of integration rules into graph transformation systems in the PROGRES language. Using the UPGRADE framework, a prototype with graphical user interface can be derived from such a specification. The resulting prototype serves as integration rule evaluation environment (IREEN). IREEN has already been successfully applied to extend the integration algorithm.

Besides working on IREEN, we prepared the transfer of the results achieved so far to industry. For instance, a C++-based framework is being developed. This framework implements the same semantics as the PROGRES-based machinery, providing an integration rule interpreter. It supports at-hoc learning of new integration rules and offers interfaces to connect a-posteriori to existing applications. The framework will be used for evaluation in industry in 2006.

To prepare industry transfer, different research activities have been performed together with our industrial partner innotec GmbH. A UML view for customizing their chemical engineering design tool Comos PT has been realized. Currently, a set of integration rules to import external data into Comos PT is being defined.

Integrated eBusiness-Systems in Home Automation

eHome systems are gaining more importance due to recent developments in hardware technology and the trend towards pervasive and ubiquitous computing. Research in this area is also attractive w.r.t. its increasing market potential. However, there are a number of problems to be solved before eHome systems are deployable to the masses, e.g. the dynamic aspects and the interaction of arbitrary devices just to name two.

EHome systems are built on top of integrable net-aware devices in households. Applicable devices, communication techniques, and infrastructures vary in several dimensions: Devices vary with respect to interfaces, features, locations, and range. Important differences in communication are protocols, bridges, name spaces, and through-put. The applied infrastructure can be centralized as well as decentralized, or even offer a mixed approach. Last but not least, the integration of external service providers is an unanswered question. Until now, just hardware-specific solutions have been investigated in commercial approaches. Hence, suitable and reasonable models and structures for this new application domain still need to be developed.

Up to now, we analyzed the life-cycle of eHome services from the development over the automatic installation at the eHome to the retirement. In the development phase, eHome services can be developed in a classical or rule-based way. The latter enables a flexible declarative specification of the service functionality. Furthermore, service interaction conflicts during runtime can be detected and a suitable notification of the user is provided. The business process part has been specified as a workflow and the instantiation and monitoring of the process are performed by a workflow management system. As a result the provider can manage lots of customer relationships easily.

Another problem that occurs in combination with many customer relationships is the expensive manual adaption of eHome services to the customers’ needs. Thus, in the domain of low-cost eHome systems, it is essential to automate the configuration process. For this purpose we developed the eHomeConfigurator tool, which supports the specification of an eHome environment, the automatic configuration of selected services based on the eHome specification, and the deployment of the configured services to gateway residing in the eHome.

Currently, we work on problems occurring when eHome environments are extended beyond the physical boundaries of individual buildings to enable the migration of personalized service functionality. These problems are related to the communication of different gateways, within buildings as well as between multiple buildings. Furthermore, new dimensions of service interaction problems occur. These have to be resolved with as few user interaction as possible. The dynamically changing environments affect the configuration of eHome systems. A dynamic reconfiguration solution has to be found to support the automatic adaptation of personal services to different environments.
PROGRES: A language for specifying graph transformations

Since 1989, we are developing the graph rewriting system PROGRES which allows rapid prototyping of complex software systems. The process of creating a PROGRES prototype is divided into several stages of development. At first the prototype’s static and dynamic features are modeled using the PROGRES language. Since PROGRES uses graphs as the underlying data structure, the emerging specification comprises a graph scheme representing the static structure of the prototype and a collection of visual graph transformations which describe the behaviour of the system to be modeled. Using control structures for combining diverse transformations, PROGRES offers the possibility to define complex transformations. Having defined the structure and the behaviour of the prototype with the PROGRES language, the PROGRES environment is used to generate efficient C or Java code from the specification. In combination with the UPGRADE framework, a prototype featuring a graphical user interface can be built based on the generated code.

We have used PROGRES for applications in various domains, e.g. for analysis of communication systems (E-CARES), the authoring tool CHASID and the process management system AHEAD. As the specifications of these systems get increasingly large and complex, it is necessary to extend PROGRES by concepts for modularization and for the modeling of distributed systems, which is addressed by the project Vilendis.

In 2005 we have extended the Java-code generation of the PROGRES environment to generate DRAGOS-specific code. With this enhanced code, PROGRES can use DRAGOS as underlying database instead of GRAS. Furthermore, we have started to introduce an import/export mechanism in PROGRES which is needed for re-using parts of specifications in different applications. This is especially needed by the Vilendis project for specifying distributed systems.

In addition to the introduction of object-oriented programming, we have extended the language in 2005 by a super-construct allowing the subclasses to call transformations of their super-classes. System maintenance and extensions of the comprehensiveness are on-going tasks in a complex environment like PROGRES.

UPGRADE: A framework for developing prototypic applications

In general, PROGRES specifications are used to model the behaviour of complex applications (like the AHEAD prototype). To create a prototype, code is generated from the specification which is embedded into the UPGRADE framework. The resulting
prototype is highly configurable and provides a graphic view on the document manipulated by the specified operations. As more functionality is needed, the prototype can be extended to use new views, complex graphic elements etc.

Work in 2005 was dedicated to the consolidation of the framework. Additionally, several significant extensions have been made according to the needs of the projects that use the UPGRADE framework and the PROGRES system. For example, the web-based views of the UPGRADE framework have been improved and further modifications concerning object-oriented concepts of PROGRES have been conducted.

Also in 2005, we started to integrate the UPGRADE framework with the DRAGOS database system (described below) to allow for UPGRADE prototypes to use either the GRAS database or commercial relational databases like MySQL.

Software Integration and Framework Development

T. Haase, M. Nagl, M. Botzen, A.-T. Körtgen

Nowadays, single engineering activities are supported by specialized, isolated tools based on heterogeneous system platforms, proprietary document formats, and different conceptual models. Typically, the overall development process, i.e. the dependencies between activities and their resulting products, the consistency between products produced by individual activities etc. are not considered by the supporting tools.

The role of the subproject I3 within CRC 476 IMPROVE is to coordinate the software development process delivering an integrated development environment. For this, it deals among others with the development of a general framework for the a-posteriori integration of existing tools. Integration is realized on the architectural level. An architecture for the integrated environment is developed on the level of subsystems, where general components are identified. Thereby, a coordinated development and reuse on the product level is enforced. Additionally, the subproject takes care of that project-specific components are embedded correctly into the overall system.

The architecture of the overall environment describes the “gluing parts” necessary for performing the integration. It defines, for example, what kinds of interfaces the tools to be integrated offer, how interfaces are wrapped in order to homogenize them, how tools and wrappers are distributed, how interfaces are accessed via certain middleware techniques and so on. Furthermore, to reduce the development effort for building the required wrappers, we aimed to specify them by visual models. A modeling formalism for the specification of such models was defined. Based on these models the executable code for the wrappers is generated and embedded into the general framework.

In 2005, the work on formally defining the semantics of visual models for the specification of wrappers using the PROGRES language was nearly completed. This also
includes the implementation of the Fire3NG-prototype for a visual modeling environment based on the UPGRADE framework. Furthermore, we started the preparation of the developed results for industrial transfer in 2006. Therefore, several presentations of the approach for potential industrial partners were given. AMB-Informatik seems to be a suitable partner.

**Vilendis: Visual languages for specifying distributed systems**


Graph-based visual programming languages are used for the specification of complex software systems. The project Vilendis focuses on the investigation of two existing specification languages PROGRES and Fujaba. Both languages support the visual design of applications. Furthermore, the visual environments are able to generate C or Java code from developed specifications. This code can be compiled using existing tools in order to create adaptable, visually displayed prototypes.

Both PROGRES and Fujaba can be used in various domains, but both lack the ability of supporting the specification of distributed systems. As the importance of distributed and heterogeneous systems increases, our project’s objective is the development and implementation of appropriate concepts, which can be used to model distributed behavior in a visual way. We create an extensive framework, making it possible to model a distributed system similar to that of a local application. For the realization, we analyze existing and established concepts of distributed heterogeneous systems like Remote Procedure Calls.

In 2005, we have analyzed the requirements for modeling distributed systems using the AHEAD system as an example. According to these requirements we have designed an adequate system architecture which we have started to implement. Up to now, it is possible to exchange interfaces of specifications and to perform remote procedure calls. On the basis of textual coupling, we are investigating how the coupling of different prototypes can be specified visually. Additionally, we develop concepts for defining views on the specifications.
Other Activities

Prototype demonstrations


Kraft, B.: Semantic Roomobjects for Conceptual Design Support, 11th Int. CAAD Futures Conf. 2005 (CAAD Futures 2005), June 2005, Vienna, Austria

Kraft, B.: Neue Funktionalität für CAD-Systeme, DFG-SPP 1103 Workshop for Industrial Relations, November 2005, Weimar, Germany


Conference Activities and Academic Administration

T. Haase: Local co-organizer of the “Ada Deutschland Tagung 2005”, October 2005, Aachen, Germany

M. Heller: Chair of the working group “Project Management” of the Regionaler Industrieclub Informatik Aachen e.V. (REGINA)

B. Kraft: Teaching position at Aachen University of Applied Sciences; Member of examination board at the chamber of industry and commerce at Cologne; Member of the Regina group “Project Management”; Member of the DFG-SPP 1103 group “Distributed Product Modelling”; Member of the DFG-SPP 1103 group “Distributed Process Modelling”
M. Nagl: Speaker of the Computer Science Department (until Sept. 05); Speaker of Collaborative Research Center 476; Member of the Board of “Forum Informatik”; Member of the Board and Speaker Substitute of REGINA; Member of RWTH Aachen University Senate; Additional Member of the Faculty for Electrical Engineering and Information Technology; Editorial Board of Compass Series by Springer-Verlag; Co-Editor “Aachener Berichte zur Informatik”; Member Editorial Board “Journal of Networks and Computer Application”; Acquisition of industrial stipends for students and organizing the competition; Local Organizer of the Workshop “Zuverlässigkeit in eingebetteten Systemen”, Ada Germany 2005, Oct. 13-14, 2005, Aachen; PC Memberships: Software Engineering 2005 at Essen; Fujaba-Days 2005, Paderborn, Ada Germany 2005, Aachen

U. Norbisrath: Referee of the Department of Computer Science of the RWTH Aachen University

U. Ranger: Co-organizer of the “Girls Day”, “Study Day for Girls”, and “Scholar information days” for Computer Science; Faculty representative for the equality commissioner Ms. Diepelt

R. Wörzberger: Chair of the working group “Project Management” of the Regionaler Industrieclub Informatik Aachen e.V. (REGINA)
Talks and Publications

Talks


Heller, M. and Wörzberger, R.: *Werkzeugunterstützung für das Projektmanagement von verfahrenstechnischen Entwicklungsprozessen*, Fachausschussitzung Prozess- und Anlagentechnik VDI-GVC-Dechema, Bad Neuenahr, 7.11.05


Kraft, B.: *Unterstützung des konzeptuellen Gebäudeentwurfs - Aktueller Stand und Ziele in Phase 3*, DFG-SPP 1103 Workgroup Meeting: Distributed Product Models, January 2005, Weimar, Germany

Kraft, B.: *Graphbasierte Werkzeuge für den konzeptuellen Gebäudeentwurf: Aktueller Stand und Ziele*, DFG-SPP 1103 Reviewers-Colloquium, April 2005, Dresden, Germany

Kraft, B.: *Semantic Roomobjects for Conceptual Design Support*, 11th Int. CAAD Futures Conf. 2005 (CAAD Futures 2005), June 2005, Vienna, Austria


Kraft, B.: *Neue Funktionalität für CAD-Systeme*, DFG-SPP 1103 Workshop for Industrial Relations, November 2005, Weimar, Germany

Kraft, B.: *Informatik an der RWTH Aachen*, Schülerinformationsveranstaltung Liebfraueschule Eschweiler, November 2005, Eschweiler, Germany

Kraft, B.: *Semantische Unterstützung des konzeptuellen Entwurfs*, RWTH Aachen, Tag der Informatik, December 2005, Aachen, Germany


Retkowitz, D.: *Operationale Semantikdefinition für konzeptuelles Regelwissen*, 17th Forum Bauminformatik, Brandenburg University of Technology, September 2005, Cottbus, Germany


**Publications**


Broy, M., Jarke, M., Nagl, M., Rombach, D. (Eds.): *Dagstuhl Manifest zur strategischen Bedeutung des Software Engineering in Deutschland*, further authors, in preparation


Kirchhof, M.: Integrierte Low-Cost eHome-Systeme: Prozesse und Infrastrukturen, Dissertation RWTH Aachen University, 331 pp., 2005


Marburger, A.: Reverse Engineering of Complex Legacy Telecommunication Systems, Dissertation RWTH Aachen University, 418 pp., Shaker, 2005


Meyer, O.: aTool: Typography as Source for Structuring Texts (in German), Dissertation RWTH Aachen University, 308 pp., 2005


Nagl, M.: The Interdisciplinary IMPROVE Project, in preparation


Nagl, M., Marquardt, W. (Eds.): Collaborative and Distributed Chemical Engineering Design Processes: From Understanding to Substantial Support - Results of the IMPROVE Project, book in preparation

Software Construction

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Overview

Our research focuses on the development of new and advanced methods and techniques in the broad area of software construction. Currently we are running a couple of projects in the context of software product line development. Here we address especially requirements and architecture issues.

In 2005 we organized the 9th Workshop on Software Engineering Education at Universities (SEUH 2005) which is a joined workshop series of GI, SI and the German Chapter of the ACM. The workshop took place the 24th and 25th of February at the Informatics Centre. The program of the workshop offered a couple of talks as well as panel discussions and a very special session where students comment on the workshop and the presented teaching approaches. The key note was given by Prof. W. Tichy, University of Karlsruhe. Before the workshop a tutorial on a project management simulation environment (SESAM) was organized together with the software engineering chair of Stuttgart University. Altogether we could welcome about 70 software engineering professors and practitioners from Austria, Switzerland and Germany.

In spring Dr. Shmuel Tyszberowicz from Tel Aviv University visited our group. He is doing research on aspect oriented programming. Together we started a case study to investigate the benefits and drawbacks of using aspect oriented programming as an implementation technique for software product lines.

Teaching

In addition to undergraduate courses on Programming and Software Development the group offers on the graduate level the following set of courses focusing on Software Construction and Software Quality Assurance:
Furthermore we are responsible for the Software Engineering course of the master program Software Systems Engineering at the Thai German Graduate School of Engineering, Bangkok, Thailand. This course was given the first time in winter term 2005.

Research Projects

**Requirements Engineering for Software Product Lines**  
*T. von der Maßen, H. Lichter*

The development of a Software Product Line (SPL) is a demanding task for all stages of the software development process especially for the requirements engineering. The identification and modeling of common and variable characteristics are an essential task during the requirements engineering process. Communicating variability to stakeholders affect the success of projects significantly.

Feature based domain modeling is a well-known technique in requirements engineering of product lines to model variability within requirements. The overall objective is to model commonality and variability in a platform feature model (PLFM). From the PLFM, dedicated product feature models (PFM) can be derived. The PLFM is part of the platform requirements specification and a PFM is part of a product requirements specification. Though quality models for requirements specification exists, quality models for feature models have been neglected so far. Especially it must be examined, how variability influences the claimed qualities.

Evaluating the adequacy, integrity and consistency of PLFM is of high importance. The derivation of PFMs can only be done, if the PLFM does not show any inconsistencies. Therefore the research group has defined categories of inconsistencies and identified the problems that can appear within the models and introduced metrics to determine if variability is adequately modeled.

Our research group continued furthermore the work on *RequiLine*, a requirements engineering tool that supports the management of natural language requirements and
feature models, equally. RequiLine has been enhanced by a PFM derivation wizard. This wizard guides the user through the derivation process to avoid the building of inconsistent PFMs. Furthermore a metric interface has been implemented that allows the determination of the PLFMs variation degree, to evaluate its flexibility and adequacy.

RequiLine has been evaluated in cooperation with Robert Bosch GmbH in the context of the development of motor control units. RequiLine detected several defects in the motor control units PLFM. Additionally RequiLine helped in retrieving information about the variation degree and other needful statistical information, that influences the further development at Bosch.

**Feature-based Architecture-Modeling for Software Product Lines**

*T. Weiler, H. Lichter*

*External cooperation: ABB Corporate Research, Ladenburg*

In the last year we have improved our methodology for developing a product line platform architecture (PLPA) based on a feature model, thus allowing for smooth transition from requirements engineering to architecture modeling. While the single phases of the software development process are mostly self-contained with continuous methodology, notation and also adequate tool support, the transitions often exhibit a gap. To bridge this gap, transformations between the different methodologies and notations used in the adjacent phases are needed. But the abstraction needed for these transformations results in information loss.

By providing a methodology which minimizes the information loss between the single phases of the software engineering process, traceability of modeling decisions can be
ensured. This results in a better documentation of the process and its products which in turn eases the evolution of the products and ensures return of investment.

Feature Modeling can assist this task by providing an input for the design process to identify components and structures of the PLPA. The main advantage of this procedure is that the feature model defines already a net of terms, which are identified to be crucial for the system, and the variability among them. These terms - the features - are thereby organized in a structure (here: a tree or graph) abstracting from the nebulous cloud of customers requirements. Thus, feature modeling supplements the output of the requirements process (namely the requirements specification), by providing a more formal and structured input for the following design phase. This aids the software architect finding the structure for the system and identifying architectural components. When analyzing the feature model to identify architectural component candidates, the categorization defined by the architectural style chosen has to be taken into account. This way all features modeled in the feature model are sieved by some kind of filter stack, defined by the chosen architectural style, see the following Figure.

Methodology for PLPA Modelling.

The categorization respectively modularization defined by the chosen architectural style will rarely map one to one to the features modeled in the feature model. Therefore each feature has to be analyzed to that effect which parts of its specification map into which category defined by the architectural style. We call these parts feature components (FC). We are convinced that features can not be directly mapped to architectural components like classes, aspects, or other technical components because a feature model and thus its features are an abstraction of the requirements of an SPL. Because an architectural design has to be concrete on its components, one has to analyze the features on how they contribute to architectural components. Hence this transformation, in our opinion, can not be automated, but supported by a set of transformation rules which help the designer to identify architectural components.

First, all features have to be analyzed with respect to the chosen architectural style to find how they contribute to the different categories defined by the architectural style. This way, lists of feature components are created for the different categories of the architecture. In the next step the relationships between the earlier identified feature components have to be analyzed, based on the feature descriptions and a set of
transformation rules. The result of this process is a net of feature components which serves as an input for the next step. The analysis of the feature components is not straightforward, and several iteration steps are needed to obtain the final net of feature components.

During identification of the feature components each variability, which is assigned to a feature in the feature model, is analyzed to determine whether it influences one of the feature components derived from the feature. If so, the feature component concerned is also assigned the variability, which is depicted in the figure above, by a red circle (denoting an option) or red diamond (denoting an alternative). Therefore, a variability modeled in the feature model can be distributed over a set of feature components which all have the same variability with the same ID assignment. This way, traceability of the domain variability modeled in the feature model is ensured.

In the next step architectural components must be formed based on the feature components identified before, according to the modularization criteria used at the subsystem level of the architecture. In order to form e.g. classes, each component feature has to be analyzed to determine whether it denotes a class, a responsibility (method) of a class, or an attribute of a class. This way a class diagram representing the static structure of the product line platform architecture is created.

### Product Line Development for Embedded Systems

A. Nyßen, H. Lichter

**External cooperation: ABB Corporate Research, Ladenburg**

While hardware development is largely understood and can be efficiently performed, state-of-the-art software engineering for embedded systems is far behind that of other application areas. Thus, embedded software systems are often monolithic platform-dependent systems that are built from scratch and are hard to maintain, upgrade, customize or even port to other platforms. To establish systematic development to this field is challenging, because the stringent non-functional requirements that are imposed on an embedded software system by its surrounding environment (like memory consumption or timing constraints) and the special application domains (e.g. hazardous application areas) do not allow to apply common software engineering practices "as is" but require that they have to be "tailored" to meet these new demanding requirements. Inspired by the large success product line engineering has brought to hardware development, it seems to be a promising approach to gain more reuse, higher product quality and lower product development costs in software development also, especially in the development of embedded software systems.

However, product-line practices cannot be reasonably applied if no systematic development is established in the developing organization, which can be taken as a firm
basis to build upon. That is why past work of this project focused on methodical aspects and - furthermore inspired by the practical needs of our business cooperation partners - resulted in the definition of an iterative development process and a detailed design method (at first for the single product case) that are capable of forming the basis for the application of more far-reaching product line engineering practices.

While the introduction and optimization of the conceived process and methodology with our business cooperation partners has been considerably supported, current research work is this project is focussing on a more sophisticated UML2-based notation for product-line architectural models, as well as on methodology to support the design of those. This elevated concentration is done, because a product-line architecture is being regarded as the major core asset of a product line - as it forms the bases for all succeeding development activities inside the product-line life cycle. In this context, much work is also spent on the development of a visual modeling tool supporting the developed notation and design methodology, called ViPER (Visual Modeling Platform for Embedded System ARchitectures). It is intended to be a research prototype to demonstrate the conceived notation and methodology. Furthermore it will later be employed to demonstrate the integration of architectural models with those models of preceding and succeeding development phases, e.g. by offering source code generation capabilities based to support the implementation.

Process and Tool Support for the Maintenance of Hierarchical Product Lines

H. Schackmann, H. Lichter

External cooperation: Kisters AG, Aachen

The parallel development and maintenance of multiple customer specific products within a product line requires serious efforts for coordination and monitoring. This is especially the case, when different product lines are based on a set of common assets and must share the development resources. The particular products may have different release plans that must be fulfilled. Development resources must be shared efficiently between product development projects and platform development. The common platform, as well as the platform of each product line based on it, must serve the sometimes diverging needs of the products. But it must be prevented that this results in different variants of a platform that are maintained in parallel. Under these circumstances adequate processes with suitable tool support are necessary to take advantage of the synergies in product line development.

In the last year we designed a development process in cooperation with Kisters AG that is targeted to fit the needs of evolving product lines better than prevalent project-centric approaches. On this basis there arise many questions for the detailed sub processes
which are subject of ongoing work. Amongst others we developed guidelines for the requirements management process and support for risk management. Current work is focused on putting these measures into practice, which will include the customizing of the processes to the needs of different product lines.

Driven by the practical experiences we are furthermore working on concepts for continuous life-cycle scoping for software product lines. We identified the necessity of investigating the cost effects of product line variabilities during the evolution of the product line. This requires a suitable approach for costing which differs from project-centric cost accounting. The intention is to use this information to enable substantiated decisions to control the evolution of variation points in a software product line. An improved transparency of the different activities, their progress and their costs will support the product-line wide coordination and planning.

**Other Activities**

Board Member of the GI-Fachgruppe 2.1.6. Requirements Engineering, H. Lichter

Member of the program comittee, GI-Workshop Informatik LIVE für Users LIFE flexible Integration macht's möglich!, Bonn, 19.9.2005

Member of the program comittee, GI-Conference Modellierung 2004, Marburg, 24.-26.3.2004, H. Lichter

Member of the program comittee, GI-Workshop SEUH 2005, Aachen, 24.-25.2.2005, H. Lichter


Reviewer for dpunkt-Verlag Heidelberg and computing reviews, H. Lichter

Organization of the Computer Science Department’s mentors program, H. Lichter

Member of the Computer Science Department’s committee for Service-Lehre, H. Lichter

Member of the examination board of Computational Material Science, H. Lichter

Organization of the Beginner’s Course in Computer Science 2005, H. Lichter, T. Weiler

Speaker of the GI-Arbeitskreis Werkzeuge für die Produktlinienentwicklung of the GI-Fachgruppe Requirements Engineering, T. von der Maßen

**Talks and Publications**

**Talks**

H. Lichter: *Techniques, Processes and Methods for Requirements Engineering*, ABB Corporate Research Centre, Ladenburg

H. Lichter: *Evolution of Software Product Lines*, University Karlsruhe

140
H. Lichter: *Grundlagen des Requirements Engineering*, Kisters AG, Aachen

T. von der Maßen: *Determining the Variation Degree of Feature Models, in Software Product Lines*, 9th International Conference, SPLC 2005, Rennes, France


**Publications**


Communication and Distributed Systems

Staff

- Faculty:
  Univ.-Prof. Dr. Otto Spaniol

- Secretary:
  Christiane Gelueck
  Petra Zeidler

- Academic and Research Staff:
  Dipl.-Inform. Yuri Babich
  Dipl.-Inform. Zinaida Benenson (until 30.11.05)
  Dipl.-Volksw. Heide Coenen (since 02.02.05)
  Dipl.-Inform. Stefan Diepolder
  Dr. Markus Fidler
  Dr. Mesut Güneş (on leave of absence to ICSI)
  Dr. Frank Imhoff
  Dr. Dogan Kesdogan
  Dipl.-Inform. Tobias Kölsch
  Dipl.-Inform. Karl-Heinz Krempels
  Dipl.-Ing. Jan Kritzner
Staff

- Academic and Research Staff ctd.:
  Dipl.-Designerin Alexandra Meyer
  Dipl.-Ing. Kittisak Ormsup
  Dipl.-Inform. Andrij Panchenko (since 01.09.05)
  Dipl.-Inform. Stefan Penz
  Dipl.-Inform. Rajendra Persaud
  Dr. Carsten Pils (until 31.08.05)
  Dipl.-Inform. Lexi Pimenidis
  Dr. Ulrich Quernheim
  Dr. Jürgen Rapp
  Dipl.-Inform. Tim Seipold
  Thitinan Tantidham, MSc
  Dr. Dirk Thißen
  Dr. Michael Wallbaum
  Dipl.-Inform. Martin Wenig
  Dipl.-Inform. Ralf Wienzek
  Dipl.-Inform. Alex Zimmermann (since 01.11.05)

- Technical Staff:
  Helen Bolke
  Kai Jakobs
  Rainer Krogull
Overview

Research focuses on design and evaluation of communication networks and distributed systems, with a particular emphasis on multimedia communication, mobile networks, agents, and security aspects. In particular, this includes:

- Mobile and Wireless Networks (Security Management, Traffic Models, Mobile Internetting, Mobile Middleware, Mobile Ad-hoc Networks)
- Network Management (Mobility Management, Quality-of-Service Support, Cooperative Management, Traffic Engineering, Differentiated Services)
- Mobile and Intelligent Agents (Agents in Telecommunications and Health Care, Agents in Mobile Telecommunication Networks)
- Security in Networks (Anonymity Protocols, Intrusion Detection)
- Applications (Service and Mobility Management, Mobile E-learning)
- Standardisation Research

In addition, several members of staff have been heavily involved in the planning, installation, and pilot testing of the University’s new Wireless Local Area Network. Funding for research staff comes from various sources, including the German Research Council, Federal and State Governments, the European Union, and industry. In addition to the mandatory undergraduate courses teaching focuses on communication systems (‘Data Communication’, ‘Distributed Systems’, ‘Web Protocols and Practice’), security aspects (‘Security in Communication Networks’, and ‘Privacy Enhancing Techniques’). Practicals in ‘Agent Technology’ and ‘Network Programming’ as well as a virtual practical ‘Computer Science’ were also offered.

For further information please see:

http://www-i4.informatik.rwth-aachen.de
Research Projects

Artificial Policy Agents Supporting Time Scheduling in Hospitals

Karl-Heinz Krempels

The project is part of the SIG ‘Intelligent Agents in Economical Applications’ sponsored by the German Research Foundation (DFG). Scheduling actions in an hospital is very much prone to interruptions as a result of emergencies. Currently available tools for time scheduling in hospitals are static, i.e., scheduling is performed manually and the schedule is then stored in a database. This approach, however, has some severe shortcomings. For instance, it is not possible to take into account personal preferences, like e.g. the preferred time of an operation. To overcome these deficiencies, in our approach everyone whose resources have to be scheduled is represented by an agent. The agent knows the preferences of its principal and negotiates with its counterparts if these preferences cannot be satisfied. As it will not normally be possible to accommodate all preferences all participants need to establish their respective priorities. The solution to this problem is NP-complete; it can only be solved through approximation algorithms or heuristics leading to solutions closed to the optimum. The decomposition of personal preferences with the help of conjoint analysis enables us to determine the personal utility of all actors, of new created schedules. The combination with interactive scheduling and time tabling seems to provide a good solution. The experimental setup is based on the FIPA compliant agent system JADE, the rule based expert system JESS, and domain specific ontology OntHoS and HL7. Problem solving methods (psm) and algorithmic heuristics are are developed from scenarios modeled with the help of the domain ontologies in the JESS knowledge base (kb). The kb as well as the psm are used by prepared agents to solve conflicting preferences through negotiation. Furthermore, the conflict free kb is used to draw the final time table of the schedule.

Development of an Ad-hoc Service Management for Self-Organizing Mobile Networks

Stefan Penz

Future mobile networks will exhibit a far more decentralized and dynamic structure than current infrastructure W-LAN or UMTS networks. Mobile devices will be able to communicate directly via wireless connections without fixed components (e.g. W-LAN access points). The ad-hoc establishment of such networks raises the need for a
dynamic and flexible service management system that enables the users and their applications to spontaneously discover, access, and use network services (e.g. a printing service or an internet connection service offered by other mobile devices). For ease of service access the service management should work transparently with a minimum of administration and configuration effort. In a first phase of the project Informatik 4 developed a flexible service management on the basis of the IETF Service Location Protocol (SLP). For many services, the network transmission has to meet specific quality requirements, e.g. a minimum bandwidth or a stable communication path for a certain period of time. Therefore, we currently extend our service management by a path quality estimation component that determines relevant parameters of communication paths between the user and discovered service providers. With this information, the user is able to consider the characteristics of the corresponding communication paths for provider selection. Amongst others, we develop routing protocol extensions to assess path stability indicators and an end-to-end bandwidth measurement system for wireless ad-hoc networks. The project is part of the German Research Foundation’s (DFG) Priority Programme ‘Basis Software for Self-Organizing Infrastructures for Networked Mobile Systems’, which currently includes thirteen research projects at German universities. The main topics of this program include routing, middleware and application support of mobile ad-hoc networks. More information can be found at http://www.tm.uka.de/forschung/SPP1140/.

Core Network Mobility based on Multi-Protocol Label Switching

Rajendra Persaud

Currently, several packet-switched wireless networks exist. These are networks based on the IEEE 802.11 standard family, networks based on IEEE 802.16 and 2.5G and 3G cellular systems. 2.5G and 3G cellular systems offer both a circuit-switched and a packet-switched core network part. All networks are evolving in terms of increasing data rates on the air interface, in terms of mobility support for mobile devices, in terms of decreasing outage periods during handovers, etc. This project deals with mobility in packet-switched wireless networks. Since link-layer mobility solutions are generally incorporated into the corresponding technology, the focus of this project is on network-layer mobility solutions. Such network-layer mobility solutions may be based on the Internet Protocol (IP) or on Multi-Protocol Label Switching (MPLS). All existing IP-based and MPLS-based network-layer mobility solutions suffer from several disadvantages. These are long outage periods and packet loss during the handover, high end-to-end delays for those data packets affected by the handover, high overhead due to IP tunnelling, non-scalability due to permanent host-specific routing table entries, etc. The deficiencies of the existing network-layer mobility solutions have been the incentive for the development of a novel MPLS-based network-layer
mobility solution. The main idea of this novel MPLS-based mobility solution is the use of two labels instead of one as in standard MPLS. One label is used as identification of the traffic aggregate placed onto the MPLS Label Switched Path (LSP). The use of this label allows for pre-establishment of all LSPs since a single LSP may be set up for aggregates of arbitrary granularity – independently of which users the traffic transported over that LSP issues from. The second label is used as identification of a particular user. An MPLS packet always carries both labels. The user label is exploited for separating the user traffic from the aggregate during intra-domain handovers. The quality of the novel MPLS-based mobility solution has been assessed through the implementation in an MPLS test bed based on Radisys evaluation boards and Intel’s IXP1200 network processors as well as through an ns-2 simulation. The main objective of the implementation has been to show the feasibility of the MPLS-based mobility solution and to compare it with two other MPLS-based approaches. The main objective of the ns-2 simulation has been to compare the novel MPLS-based solution with IP-based approaches that could not easily be implemented in the MPLS test bed. The novel MPLS-based mobility solution avoids all the disadvantages of the existing network-layer mobility solutions. In particular, a mobile device does not need to acquire a new IP address during intra-domain handovers, thus eliminating the time-consuming acquisition of a new IP address as well as Duplicate Address Detection. Furthermore, no paths have to be established during intra-domain handovers. Such paths may be host-specific routes, IP tunnels or LSPs. All paths (LSPs in the novel MPLS-based approach) can be pre-established. Consequently, the outage period and thus packet loss is much reduced with respect to many other approaches. The overhead is reduced with respect to IP-based solutions applying IP tunnelling since only two MPLS shim headers of 4 Byte each are used. Unlike some IP-based approaches, the novel MPLS-based approach is also scalable with respect to the number of permanent user-specific entries in the domain. Last but not least, no time- and resource consuming re-classifications of IP packets are necessary during intra-domain handovers, thus reducing the overhead within the domain as well as the end-to-end delay of user IP packets.

**Ant Routing in mobile multi-hop Ad Hoc Networks**

*Martin Wenig, Dirk Thißen*

A mobile multi-hop ad hoc network is a set of mobile nodes which communicate by radio and do not require any infrastructure. Due to the limited transmission range of wireless interfaces, packets would most likely have to be forwarded by intermediate nodes. Therefore, each node has also to be a router. Because link changes occur frequently in such networks, the network topology is highly dynamic - traditional routing algorithms are useless for efficient and reliable data transfer; instead, adaptive
routing algorithms are required to overcome the dynamics of the topology. The aim of this project is to develop and implement a new routing algorithm based on a swarm intelligence concept. The basic idea of the ant algorithm is taken from the behavior of real ants. When ants search for food, they start from their nest and walk towards the food. When an ant reaches an intersection, it has to decide which branch to take next. While walking, ants deposit pheromone which marks the selected route. The concentration of pheromone on a certain path is an indication of its usage. This ant behavior is transferred to find the shortest path in a network. The implemented algorithm consists of three phases. In the route discovery phase, a host sends out a packet called Forward Ant which discovers the shortest path to the destination node. The destination node responds with a Backward Ant packet. Both are modifying the routing tables of the visited nodes by leaving a pheromone value. After the route establishment, the route maintenance phase starts. For each passing data packet, a node increases its corresponding pheromone value. To model the real world scenario, the pheromone value decreases over time with an exponential function. The third phase in failure handling to deal with broken paths. When a node detects a link loss, it starts with establishing a new path by sending out new ant packets resp. informing the neighbor hosts which maybe have alternative path information in the routing tables. The algorithm is implemented as an overlay socket for small handheld devices; a chat application is implemented to demonstrate and observe the routing algorithm.
Communication does not exist without context: it is always as strong as it’s weakest link. We therefore do some research in general security issues as well, i.e. teaching security in user education, security awareness in risk management, measuring security and applied IT security.

Service Management and Trading for Design Tools
Yuri Babich, Dirk Thißen

The Co-operative Research Center IMPROVE (SFB 476) aims to support and accelerate design processes in chemical and plastic engineering through computer science concepts. It is promoted by several computer science institutes working on concepts for direct and indirect process support as well as engineering institutes that bring in their domain-specific knowledge and ergonomics experts. The subproject Service Management and Trading for Design Tools provides the other project partners with a service layer that separates the tools used in the design process from the different underlying platforms. This allows an abstraction from the details of systems, networks and applications. In order to account for the heterogeneity of systems and tools and their physical distribution, the service management is based on the Common Object Request Broker Architecture (CORBA). The service layer has to guarantee high availability and fault tolerance of the applications and tools involved. To set the project partners free from dealing with faults and performance bottlenecks, we use alarm correlation to determine causes of abnormal situations. Strategic mobile agents react to these situations. They can decide whether to migrate to a target system or to perform a remote procedure call from the viewpoint of a maximum efficiency, thus realizing a scalable management approach. Likewise, the trading process and service management must ensure a good execution performance of all tools, so load balancing is performed when selecting services to execute. The prediction of resource use by different applications and their combinations is investigated along with approaches to composition of distributed services in order to meet tools’ Quality of Service (QoS) requirements. The uniform access to a-posteriori integrated legacy applications to extract management information and perform management actions (monitoring and control) is a central aspect in an integrated engineering design environment. We use intelligent wrappers, or management proxies, that encapsulate the tools and enable uniform access as well as adapted management actions. External services that are implemented in the Web Services technology are loosely integrated by means of a gateway. They reside in foreign administrative domains and are subject to heuristic trading decisions and limited management in the service layer. Security communication plays a prominent role in the acceptance of developer support systems should the developers cooperate across the boundaries of enterprises. We work on approaches to efficient security mechanisms that work across CORBA, Web Services and, in general,
other middleware domains.

Service Mobility for Nomadic Users
Stefan Diepolder

The goal of this project is to develop a Service Support System capable of coping with the new challenges posed by next generation networks in the area of service provisioning and enhanced mobility support for nomadic users. The variety of access networks provide high bandwidth and physically enable ubiquitous access for nomadic users to their personalised services. However, user terminals are becoming more and more complex to use. Likewise, their proper configuration for services like VoIP is becoming increasingly difficult. Therefore, a universal configuration service is an important aspect to enable service mobility for nomadic users. With the demand for mobile services growing proportionally with the numbers of participants another part of the framework being developed is to establish a new approach towards creation and deployment of these services. Due to the ongoing integration of middleware concepts into data- and signalling networks we are using object oriented-aware techniques to abstract from users, services, and resources on top of a PARLAY enabled service delivery platform. The main benefit of this approach is to achieve more flexibility, enable service mobility, and to open up the network to 3rd party service providers. The proposed management approach consists of several components which offer access to specific service capability features of the underlying network technologies, including, for instance, today’s Intelligent Networks, GSM, UTMS, and WLANs. Each component is associated with a dedicated domain, referred to as provider domain in case of to the domain of a supplier, or it remains at the terminal of a user, in which case it is called user domain. In a distributed system possibly comprising millions of objects with different mobility patterns and different service preferences, it is a major challenge to limit the signalling traffic and the servers’ load. This can be achieved by positioning the service objects according to their mobility behaviours, user’s service preferences, and provider policies. As component migration is mainly initiated on behalf of user’s behaviour this has to be identified and classified. Ongoing simulations studies evaluate how the management is able to adapt by different algorithms to different user pattern.

Ant Algorithm Approach on Routing Protocols for Sensor Networks
Kittisak Ormsup
Existing routing protocols for wireless sensor networks don’t perform very well in real sensor applications due to reasons listed below: 1. Gradient Technique (Directed Diffusion, GRAB, GEAR):

- Gradient setup phase is expensive.
- It is not energy aware as the best paths might be used too often.
- Interest retransmission and alternate path maintenance is needed.

2. Flooding Technique (SPIN):

- Nodes are always active (idle nodes still consumes energy).
- Flooding not always wanted.

3. Clustering Technique (LEACH, TTDD, GEAR, GAF):

- Failure of cluster heads due to excessive use.
- Cluster head selection is to be optimized.
- All nodes assumed to be capable of long range communication.

4. Geographic Technique (GPSR, GAF GEAR):

- Not energy aware.

This project explores a new approach, based on Ant Algorithm: forward and backward agents(packets) are sent between source and destination nodes, thereby leaving pheromone values on the paths, with the help of this values and some calculations, best path can be found without large overheads and maintenance efforts. The goal of the project is to implement the routing protocol on ns-2 network simulator, find the equation that best calculates the path, compare the protocol to existing ones, find the MAC-protocol that best suit this routing protocol and test it on a real sensor test bed.

**Mitigation of malicious behaviour in mobile ad hoc networks**

*Ralf Wienzek*

Wireless networks in general and mobile ad hoc networks (MANET) in particular are supposed to play an important role in the future. Since ad hoc networks are independent from any fixed infrastructure, the participating nodes have to organise
themselves and take over the functionality normally provided by network routers. This runs contrary to the limited amount of resources normally available in mobile nodes. They are expected to be portable and battery driven and are therefore naturally not interested in spending energy to forward other nodes’ packets. A node that wants to save energy can do this by simply refusing to act as an intermediate node and dropping all packets that are not destined to it. By not participating in the routing protocol at all or propagating false status information it can even prevent to become part of a route in the first place. As already a small fraction of misbehaving nodes can significantly affect the network’s performance adversely, it is essential for a well-functioning ad hoc network to prevent nodes from using network resources without contributing theirs. Today’s standards for MANETs deal only marginally with these kinds of security issues. Furthermore, since these attacks are not a threat to already well-established networks like the Internet countermeasures that could easily be adopted to MANETs do not exist. In order to mitigate the effect of maliciously behaving nodes in MANETs a distributed approach for identifying these nodes and excluding them from the network is being developed. Instead of using a set of dedicated detection nodes distributed over the network all nodes are involved in the detection process. It is assumed that since MANET nodes should be interested in excluding malicious nodes from the network, they should also be willing to spend some energy and help to detect nodes not following the rules of the game. Over time each node is supposed to probabilistically decide whether to be in monitoring mode or not. The actual probability can be dynamically adapted and is for example dependent on the security requirements of the particular network, the amount of available energy, and the current threat level in the network. As a consequence it is unpredictable for an attacker whether or not it is monitored and by whom. The detection mechanism is based on an anomaly detection approach and is enriched with a mechanism to securely exchange detection-relevant information among the nodes. This becomes necessary because a single node is unable to obtain a complete view of a monitored node on its own and has to rely on information provided by other network nodes in order to complete its view. Beside the problem of detecting malicious nodes the resistance of the detection mechanism itself against attacks is also taken into account.

**FAST Integration - Framework Architecture Supporting Telematics Integration**

*Carsten Pils, Tim Seipold, Thitinan Tantidham*

Telematics systems combine IT and mobile communication for the delivery of information towards vehicles and mobile users, improving road efficiency, safety, comfort, asset management and vehicle utilization. The result is an enhanced logistics system that is be used by e.g. truckage companies to distribute information to and gather
information from their vehicles. This is the business case of the FAST Integration project is used to present a comprehensive set of problems that are found in mobile, distributed applications together with the proposed solutions. Terminals ranging from stationary desktop workstations to moving embedded systems using communication networks ranging from LAN and WLAN to UMTS and TETRA create a vast amount of heterogeneity that needs to be overcome to efficiently develop and deploy enterprise applications for mobile users. With conventional middleware, the integration of non-IP-networks, the handling of multiple concurrent access networks, the usage over very low bandwidth networks and the suitability for resource-limited embedded systems are not given. To tackle these problems, within the FAST Integration project a framework was designed, that provides:

- Transparent use of communication facilities despite the underlying network technology, similar to conventional middleware solutions.
- Continuous provision of connectivity for highly mobile terminals in spite of intra- and inter-network roaming with varying transmission properties.
- Cost-sensitive dynamic selection of the currently used access networks.
- Location-awareness for services to trim the transmitted data to the mobile user’s exact needs.
- Possible use of dynamic service adaptation to fit it to the currently used access network and access terminal to optimize the bandwidth consumption.
- Integration of third party/legacy service providers regardless of the used middleware or access technology on the back-end.
- A solution lightweight enough to be run even on embedded systems.
- Fast and efficient integration of new mobile access technologies into an existing system.
- Good composability for fast deployment of individually configured systems.

Our solution is to deploy an intermediate hub between the terminals and the service providers. This splits the communication into one half dependant on the access network and terminal, and a middleware dependent server side half, each of which may be implemented and optimized individually.
The aim of the URMEL project (Ubiquitous RWTH for Mobile E-Learning) was to provide students with ubiquitous access to lecture contents and e-learning resources as well as to electronic services of the university’s administration and institutes. As an initial step to achieve this goal notebooks have been made more affordable to students through agreements with selected manufacturers. Furthermore, the benefits of the university’s wireless LAN (WLAN) called MoPS (Mobile Professors and Students) have been promoted and students have been motivated to buy WLAN-enabled devices. Using MoPS students and staff are able to access the Internet and university resources in a much more flexible manner than through fixed desktop and CIP-pool computers. To complement this, a set of basic services have been developed which facilitate authentication, secure communication, and location-aware services. The overall objective of these activities was to enhance conventional teaching at RWTH Aachen University and to make it more effective. These demands can hardly be fulfilled by a single software package, since the various departments have widely differing requirements with respect to e-learning, and since many institutes already have relevant software in use. To this end, a service platform has been developed which offers value-added services that can be integrated into existing e-learning software, or be used stand-alone to enhance group communication, to lend software licences, to book meeting rooms and lecture halls, and to enrol for courses. One of the most innovative features of this platform is the ability to locate users within the university’s wireless LAN network. The so-called Location Server has been integrated with myReiff, to demonstrate the use of location information in an e-learning environment. myREIFF is a collaboration platform used by the Department of Architecture, which has been developed in the course of the URMEL project. As an accompanying measure, and to ensure sustainability, the grant of the Germany Ministry for Research and Education also includes funds for the acquisition of notebooks which can be purchased by institutes for lectures and other forms of learning and teaching. This pool of notebooks is administered by the Centre for Computing and Communication, and currently comprises of 100 machines of four different types as well as peripheral devices such as cameras and headsets. URMEL was officially completed in June 2004, but the work is ongoing. For more information please see http://www.urmel.rwth-aachen.de

MoPS (MOBILE PROFESSORS AND STUDENTS) - RWTH AACHEN UNIVERSITY’S WIRELESS LAN

Michael Wallbaum

MoPS (Mobile Professors and Students) is a joint project by Informatik 4 and the Computing and Communication Centre. The aim of MoPS is to set up a city-wide wireless local area network (WLAN) as a supplement to the wired network infrastruc-
The existing coax and fibre network offers RWTH students and employees a high bandwidth, however it also exhibits some drawbacks:

- no or bad connectivity in lecture halls, seminar rooms and public places;
- wired network usage is necessarily stationary;
- the deployment of a wired infrastructure is generally more costly and in some cases not possible at all.

In contrast to that, a Wireless LAN comes at a lower cost, involves less installation effort, and offers its users far greater flexibility. The MoPS-network currently comprises of nearly 400 access points spread across some 50 buildings. Many central areas of Aachen University – such as the library, the main mensa, and the Karman-Auditorium – are already covered by MoPS and the network is still expanding. In addition, WLAN-coverage also extends to areas where the university is not present, such as train stations, pubs and the main market square. To date, the networks serves several thousand users - during the peak hours of the day more than 2000 users employ the network. MoPS is based on the IEEE 802.11 a/b/g standards and thus offers a bandwidth of up to 54 Mbps per cell. In comparison to mobile communication networks the cell radii are significantly smaller, and hence the available bandwidth usually has to be shared among few users. Qualitative and quantitative observations show that the available bandwidth is sufficient for most applications in use today. Apart from serving as an access network to the RWTH backbone the Wireless LAN is also used for research purposes. Examples include the localisation of mobile stations as well as location-based and wireless multimedia services and applications for mobile e-learning. The expansion of the network continues – the ultimate aim is to provide city-wide coverage offering RWTH staff and students ubiquitous access to information and communication resources. For more information see http://www.mops.rwth-aachen.de

Advanced Interactive Mobile Television

*Jan Kritzner*

These days two important trends are converging: The growth of the Internet with the possibility to exchange data wherever you are, and the existing importance of television for home entertainment. Today, these trends offer the opportunity for the development of mobile television services. Mobile broadcast services have been addressed by 3GPP in a work item called MBMS (Multimedia Broadcast Multicast Service). MBMS provides a flexible system environment for mobile broadcast services over 3rd generation cellular networks. By combining MBMS with interactivity, true interactive mobile TV services can be delivered. However, many details of such a
system have not been defined by now, and a general framework integrating unicast with multicast/broadcast transmission bearers is missing. Users want to be able to receive mobile entertainment wherever they are. Each user wants to access just the service he feels like. Some services may be popular, e.g. news or live tickers from sports events. However, today the interest in mobile TV is just growing, and it is not necessary to permanently reserve multicast resources for every channel. Instead, occasionally used services will be transmitted by the means of unicast transport protocols. Basic solutions like the TPTR (Transport Protocol with Tuneable Reliability) streaming protocol exist, but some problems remain. While the resources of MBMS bearers are reserved and constant the available bandwidth for unicast connections may change depending on the load of the radio cell. Especially up-switches where the available bandwidth increases are difficult to detect. Some rate-control algorithms which can do that exist but both their relative performance and their interaction with stream switching algorithms for adaptive streaming have not been analysed until now. As another problem of digital TV many users dislike the delay for switching channels they experience with DVB-T or DVB-S systems, and novel systems should perform better regarding this aspect. In the case of unicast streaming an additional delay for notifying the server is added. This problem is not only relevant for mobile TV, but for the complete range of IP-based TV services. Up to now there even does not exist a standardised way for signalling a channel switch to the backend.

Robust Access Control in Wireless Sensor Networks

Zinaida Benenson

Wireless Sensor Networks (WSNs) are networks of tiny sensing devices which are spread over a large geographic area and can be used to collect and process environmental data like temperature, humidity, light conditions, seismic activities, images of the environment etc. This data can be used to detect certain events and to trigger activities. Some of applications are habitat monitoring, precision agriculture, wildfire detection, building and perimeter security. With the increasing ubiquity of WSNs, their data will be available almost everywhere in our environment. Of course, accessing this data will in general not be for free since deployment of WSNs induces some costs. In this case, a WSN must be able to distinguish legitimate users from illegitimate users, resulting in the problem of access control. Access control problem also arises inherently in such applications as building and perimeter security. Realizing access control in WSNs is especially challenging due to the resource-constraints with respect to computational and battery power. Furthermore, as WSNs usually cannot be protected against node capture, security solutions in this domain cannot rely on single sensors. Most of the current protocols for any sensor network operations (routing, query processing, data dissemination and storage, access control) are highly susceptible to node capture. The
goal of this project is developing access control mechanisms for WSNs which are robust to node capture. We developed a formal framework for access control in WSNs. On the basis of this framework we specified a protocol for user authentication in sensor network which uses symmetric as well as asymmetric cryptography in efficient way. We have implemented this solution on a Telos sensor node platform. T-robust sensor networks can withstand capture of up to t nodes and consider three basic security concepts for such networks:

- t-robust storage, a mechanism to securely store data within a set of sensors such that capture of any t sensors does not reveal that data to the adversary;

- n-authentication which ensures that authentication is achieved with every uncompromised sensor in the broadcast range of a client (n denotes the number of nodes in that broadcast range); and

- n-authorization, an authorization primitive with similar properties like n-authentication. We present a generic t-robust protocol for implementing access control using these primitives.

The Information Society Technologies (IST) programme is a thematic area of the Sixth European R&D Framework Programme (FP6). The NO-REST project is part of this programme. The project investigated the applicability and dynamics of standards in the e-business and e-government sectors, and developed tools for the assessment of their performance, and of the impact they have on networked organisations. To this end, NO-REST has evaluated the various standards development platforms, studied whether or not links exist between a standard’s origin and its success in the market, examined how implementations affect standards and interoperability, and analysed the various sources of dynamics in standards setting. Integrating the above, NO-REST has developed a comprehensive framework, and the associated methodologies, to assess the impact standards have at firm level. A quantitative study based on the survey methodology yielded some interesting results. These will be made publicly available upon acceptance of the deliverables by the EU. Older deliverables, as well as further information may be found at http://www.no-rest.org.
Standards are a proven mechanism for technology transfer, fostering the diffusion and utilisation of technology. Thus, standards may be considered as an important aspect of various fields of policy, like innovation, trade and environmental policies. INTEREST aims to support Community policies by improving the interface between research and standardisation. Work started with a literature survey on the types of research and standard products. This was followed by a survey of the different interfaces that exist between research and standardisation. The rationales and incentives schemes that exist within the research communities, and their contacts to standardisation bodies and industry will are being compiled through a survey-based study. Following an indicator based approach, INTEREST is also developing a matrix linking the science and technology base of companies (e.g. their patent portfolios) and their standardisation activities. Through case studies the project has analysed the internal organisational structure of the interface between research and the standards department within companies. Thus, solutions and organisational models can be identified suitable to support the transfer of research results into standards and to appropriate results from research institutions in order to transpose them into standards. In addition, the project is analysing the pros and cons of patent pools as a means to transfer complex research results produced by various partners to standardisation processes and to reduce complex IPR-related problems within standardisation processes. Based on these new insights, and on the taxonomies of standards and research outputs, respectively, a taxonomy will be developed to characterise the typical relationships of the two dimensions. This taxonomy will be the basis to identify relevant combinations between R&D, but also innovation and standardisation and to develop specific policies, since standardisation does not only benefit from R&D, but has also positive impacts on innovation. The project is co-funded by the European Commission under their Framework Programme 6. Further information may be found at http://www.interest-fp6.org

Talks and Publications

Talks

Publications


Günes, M.; Siekermann, J.: Are Ad-hoc Networks Able to Substitute Cellular Networks? - A Performance Comparison of Ad-hoc Network Routing Protocols in Real-


Laboratory for Dependable Distributed Systems

Staff

• Faculty:
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• Research Assistants:
  M. Sc. Lucia Draque-Penso Rautenbach
  Dipl.-Jur. Maximillian Dornseif
  Dipl.-Inform. Martin Mink

• Student Researchers:
  Michael Becher
  Diego Biurrun
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  Patrik Hof
  Thorsten Holz
  Alexander Neumann
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  Christina Roeckerath
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  Franziska Roloff
  Julie Wagner
  Tobias Walter
Overview

The Laboratory for Dependable Distributed Systems (Verlässliche Verteilte Systeme) pursues research in all aspects of dependable systems. A system is dependable if trust can be justifiably placed in its correct operation even in exceptional circumstances. Exceptional circumstances can be random hardware or software faults so that systems must be fault-tolerant. Other circumstances include malicious or worst-case system behavior so that systems must tolerate intentional attacks. The laboratory contributes to a sound engineering practice for the design, deployment and operation of dependable systems. As first laboratory in Germany, we cover the two main aspects of dependability, namely safety and security, in a unified research and teaching structure.

The laboratory moved to University of Mannheim in October 2005 where Prof. Freiling now holds the Chair of Computer Science 1.

Research Projects

New Teaching Concepts for Applied Computer Security

Martin Mink, Felix Freiling

In industry there is an enormous demand for IT professionals which know how to make systems secure and trustworthy. Despite this large demand, most universities have failed to address this issue adequately within the core of their computer science curriculum. One of the main reasons for this is that it is not entirely clear how best to teach IT security at a university degree level. The discussions in the security community manifest a central dilemma: should one teach hard practical knowledge of concrete systems (which is quickly outdated) or the mainly underlying principles (which are of no use in practical settings)?

This research project aims at finding new university-level teaching concepts for IT security which combine fundamental knowledge and practical skills in a suitable way. For this we are experimenting with teaching concepts from the “hacker” community, e.g., “Linux death matches” or “Capture-the-Flag” contests, to see which basic skills are most important and which ones can be learned and applied most effectively. The aim is to combine these teaching concepts with more “organized” forms of university teaching to give students an idea of a scientifically sound engineering methodology to design, deploy and operate modern information systems in a dependable way.
In this research project we investigate problems that make use of fault-tolerant distributed ideas to solve open issues in the security area, especially in mobile communication systems. Our aim is to give efficient and practical solutions to (mobile) problems, while bridging the gap between fault-tolerant distributed algorithms, which assume random but rather benign faults (such as crashes and message losses), and security protocols, which consider malicious and worst-case types of faults (such as bad intentioned network sniffers).

In particular, we study the problem of multi-party computation in wireless networks where processes are equipped with tamper-proof security modules. This model is realistic and contemporary, as manufacturers are now producing such hardware (like smart cards or security subsystems in laptops). It also provides a theoretical interesting link to agreement problems in distributed systems (such as consensus and atomic commit), that is being proven by us to result in efficient and practical solutions and implementations. Hence, it is highly expected that in the near future it forms the basis of a novel theory of dependable systems that includes both safety and security characteristics.

In order to measure security threats in communication networks and for the purpose of collecting information on security incidents, we installed a so called Honeynet. A Honeynet is a network of so called Honeypots: Honeypots are electronic bait, i.e. network resources (computers, routers, switches, etc.) deployed to be probed, attacked, and compromised. Honeypots run special software which permanently collects data about the system and greatly aids in post-incident computer and network forensics. Because of the wealth of data collected through them, Honeynets are considered a useful tool to learn more about attack patterns and attacker behavior in real networks.

This research project aims at learning more about the tools, tactics, and motives involved in computer and network attacks. We are currently running a Honeynet with several Honeypots that permanently collect data about security threats. In addition, we participate in a research project called Leurre.com that aims at developing a distributed approach to Honeypot-based research. The main project of 2005 was work in the area of botnets. A botnet is a network of compromised machines that can be remotely
controlled by an attacker. These networks are used by attackers to carry out Distributed Denial-of-Service (DDoS) attacks, to send out spam, or other nefarious purposes. We developed a methodology to fight against this threat and are currently researching more ways to stop botnets.

Dependability Metrics

Felix Freiling, Ralf Reussner, Irene Eusgeld, Thorsten Holz, Maximillian Dornseif, Martin Mink

Justification of trust in a dependable system implies a way to measure relevant attributes of dependability such as reliability, safety, or security. For some of these attributes (like hardware reliability) there exist well-defined and broadly accepted methods of measurement, for others (like security) methods of measurement are still very much the focus of research. In this project, we aim at improving the state of the art of measuring aspects of dependability, i.e., we seek new and improved dependability metrics. The first step of this project aims at establishing an overview over the state of the art in selected areas of dependability, namely reliability, security and performance metrics, and publishing it as a printed volume. The project leaders coordinate a group of researchers in a collaborative effort. The main thrust of activities occurred at a research seminar at Schloss Dagstuhl which was supported by Gesellschaft für Informatik and took place between October 30 and November 1, 2005. The laboratory is in charge of the security metrics part of the project. In this part results of the Measuring Security Threats in Communication Networks project are used.

Computer Forensics

Maximillian Dornseif

Forensic science faces great challenges by the fact that information technology now is present in every aspect of our lives. Information technology from PDAs to digital telephone systems, from email to car navigation systems can provide the forensic analyst with a wealth of data to be used. But this data is often hard to access since on one hand the interfaces intended by the designers of the systems were not designed with forensic requirements in mind, on the other hand the internal workings of most of theses systems are undocumented or even considered a trade secret. Extracting possible evidence effectively from a multitude of sources and aiding the forensic analyst in filtering out the relevant information is still a great challenge.
This project aims at establishing computer forensics as a scientific discipline instead of a handicraft. Recognizing the demand not only on tools, tactics and techniques to make forensic discovery as effective as possible but also for trained forensic experts by public administration and industry we incorporate the New Teaching Concepts for Applied Computer Security project looking at different didactic concepts for teaching computer forensics to students. One of the main challenges is the need for data which can be used for forensic analysis in a research or in a teaching context. Most data connected to real world incidents is associated with serious privacy and corporate confidentiality issues. There the Measuring Security Threats in Communication Networks project allowed us access to a wealth of data related to incidents but uncontaminated with personal or otherwise to be kept secret data. We also started cooperating with scholars from the legal and criminological disciplines to work out an understanding of forensic requirements and capabilities.

### Common Security Failures

*Maximillian Dornseif, Thorsten Holz*

Traditionally computer security research focused very much on steps to make information technology more secure while there was little interest on the actual failures of security measures. Thread analysis is an established technique in information security, but it can not compare to the rigor other engineering disciplines exhibit when testing real world systems and analysing failures of such systems. While the general principles of failures in computer security – e.g. buffer overflows – are known and understood by the scientific community, in regard to more advanced techniques – e.g. heap overflows – the field is more or less left to the blackhat community. This leads to the paradox situation that often it is not exactly clear against what attacks a security technology is actually supposed to protect.

This project aims at gaining an in-depth understanding on how real world systems fail under real world attacks. In close cooperation with the Measuring Security Threats in Communication Networks project and other interested researchers we monitor attack trends and try to get a detailed understanding on the workings of attack techniques. Building on this knowledge not only more secure systems can be developed but also testing of existing and future systems can be greatly improved.

### Other Activities

Prof. Freiling served as a member of the program committees of the 2nd Workshop on Sensor Networks at INFORMATIK 2005, the workshop on “Sicherheit in komplexen, vernetzten Umgebungen” at INFORMATIK 2005, the Seventh International

Prof. Freiling served as the Vice Chair of the Distributed Systems and Algorithms Track at Euro-Par 2005.

Maximilian Dornseif served as a member of the program committee of the IASTED International Conference on Parallel and Distributed Computing and Networks (PDCN 2006).

The team “Old Eur0pe” of RWTH Aachen consisting of students which had previously attended lectures or labs offered by the Laboratory for Dependable Distributed Systems participated in several network security contests and finished in respectable positions. In the June 2005 UCSB Capture The Flag (CTF) contest the team finished 2nd out of 11 teams. In the security exercise “op3n” which was organized by TU Darmstadt in September 2005 the team finished 1st out of 6 teams. In the CTF competition organized alongside the Hack.LU conference in October 2005, the team finished 2nd out of 4 teams. Finally, in December 2005 the team managed to win for the first time the UCSB CTF contest and currently holds the world title of “UCSB CTF champion” (the team finished 1st out of 22 teams).

The Laboratory was active in organizing its own network security exercise called CIPHER in July 2005. 14 teams from 8 countries and 4 continents participated.

Prof. Sukumar Ghosh of the University of Iowa, USA, visited the Laboratory for a period of 6 weeks in May/June 2005. His visit was supported by the Alexander von Humboldt Foundation.

Prof. Josef Widder of TU Vienna, Austria, visited the Laboratory for a period of 4 weeks in July/August 2005. His visit was supported by the Graduiertenkolleg “Software for Mobile Communication Systems” at RWTH Aachen.

In August, the group organized a two-day workshop on education in IT security (Ausbildung im Bereich IT-Sicherheit - Hochschulausbildung, berufliche Weiterbildung, Zertifizierung von Ausbildungsangeboten) in cooperation with BITKOM, BSI, DLR and Gesellschaft für Informatik (GI). This workshop was intended to bring together representatives from German universities, companies and organisations involved in IT security training to get an overview on and discuss the status quo. A detailed review of the event can be found in RWTH Technical report AIB-2005-20.

The lab organized the Aachen Summer School Applied IT Security for the second time in late September. The summer school was attended by 16 researchers from Australia, Great Britain, Czech Republic, the Netherlands, Belgium, Austria and different parts of Germany. Goal of the summer school was to get a better understanding on how security systems fail in the real world and to foster networking between interested researchers.

The Competence Center for Applied Security Technology (CAST) honored two Diploma thesis which were pursued at the Laboratory with the prestigious “CAST Förderpreis”:
Thorsten Holz won a second prize with his thesis on “new Fields of Application for Honeynets” and Thomas Apel finished fifth with his thesis on “Generating Fingerprints of Network Servers and their use in Honeypots”.

“RedTeam-Penetrationtesting” spun-off from a teaching experiment at our group and is now an independent limited company with offices in the “Technologiezentrum Aachen”. The *RedTeam* practical was originally an experiment at intense practice of offensive security evaluation techniques with a workload of about 15 hours per week.

**Talks and Publications**

**Talks**

Thorsten Holz: *Reale Phishing Angriffe*, IsSec / ZertiFA 2005, Berlin, Germany, 2005-12-05

Thorsten Holz: *New Fields of Application for Honeynets*, CAST Förderpreis IT-Sicherheit 2005, Darmstadt, Germany, 2005-11-17

Thorsten Holz: *Exploring a Root-Cause Methodology to Prevent Distributed Denial-of-Service Attacks & Other Honeynet-related Work*, Georgia Tech, Atlanta, USA, 2005-11-16


Felix Freiling: *Safety, Liveness and Information Flow: Dependability Revisited*, Gastvortrag, Technische Universität Wien, 2005-10-06


Thorsten Holz: *Botnet Tracking: Exploring a Root-Cause Methodology to Prevent Distributed Denial-of-Service Attacks*, ESORICS 2005, Milan, Italy, 2005-09-12


Martin Mink: *IT-Sicherheitsausbildung an der RWTH Aachen*, Workshop zur Ausbildung im Bereich IT-Sicherheit, Köln, 2005-08-11


Michael Becher, Maximillian Dornseif: *FireWire - all your memory are belong to us*, CanSecWest/core05, Vancouver, 2005-05-05
Martin Mink: *Teaching Data Security at University Degree Level*, Graduiertenkolleg 643, RWTH Aachen, 2005-05-04


Maximillian Dornseif: *Anti-honeypot technology*, IT-Underground, Prague, 2005-03-17

Thorsten Holz: *Ein kurzer Überblick über das Deutsche Honeynet Projekt*, 12. DFN-CERT Workshop, Hamburg, Germany, 2005-03-02

Thorsten Holz: *Spyware in the Form of Bots*, hack.lu 2005 / IT Underground, Luxembourg / Warsaw, 2005-10-12

**Publications**

Thorsten Holz: *Spying With the Help of Bots*, USENIX, ;login:, Vol. 30, Nr. 6


Alexander Becher, Maximillian Dornseif: *Ungebremster Speicherzugriff mit FireWire*, MISC

Maximillian Dornseif: *Network Footprinting*, MISC

Fred Arbogast, Sascha Rommelfangen, Thorsten Holz: *Sammeln und Analysieren von Malware*, MISC


Thorsten Holz: *Detecting Honeypots and Other Suspicious Environments*, Proceedings of the 6th IEEE Information Assurance Workshop IEEE, United States Military Academy


Felix Freiling, Sukumar Ghosh: *Code Stabilization*, Technischer Bericht, RWTH Aachen, AIB-2005-14


Lexi Pimenidis, Martin Mink, Felix Freiling, Maximillian Dornseif: *Teaching Data Security at University Degree Level*, Proceedings of the IFIP TC11 WG11.3 Fourth World Conference on Information Security Education


Felix Freiling, Klaus Kursawe: *Byzantine Fault Tolerance on General Hybrid Adversary Structures*, Technischer Bericht, RWTH Aachen, AIB-2005-09


Security Engineering Group

Staff

- Faculty:
  Professor als Juniorprofessor Dr.-Ing. Heiko Mantel

- Research Assistants:
  Dipl. Inform. Tina Kraüßer
  Dipl. Math. Henning Sudbrock

- Student Assistants:
  Corinna Habets
Overview

The high frequency of reports about security incidents and the persistency of this topic already indicate that there are substantial difficulties in this area that need to be overcome. A theoretical explanation for some of these difficulties was given by Jim Gray already in the 1980’s (but it is not so widely known): There are fundamental differences between many security requirements and traditional system requirements such as safety or liveness properties. This observation has severe consequences for the development of secure software systems. For instance, design decisions might cause security properties to be violated even if all other properties of interest are preserved. This is one explanation for why security needs special treatment during software development and why established development techniques are not necessarily suitable for engineering security-critical systems.

We approach this problem from several directions in our research:

- by analyzing security properties with the aim of supporting software engineers in making intuitive security requirements precise;
- by developing analysis techniques for verifying that software systems meet given security requirements;
- by deriving development principles that respect given security properties;
- by providing tool support for system development and analysis;
- by deepening the formal foundations of information security.

Given the difficulty of developing secure systems, we usually employ formal methods in our investigations. This choice allows us to derive reliable guarantees using mathematical reasoning. We develop analysis techniques for different levels of abstraction: for analyzing programs given in source code or in machine code as well as for analyzing more abstract specifications. The latter approach has the advantage of reducing the complexity of the analysis and of being applicable at development stages where code is not yet available. We evaluate our analysis techniques, development techniques, and tools in case studies that we also intend as guidelines for the analysis and development of other systems. The systems that we consider include application-level programs such as midlets and also system software, in particular, aspects of operating systems.

Research Projects

Formal Methods for Security Engineering (FM-SecEng)

Heiko Mantel, Henning Sudbrock
(funded by the DFG)
It is difficult, if not practically impossible, to modify an existing software system such that it satisfies rigorous security policies. A more promising approach is to consider security aspects already during system development. However, it is still common practice to patch security features onto otherwise completed products. One reason for this shortcoming is the lack of techniques for adequately integrating security aspects into the software development process.

The objective of this project is to improve this situation. Our research shall contribute to making it more feasible to consider security aspects throughout the entire software development process. This includes activities such as the definition of requirements, the architectural design and other design choices, the implementation, and the validation and verification. We aim at providing methods, techniques, and tools that adequately support the development of secure software.

A key difficulty is the stepwise transition from a high-level specification to a secure, low-level implementation. In particular, one must map the system-wide, high-level security requirements to low-level security requirements for the individual software components while ensuring that the composition of the components, indeed, enforces system-wide security. Here, it must be taken into account that insecurities can originate from the interaction of components even if these are secure if operating in isolation.

Security is an aspect of software where small errors can result in major problems when exploited by malicious users. Therefore we utilize formal methods in our research. Formal methods allow us to reason with mathematical rigor about system properties and thus to give reliable guarantees for the correct functioning of a system.

As a first step we analyze the formal specification of security properties in case studies, focusing on information flow properties. Since operating systems are the basis for many other software applications we investigate security properties adequate for operating systems and implementation techniques enforcing these properties. After having gained a deeper understanding of the formalization and application of information flow properties we plan to study how information flow security can be integrated into the software development process, e.g., by using design patterns, modeling languages, or implementation techniques. This must be achieved in such a fashion that software engineers can intuitively understand and thus successfully employ these methods.

In parallel, we develop analysis techniques that can be directly applied at the level of source code or machine code. While such techniques are yet completely ignorant of the software engineering process, they are nevertheless needed to complement proper security engineering with a possibility for integrating existing code and COTS (components of the shelf). On a technical level, our aims are to more adequately capture the intuitive security requirements, to invent more precise analysis techniques, to provide better tool support, and to extend the scope of language-based security techniques to a broader range of practically relevant programming languages.
The amount of sensitive data that is stored on mobile devices has tremendously increased in recent years and a further increase can be expected due to new devices and services. Security and privacy issues arise, for instance, when using mobile devices in unknown environments or for communicating with initially untrusted communication partners as well as when dynamically extending or updating software on the device.

Mobius addresses the security problems accompanying the manifold possibilities that originate from increasing mobility and ubiquity. One goal is to guarantee that sensitive information used by a program is not released to untrusted communication partners. This complements traditional security mechanisms such as access control or sandboxing. The use of type systems and verification for the security analysis reduces the burden of checking the security of a downloaded, updated, or dynamically extended application on the mobile device. The Proof Carrying Code (PCC) paradigm imposes the responsibility of securing a program and of providing reliable evidence that security has been achieved onto the developer. The code producer provides not only the code, but also a certificate that helps the code consumer in checking the security of the program that he receives as illustrated in the figure below.

Different notions of certificates are possible. For instance, certificates can have the form of proofs of the given security property, of tactics that generate such proofs, or of types that can be checked with a type system. This allows the code consumer to easily verify that the program indeed is secure. This is the advantage over using cryptographic certificates where the user needs to trust the developer’s claim about the security of the program.

Within this project, the focus of our group is to formalize the security requirements with policies that control the flow of sensitive information during program execution. For the automatic enforcement of these policies, we aim at a type-based solution. We capture the requirements with security types and develop typing rules for automatically checking the security of a given bytecode program.
Other Activities

Courses

Winter Term 2005/06

• Seminar: Current Topics in Information Security
• Seminar: Network Security

PC and SC Memberships

H. Mantel was a PC member of the following conferences

• European Symposium on Research in Computer Security (ESORICS’05)
• ACM Workshop on Formal Methods in Security Engineering (FMSE’05)
• ACM Symposium on Applied Computer Security (SAC’05)
• Sicherheit - Schutz und Zuverlässigkeit (Sicherheit’05)
• IFIP WG 1.7, ACM SIGPLAN and GI FoMSESS Workshop on Issues in the Theory of Information Security (WITS’05)

H. Mantel was a member of the steering committee of the GI working group Formale Methoden und Software Engineering für sichere Systeme.

Talks and Publications

Talks

H. Mantel: Using Unification for Security Analysis and for Repairing Insecure Programs, German Research Center for Artificial Intelligence (DFKI GmbH), Saarbrücken, November 25, 2005.


**Publications**


Staff

- Professors:
  
  Prof. Dr. rer. pol. Matthias Jarke
  Prof. Dr. Thomas Berlage
  Prof. Gerhard Lakemeyer, Ph.D.
  Prof. Wolfgang Prinz, Ph.D.
  Prof. Dr. Thomas Rose

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  Sebastian Brandt
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  Mohamed Amine Chatti
  Aida Jertila
  David Kensche
  Dr. Ralf Klamma
  Dr. Erika Linz (since 1.7.2005)
  Dominik Lübbers
  Michael Miatidis
  Bernd Quade (until 31.7.2005)
  Dr. Christoph Quix
  Marcus Raddatz (since 1.3.2005)
  Dr. Lemonia Ragia
  Dr. Marcus Schlüter (since 1.10.2005)
Researchers continued:

Dominik Schmitz
Martin Sedlmayr (until 28.2.2005)
Christian Seeling
Marc Spaniol
Satish Srirama
Carla Valle (until 31.8.2005)

Visiting Lecturers:

Dr. Andreas Becks, Fraunhofer FIT
Dr. Wolfgang Broll, Fraunhofer FIT
Jessica Huster, Fraunhofer FIT (since 15.5.2005)
Dr. Yehya Mohamad, Fraunhofer FIT

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Overview

Informatik V represents the field of databases and information systems at RWTH Aachen University. A major focus is the formal analysis, prototypical development, and practical application of metadata systems. Specific areas include Internet Information Systems and Knowledge Management, Electronic Business Support, Electronic Learning, Database and Repository Technologies, and Requirements Engineering for Complex Systems.

Informatik V cooperates closely with the Fraunhofer Institute for Applied Information Technology (FIT) of which Prof. Jarke is Executive Director. Two FIT area managers, Professors Wolfgang Prinz and Thomas Berlage, hold cross appointments as Associate Professors in Informatik V. Prof. Jarke is also one of the Founding Directors of the Bonn-Aachen International Center for Information Technology (B-IT); within B-IT, a third joint professorship has been established and filled with Prof. Thomas Rose. Other joint activities with FIT included Semantic Web EU project SEWASIE and the European Network of Excellence in Technology-Assisted Learning (PROLEARN). Dr. Ralf Klamma of Informatik V chaired the highly successful first PROLEARN Summer School with over 45 doctoral students, held in Şile, Turkey.

Two major efforts characterized much of 2005 in Informatik V. Firstly, as president of the German Computer Society GI, Prof. Jarke led the lobbying activities and the preparation effort for the Science Year 2006 which the Federal Government has dedicated, for the first time, to the field of Informatics. Secondly, Informatik V took leading roles in proposals for excellence clusters and graduate schools within the so-called Excellence Initiative of the German government. The BITGRAD Graduate School proposal coordinated by Prof. Jarke as an effort to extend B-IT by a doctoral studies programme, passed the first round of evaluation as the only proposal in computer science throughout Germany.

The staff of Informatik V now comprises about 25 scientists and technicians with a high degree of diversity. Staff members come from six countries in three continents, with about 25% females. In 2005, Yehya Mohamad successfully defended his doctoral thesis and Carla Valle left for a job with the United Nations headquarters in New York, after handing in her thesis. 22 diploma and master theses were also completed at Informatik V. Prof. Prinz received an offer from the University of Vienna, whereas Ralf Klamma spent the spring semester as substitute professor at the University of Passau.
Research Projects

Metadata and Cooperative Knowledge Management

M. Jarke, C. Quix, M.A. Chatti, D. Kensche, M. Jeusfeld (Uni Tilburg, NL),
R. Linde, T. Gan, Z. Huma, T. Novotny, X. Li

ConceptBase is a multi-user deductive object manager mainly intended for conceptual modelling, metadata management and model management. The system implements the knowledge representation language Telos which amalgamates properties of deductive and object-oriented languages. After the successful release of ConceptBase 6.1 at the end of 2004, the work concentrated on improving the query evaluator, the active rule system, and the graph editor. In the meantime, almost 400 users have registered for ConceptBase 6.1.

Research in model management focusses on the formal definition of structures and operators for the management of complex data models to support applications dealing with the integration, maintenance, and evolution of data models. The research group defined the generic role-based meta model GeRoMe which simplifies the development of model management applications as operators have to be implemented only once for the generic meta model.

Metadata in Community Information Systems

R. Klamma, Y. Cao, M.A. Chatti, E. Linz, D. Lübbers, M. Spaniol, D. Denev,
H. Haegert, I. Ivanova, H. Janßen, I. Kireyev, E. Lapi, A. Martini,
N.F. Muhammad, M. Pienkos, D. Renzel, P. Selders, S. Steinfels,
P. Stojadinovic, O. Yamcharoen, L. Ragia, S. Srirama

Community information systems are a combination of work practices, information, people, digital media theories organized in a way that they support the goals of the community. Metadata in community information systems stabilize the ongoing change management process in these systems. The research goal of the working group is a better understanding of the creation, use, and maintenance of metadata in the context of community systems. Metadata are based on international standards in different domains like Audio-visual Media, E-Learning, Cultural Heritage, Music Information Retrieval, and Geographical Information Systems. Central for our approach is the reflective conceptual architecture ATLAS which incorporates a set of (self-)monitoring tools for the community members and the repository/community middleware. Communities can assess their community needs and evolve the community through the development and change of the community information systems. The monitoring tools allow the measurement, analysis and simulation of community aspects with methods from the semantic web, information retrieval & visualization, data/text/media
mining, geospatial database querying, social network analysis, transcriptive algorithms etc. On the database/repository level we use and develop further scalable state-of-art database technologies for the management of mass data and metadata for community systems. On the middleware level we realize scalable community hosting services like single-login, variable and fine-granular access control, mobility support, multimedia management, multimedia annotation, interoperable search and retrieval, matching, data/text/media mining etc. The following projects have been worked on in the year 2005:

SFB 427: Media and Cultural Communication: Agency in Digital Social Networks by Visualization of Multidimensional Patterns of Disturbance
In 2005 the final four year period of the collaborative research center started with a new project covering community information system and social software analysis by a pattern database. In a multidisciplinary approach we want to identify media constellations which lead to success or failure in media usage. Field of research primarily was intercultural and intergenerational learning. Together with the Chair of Urban History (Prof. M. Jansen) we started a joint initiative to preserve the cultural heritage in Afghanistan by a community driven information system called ACIS. This system is intended to reestablish a community of (old) scientists spread all over the world and to make their knowledge accessible to a new generation of researchers in Afghanistan. In order to understand the impact of media on intercultural learning better, the non-linear multimedia story-telling environment called MIST has been developed. Again, this project was developed in transdisciplinary cooperation together with Prof. Nalin Sharda (Victoria University Melbourne, Australia) and Prof. Jörg Schönert (Forscherguppe Narratologie, University of Hamburg). Recent research results were presented at international conferences such as I-Know, ICITA, ICWL, ICALT. In parallel, we established an MPEG-7/21 community (http://www.multimedia-metadata.info) that brings together leading researchers from across Europe and industry partners (e.g. T-Systems and Siemens). Highlight was the hosting of the 3rd MPEG-7/21 community workshop in Aachen in November.

BMBF/DFG Information System in Earth Management (GeoTech): from Geodata to Geoservices
The goal of the project was the development of a geodata infrastructure (GDI) for the preparation of heterogeneous data according to data-driven rules and independent of scales. To demonstrate the use of the GDI, an example application - the development of an ground water protection function - was deployed. The role of our chair in the project was to share our expertise in data mining, databases, web services and information systems architectures. The project was finished successfully in 2005. Three diploma theses have been monitored jointly with the project partners in the context of the project.

Living Coopetition - IBM Shared University Research
Knowledge discovery, knowledge management and mobile access in combination with trusted security play a crucial role in the business processes of the future. Flexible information and knowledge networks with several partners provide the basis for success in the information society. The “Living Coopetition” initiative of Informatik V, FIT, and FIR aims to enable
such networks by powerful concepts and information architectures like services-on-demand. In 2005, we have implemented the distributed infrastructure for the project as well as performed first feasibility studies to demonstrate the advantages of our approach base on a software infrastructure centered around WebSphere and DB2. The results were presented at the Workshop “Living Coopetition”, IBM Mainz in May of 2005.

**SunSITE Central Europe** ([http://sunsite.informatik.rwth-aachen.de](http://sunsite.informatik.rwth-aachen.de))

Since 1995, Informatik V is active in the field of internet-based community support, both in terms of research on community and web service tools and in terms of providing infrastructures for scientific communities worldwide. For example, Informatik V hosted the first website for the city of Aachen in 1995 and, since the same year, manages one of the most successful public-domain internet servers in the German science net, SunSITE Central Europe. Supported by Sun Microsystems with powerful hardware and base software, SunSITE Central Europe focusses on scientific community support, including mirrors of some of the most important research literature indexes, workspaces for internet cooperation, and about 1 TB of open source software. Typically, the SunSITE enjoys several million accesses per month.

**Mobile Web Service Provider**

Intelligent phones as web service provider is the topic of a doctoral thesis in cooperation with Ericsson Eurolabs done in the context of the Graduate College “Software for Mobile Communication Systems”.

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**ERASMUS MUNDUS European Master in Informatics (EuMI)**

*M. Jarke, G. Lakemeyer, R. Klamma, P. Selders*

In winter term 2004/2005 the first row of students were enrolled in this pan-European master programme jointly executed with the universities of Trento and Edinburgh. In three different areas of specialisations, Net-Centric Computing, Embedded Systems, and Lifescience Informatics, students are trained at two of the universities to get a double degree in computer science. The programme is accompanied by a scholar programme to get world class lecturers from different parts of the world. First students will finalize their studies in 2006.
PROLEARN: EU Network of Excellence

R. Klamma, Y. Cao, M.A. Chatti, M. Spaniol, H. Haegert, I. Ivanova, A. Martini, N.F. Muhammad, O. Yamcharoen, D. Senk (IEHK), H.W. Gudenau (IEHK), K. Mavromatis (IEHK), A. Babich (IEHK), and more than 200 other researchers

PROLEARN, started January 1, 2004, is dedicated to join research in the area of professional learning and training focusing on small and medium enterprises (SME). The NoE advances the state of the art in the key areas personalized adaptive learning and interactive media, with learning resources connected to real-world settings and reusable in different contexts. It investigates and advances issues especially relevant for professional training in SME’s and larger companies, including brokerage platforms and services, business models for specific markets, and advanced eLearning and knowledge work management arrangements. As a major event the chair co-organised the PROLEARN summerschool 2005 in Şile, Turkey, from September 5-9. The summerschool brought together PhD students, teachers, academics and industry people for PhD training, entrepreneurial activities, and network events. More than 45 PhD students have successfully attended the summerschool in 2005.

SFB 476 IMPROVE
Information Technology Support for Collaborative and Distributed Design Processes in Chemical Engineering

M. Jarke, M. Miatidis, S. Brandt, M. Schlüter, M. Comanns, M. Ikram, A. Passen, J. Renner

The collaborative research center (CRC) SFB 476 IMPROVE is funded since August 1997 by the Deutsche Forschungsgemeinschaft (DFG), and aims at improving the processes in chemical and plastics engineering.

In the final current phase of the CRC, the research focusses on cooperative work process support and the aspect of synergetic interleaving. Plans are also being made about continuing the basic research while transferring the research results into concrete projects, in cooperation with the chemical and plastics industry. In this context, Informatik V works on two projects.

In the project “experience-based support for cooperative engineering processes” (B1), research concentrates on the direct, experience-based support of developers during creative design processes. The followed approach is based on the key idea of a posteriori process integration of tools that offers the potential for integrated method guidance and traceability. Currently, further research is being conducted towards cooperative and reuse aspects of design.
In the project “goal-oriented management of information flows in engineering design processes” (C1), a process data warehouse is offered as an ontology-oriented infrastructure for semantic access to product and process experience data. The research focusses on supporting interdisciplinary design processes, especially on the problems encountered in the case of inter-organizational cooperation between the domains of chemical and plastics engineering.

**MErKoFer**

*M. Schlüter, M. Jarke, B. Quade, M. Raddatz, M. Sedlmayr*

MErKoFer (“Identification and reuse of experience knowledge in rubber extrusion processes”) is a collaborative project of Informatik V and aiXtrusion GmbH in cooperation with Meteor Gummiwerke K.H. Bädje GmbH & Co. KG. The project began in October 2004 and is supported by the Bundesministerium für Bildung und Forschung (BMBF).

In continuous production processes the effects of a modification of process parameters on the product can often only be observed after the entire production cycle has been completed. In case of disturbances this causes the waste of ecological and economical resources, if countermeasures do not directly lead back to a stable production within desired specifications.

After determining the most influential process parameters and applying explorative data mining methods to identify interrelations and temporal dependencies, we correlate product flaws and the according process states. By recording the operator’s actions and evaluating their efficiency, we are able to construct an experience knowledge base. When another problem occurs, we can provide decision support for operators by supplying a number of previously taken actions and an evaluation of their respective efficiency to correct anomalies in a similar context. Based on this additional information the chance to compensate interferences in the production process is significantly increased.
Inter-organizational networks of people, information and communication systems are often described by the interplay between individual goals and actions and the strategic dependencies among individuals and subgroups. The TROPOS project started in the context of the DFG Focussed Research Programme on Socionics, jointly conducted with the KBS group of Prof. Lakemeyer and the network sociology group of Dr. Funken, and is expanded in the context of the DFG-funded Graduate School 643 “Software for mobile communication systems”. It aims at improving requirements engineering for such networks by not just representing their goals and dependencies statically, but also by studying the dynamic interactions between both (esp. trust) via agent-based simulation through our SNet prototype environment. Key features of SNet are the automatic translation of extended i* models into the process modeling environment ConGolog (via ConceptBase) and to use sophisticated deliberative representatives within the simulations. This year’s work concerned strengthening of international cooperations and expanding to new application areas. As a result of the 2nd i* Workshop at London in May, a new community platform was established at http://istar.rwth-aachen.de by a team of Ph.D. students from Aachen, Barcelona, and Toronto. Furthermore together with researchers from CSIRO Australia, trust relationships within a health care service network were considered as an additional application example.

SEWASIE: Semantic Webs and AgentS in Integrated Economies

M. Jarke, M. Schoop (Uni Hohenheim), D. Kensche, A. Jertila, C. Quix, Y. Cao, A. Becks (Fraunhofer FIT), J. Huster (Fraunhofer FIT), C. Seeling

SEWASIE was a European project with partners from Germany (RWTH Aachen, Informatik V; Fraunhofer Institute for Applied Information Technology (FIT); Thinking Networks AG) and Italy (Universita di Modena; Universita di Roma “La Sapienza”; Universita di Bolzona; CNA Servizi Modena; IBM Italia) funded from 2002-2005 within the Semantic Web initiative. The project designed and implemented an advanced search engine enabling intelligent access to heterogeneous data sources on the web via semantic enrichment to provide the basis of structured secure web-based communication. Informatik V closely cooperates with Fraunhofer-FIT in SEWASIE.

Informatik V has developed a communication tool that supports electronic negotiations in business-to-business electronic commerce in two ways. Firstly, ontology-based contract negotiations are enabled that allow human negotiators to use the ontological context of
semantic search for structured web-based negotiations. Secondly, ontology negotiations enable negotiators to negotiate about ontologies, the normative and terminological basis of their contract negotiations. FIT developed a monitoring agent on top of the query engine to observe information according to long-term interests of users. Graphical methods to explore these personalised information spaces, developed at Informatik V, are included. FIT also provides functionalities to link observed information into decision support environments based on OLAP.

The project was concluded in April 2005 with a very successful final project review in Aachen. The final prototype of the project was also demonstrated at the International Semantic Web Conference (ISWC) in Galway, Ireland.

Zentrum für Softwarekonzepte

M. Jarke, A. Becks (Fraunhofer-FIT), C. Quix, T. Knieps(Fraunhofer-FIT), A. Schneider(Fraunhofer-FIT), W. Wirsam(Fraunhofer-FIT)

The “Zentrum für Softwarekonzepte (ZfS)” is an initiative of Microsoft in cooperation with several academic research institutions in Germany. The goal is to support small- and medium-sized enterprises (SMEs) in Germany by enhancing the knowledge transfer from research institutions to companies. The support is given in form of seminars related to .NET technologies as well as consulting activities for specific problems of a SME. In addition, the ZfS will cooperate with Microsoft Research in researching and developing new and innovative technologies in the area of cooperative information systems, user interfaces, and database technology.

Informatik V works closely together with Fraunhofer-FIT in this project which started in October 2005. The initial work concentrated on defining the contents and timeline for the seminars and marketing activities in early 2006. For example, the ZfS will be presented at the exhibition stand of Microsoft at the CeBIT 2006.

In addition, Informatik V will offer lab courses, lectures and seminars to computer science students that are related to .NET technologies. A first example is a lab course for the development of web services based on .NET.
Other Activities

Service

Prof. Jarke’s major administrative and service activities in 2005 included:

- Executive Director, Fraunhofer FIT, Birlinghoven
- Founding Director, Bonn-Aachen International Center for Information Technology (B-IT)
- Coordinator, BITGRAD Graduate School Proposal
- President, GI German Informatics Society (re-elected for 2006-2007)
- Scientific member, steering council Informatikjahr - Science Year 2006
- DFG elected reviewer for practical computer science
- Reviewer for BMBF Programme SE-2006
- member, extended management board of FIR e.V. at RWTH Aachen
- Scientific advisory board, Faculty of Informatics, University of Vienna, Austria
- Scientific advisory board, Learning Lab Lower Saxony (L3S), Hannover
- Scientific advisory board, Beta Research School, Eindhoven/Twente, Netherlands
- Supervisory, curatory and scientific advisory board, IBFI, Schloss Dagstuhl
- Nomination committee, Association for Information Systems, Atlanta, USA
- Jury member, Wissenschaftspreis Stifterverband der Deutschen Wirtschaft

In the context of Informatikjahr 2006 and other GI activities, Prof. Jarke gave about 20 interviews for TV stations (e.g. Heute-Journal), radio stations (e.g. Deutschlandfunk), specialized newspapers (e.g. ComputerZeitung, CHIP, c’t), and general newspapers.

Dr. Klamma held a stand-in professorship at the University of Passau (winter term 2004/05). He is a substitute member of the PROLEARN executive board. Dr. Klamma served as advisor of the ERASMUS Mundus master programme European Master in Informatics (EuMI).

Editorial Boards

M. Jarke served on editorial boards:
- Decision Support Systems
- Requirements Engineering Journal
- Organizational Computing and Electronic Commerce
- Intelligent Information Systems
- Group Decision and Negotiation

Conference Organization

M. Jarke was co-organizer of a Dagstuhl Strategy Workshop on “Challenges for Software Engineering in Germany” with M. Broy, M. Nagl, and D. Rombach, held Oct. 11-12, 2005 and co-editor of the resulting Dagstuhl Manifesto on Software Engineering. He also served on the programme committees of the following conferences: Wirtschaftsinformatik 2005, Bamberg (Feb. 2005); 2nd International Workshop on Information Quality for Information Systems (IQIS-05) at ACM-SIGMOD, Baltimore, USA (June 2005); International Workshop on Context Modeling and Decision Support at CONTEXT 05, Paris (July 2005); 6th
International Workshop on Agent-Oriented Software Engineering (AOSE-05) at AAMAS-05, Utrecht (July 2005); 20th International Conference Conceptual Modeling (ER 2005), Klagenfurt, Austria (Oct. 2005); European Conference Information Systems, Göteborg, Sweden (June 2006).

A. Becks was member of the programme committee of the 2nd Indian International Conference on Artificial Intelligence, IICAI-05, Pune, India, December 2005 and the 2nd International Conference on Communities and Technologies, Milano, Italy, June 2005.


E. Linz co-chaired the intensive workshop “Politiken der Schrift” hosted by the Kurt-Schumacher-Akademie, Friedrich-Ebert-Stiftung, Bad Münstereifel, Germany, May 30 - June 1, 2005. She was a member of the programme committee of the conference “Unmengen. Szenen verteilter Handlungsmacht” (“Agency”), SFB/FK 427, University of Bonn, Germany, December 15-16, 2005.

M. Spaniol was co-organizer of the 3rd MPEG-7/21 Community Workshop on “Test Sets for Multimedia Interoperability & Application Scenarios”, Aachen, November 24-25, 2005. He was member of the programme committee of the I-Know’05 special track on “Knowledge Discovery and Semantic Technologies (KDaST’05)”, Graz, Austria, June 29, 2005.

Software Demonstrations
· Meta Modelling with ConceptBase, Workshop on Meta-Modelling and Corresponding Tools, Essen, Germany, March 2005.
· ACIS: 1st International Workshop on Geographic Hypermedia, Denver, USA, April 2005.
· SOCRATES end-user workshop, Cologne, July 15-16, 2005.
Talks and Publications

Talks


Y. Cao: **A Hypermedia Afghan Sites and Monuments Database**, 1st International Workshop on Geographic Hypermedia, Denver, CO, USA, April 4-5, 2005.


M. Jarke: **Informatics in Germany and Austria**, 30 Years OCG, Vienna, April 13, 2005.


M. Jarke: *Human-Centered Computing*, Inaugural Keynote Talk, Faculty of Informatics, University of Vienna, June 16, 2005.


M. Jarke: *Bonn-Aachen International Center for Information Technology (B-IT)*, Unterausschuss Wissenschaft der Stadt Bonn, September 7, 2005.


M. Jarke: *Universitäten als Wirtschaftsförderer - Innovationsmotor Informatik*, Invited Talk, 10 Years TZI, Bremen, October 6, 2005.


R. Klamma: *MPEG-7 Databases in Cultural Heritage Management*, 2nd MPEG-7 Community Workshop, Know Center, Graz, June 30, 2005.


W. Prinz: Using content analysis to support the noise detection and visualization of shared workspaces, Mensch und Computer 2005, Linz, Austria.

W. Prinz: Kooperationssysteme: Trends und Herausforderungen, an invited talk at University Hamburg.


D. Schmitz: Coupling Agent-Based Simulation and Execution Environments in Applications for Mobile Production Engineering, Dagstuhl-Workshop von 7 Informatik-Graduiertenkollegs, Dagstuhl, May 24, 2005.


M. Spaniol: From MECCA (Movie E-learning Combination and Categorization Application) to MASTER (Multimedia Analysis of Soccer/Sports Tactics and E-training Resource): Proposing MPEG-7 annotated sports videos as part of a testbed, 2nd Workshop “MPEG and Multimedia Metadata Community”, Graz, Austria, June 30, 2005.

M. Spaniol: MEDINA: A Semi-automatic Dublin Core to MPEG-7 Converter for Collaboration and Knowledge Management in Multimedia Repositories, Conference I-KNOW ’05, Graz, Austria, June 30, 2005.

M. Spaniol: “Do you know a similar project I can learn from?” Self-monitoring of Communities of Practice in the Cultural Sciences, Conference ICITA’05, Sydney, Australia, July 5, 2005.

M. Spaniol: Collaborative Multimedia Information Systems for Cultural Science Communities, Seminar at School of Computer Science & Mathematics (CSM), Melbourne, Australia, July 15, 2005.

M. Spaniol: MECCA-learn: A Community Based Collaborative Course Management System for Media-rich Curricula in the Film Studies, Conference ICWL 2005, Hong Kong SAR, China, August 1, 2005.

M. Spaniol: Media-centric Information Systems for Communities of Practice in the Cultural Sciences, PhD students forum at the PROLEARN Summer School 2005, Şile, Turkey, September 7, 2005.


Publications

Books and Edited Volumes


Journal Articles


Conference and Book Contributions


L. Ragia: Seven Important Issues to a Successful Geo Model, IEEE Conference IPSI 2005 Special focus: Quality of life, Bled, Slovenia, December 8-11, 2005.


Knowledge-Based Systems &
Cognitive Robotics Group

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Overview

A major focus of our group is *Cognitive Robotics*. Research in Cognitive Robotics is concerned with the theory and the implementation of robots that reason, act and perceive in changing, incompletely known, unpredictable environments. Such robots must have higher level cognitive functions that involve reasoning, for example, about goals, actions, when to perceive and what to look for, the cognitive states of other agents, time, collaborative task execution, etc. In short, Cognitive Robotics addresses the integration of reasoning, perception and action within a uniform theoretical and implementation framework.

Our own research in Cognitive Robotics is concerned with the development of logic-based languages suitable for the high-level control of mobile robots, and their embedding into robotic systems, which includes issues like user interfaces and monitoring of execution failures. On the one hand, such languages allow the description of robotic tasks at an abstract level in terms of high-level actions and their effects on the state of the world. On the other hand, by interpreting these languages, the robots are able to reason about their own goals, the actions they have at their disposal and the way the world changes as a result of these actions. The languages we are considering are extensions of GOLOG, whose semantics is based on the situation calculus and which was originally developed by Ray Reiter and his colleagues at the University of Toronto. We are investigating extensions regarding actions which change the world continuously and actions with probabilistic outcome. Funded by the German Science Foundation (DFG), we are applying these techniques to the control of robots in highly dynamic domains like robotic soccer. Furthermore, we are investigating foundational issues regarding the diagnosis of execution failures of a robot, again in the framework of the situation calculus.

In other work and in collaboration with M. Jarke’s group and sociologists from the University of Freiburg, our group is involved in applying GOLOG to a requirements engineering methodology for the design and analysis of so-called strategic networks. In particular, we are interested in providing the means to characterize the dynamics of such networks as well as to simulate various scenarios that arise in such networks.

In collaboration with Hector Levesque at the University of Toronto, we have been investigating basic issues in knowledge representation regarding the logic of knowledge bases and tractable forms of inference. This work has led, among other things, to a book recently published by MIT Press. Gerhard Lakemeyer is also the co-editor of the book “Exploring AI in the Next Millennium,” published by Morgan Kaufmann, which features a collection of “best” papers in a wide range of areas in Artificial Intelligence.
The goal of this project is to develop a deliberative component supporting coordinated actions of multi-robotic systems under real-time constraints, using robotic soccer as a benchmark application. This project is part of the research initiative “RoboCup” (SPP 1125) funded by the German Science Foundation. The basis for the deliberative component to be developed in this project is the logic-based action language GOLOG, which was initially conceived at the University of Toronto. GOLOG has been extended within our group in recent years and applied successfully to the control of mobile robots in office environments and museums.

In this project, a dialect of GOLOG featuring models of continuous change and uncertainty will be suitably adapted and integrated into a system, which combines both the reactive and deliberative choice of actions. Moreover, for the action selection process a decision-theoretic planning approach based on Markov Decision Processes is used. With this kind of planning integrated into the GOLOG framework the robot is able to choose an optimal course of actions with respect to a suitable utility function. Additionally, this framework allows for taking into account the uncertainties arising in the domain, e.g. a pass to a teammate may succeed or fail with a certain probability.

To validate our approach in the framework of RoboCup, we will apply our approach to both the simulation league and real robots in the so-called mid-size league, using robots we recently acquired with the help of a grant of the NRW ministry of Education and Research and in collaboration with the Department of Electrical Engineering (Prof. Kraiss). In 2005, we participated at the RoboCup German Open Championships in Paderborn, Germany, where we missed the semi-finals, though, proving our concept.

Moreover, we evaluated our approach not only in the soccer domain, but also showed its usefulness for the encoding of computer players (so-called game bots) in interactive computer games like UNREAL Tournament 2004. Our approach is competitive with the original omniscient game bots which come with UNREAL Tournament 2004, although the perception of our game bots is restricted.
Although there is a common origin, research on automated planning on the one hand and action logics on the other hand developed rather independently over the last three decades. This is mainly due to the fact that work on action languages was concerned with formalisms of high expressiveness, whereas for planning methods, the focus had to lie on computational efficiency, yielding input languages with less expressive possibilities. However, one can observe that during the last few years, the two separate fields began to converge again. Exemplary for this trend is the development of the planning domain definition language PDDL, which extends simple STRIPS-based planning by features such as conditional effects, time, concurrency and preferences, and which virtually constitutes a standard in the field of planning.

This DFG-funded project is conducted in cooperation with the Research Group on the Foundations of Artificial Intelligence of Bernhard Nebel at the University of Freiburg. It aims at integrating latest results in the areas of both action languages (in particular, GOLOG) and planning techniques (in particular, PDDL-based planners like Hoffmann and Nebel’s FF) to acquire systems that are both expressive and efficient. For this purpose, the objective is to on the one hand establish a common semantical basis for both GOLOG and PDDL in the situation calculus. On the other hand, expressiveness is to be studied by means of compilation schemes. This provides the foundation for embedding state-of-the-art planning systems like FF in GOLOG and enhancing planners with GOLOG relevant features such as time, concurrency and continuous actions.

Strategic networks are emerging as an important new form of cooperative problem solving beyond the traditional forms of hierarchical organization or market. A prototype environment, called SNet, supporting the representation and dynamic evaluation of designs for strategic networks comprising human, hardware, and software agents was developed. The environment employs meta-data management technology to integrate an extended version of the i* formalism for static network modeling with the ConGolog logic-based activity simulator. SNet’s intended application domain is requirements management and mediation support for inter-organizational and embedded
process systems, as well as simulation support for inter-organizational studies e.g. in high-tech entrepreneurship networks.

This DFG-funded project is conducted by Informatik V (Profs. M. Jarke and G. Lakemeyer) in cooperation with the Sociology group of Christiane Funken at TU Berlin. Cooperations also exist with the group of John Mylopoulos/Eric Yu at the University of Toronto concerning modelling issues, and with the Sloan School of Management at MIT (esp. Ken Morse, Director of the MIT Entrepreneurship Center) concerning application studies in Entrepreneurship Networks.

**Diagnosis of Plan Execution Failures and Subsequent Recovery**

*Gero Iwan, Gerhard Lakemeyer*

Autonomous agents (e.g. autonomous mobile robots) that plan their actions on their own have to cope with plan execution failures, i.e. the execution of the planned actions can fail totally or partially or unexpected events may occur. Also, an incorrect, incomplete or inaccurate world model at planning time can cause a putatively correct plan to be actually not or only partially executable at run-time. This will usually have the consequence that the targeted goals are not achieved. An autonomous agent should therefore be able to detect and remedy such errors.

So, when agents like mobile robots discover that the world is not as expected after carrying out a sequence of actions, they are interested in what action failures or unnoticed actions could have actually occurred which would help them rectify the situation. For this purpose, we investigate a kind of *history-based diagnosis* which is appropriate for explaining what went wrong in dynamic domains. Based on the semantics of actions and world states (as they are underlying, for instance, the robot control language GOLOG) possible causes of a failure are to be detected and corrections can be made by plan modification, re-planning or special recovery procedures.

**Robust Real-Time Localization and Mapping in Single and Multi-Robot Systems**

*Vazha Amiranashvili, Gerhard Lakemeyer*

Autonomous robotics has been paid increasingly more attention to in the past 10 years. This is to a considerable extent due to the development of efficient algorithms for the robotic localization and mapping. The most successful of these algorithms are probabilistic and are based on the HMM (Hidden Markov Models), Kalman filters and EM (Expectation Maximization). The objective of this project was to develop more
efficient solutions to these problems in the single robot case and also to extend these single robot approaches to autonomous multi-robot systems. The extensions should work more efficiently, they should be more robust, and their complexity should not be more than that of the single-robot algorithms. In addition they should enable the fusion of data from various communicating robots. In the course of the project we developed new methods for single robot localization and mapping and also provided extensions of these methods to the multi-robot case. For the single robot localization we used a hierarchical representation of the perception sensor model, which made the position estimation by the Monte-Carlo algorithm faster and more robust. For the single robot mapping we provided a new implementation of the Rao-Blackwellized particle filter algorithm, which is more efficient than the solution known from the literature - FastSLAM. We extended these approaches to the mult-robot case using the perception data matching of different robots. This approach does not need the detection of robots by cameras or other sensors, which makes it more efficient than the most approaches known from the literature.

A New Situation Calculus
Gerhard Lakemeyer, Hector Levesque (University of Toronto)

Recently, we presented a new logic called ES for reasoning about the knowledge, action, and perception of an agent. Although formulated using modal operators, we argued that the language was in fact a dialect of the situation calculus but with the situation terms suppressed. This allowed us to develop a clean and workable semantics for the language without piggybacking on the generic Tarski semantics for first-order logic. In this paper, we reconsider the relation between ES and the situation calculus and show how to map sentences of ES into the situation calculus. We argue that the fragment of the situation calculus represented by ES is rich enough to handle the basic action theories defined by Reiter as well as Golog. Finally, we show that in the full second-order version of ES, almost all of the situation calculus can be accommodated.

Only-Knowing: Taking It Beyond Autoepistemic Reasoning
Gerhard Lakemeyer, Hector Levesque (University of Toronto)

The idea of only-knowing a collection of sentences has been previously shown to have a close connection with autoepistemic logic. Here we propose a more general account of only-knowing that captures not only autoepistemic logic but default logic as well. This allows us not only to study the properties of default logic in terms of an underlying
model of belief, but also the relationship among different forms of nonmonotonic reasoning, all within a classical monotonic logic characterized semantically in terms of possible worlds.

**HeRBiE: Hearing on a robot, binaurally enhanced**

Laurent Calmes, Gerhard Lakemeyer, Hermann Wagner (Biologie II)

The aim of this work is to equip a mobile robot with a method of sound source localization by using biologically inspired algorithms. The Jeffress model has been a fruitful scheme for understanding the representation of inter-aural time difference as an azimuthal sound-localization cue. As an improvement over previous work, we used the complete three-dimensional coincidence map for determining the azimuth of a sound source. A first implementation of the algorithm on the mobile robot Carl has been completed with promising results. Localization of broadband sound sources could be achieved with excellent precision. Although the precision for low frequency, narrowband signals is less than satisfactory, this can be ascribed to the acoustical characteristics of the microphone mounting and not to the algorithm. We are currently in the process of integrating a sound localizer based on inter-aural level differences as well as an attention module with the current system. Future work includes an integration with state-of-the-art probabilistic methods used for other localization tasks in robotics.
Other Activities

Robotics Lab
The Cognitive Robotics Group runs a Robotics Lab, having at its disposal the mobile robot CARL, a RWI B21 robot platform manufactured by Real World Interface, and five robots for playing soccer, developed and manufactured in cooperation with the Department of Electrical Engineering (Prof. Kraiss). CARL is equipped with ultrasonic, infrared, and tactile sensors, a proximity laser scanner and a stereo vision system. The two on-board computers (Intel Pentium 200-Pro, Intel Pentium 233) are connected to the Ethernet of the department by wireless radio Ethernet. The soccer robots are equipped with a 360° laser scanner and a mono vision system. Furthermore they contain two on-board computers (Pentium3-933) connected to Ethernet by wireless LAN. With few changes to the hardware the robots can be used for service robotic purposes as CARL.

Conference Organisation
Gerhard Lakemeyer was on the program committee of a number of international conferences and workshops.

Membership in Editorial Boards
G. Lakemeyer is an Associate Editor of the Journal of Artificial Intelligence Research.

Research stays
G. Lakemeyer visited the University of Toronto in October and November 2005.
Publications


V. Amiranashvili and G. Lakemeyer: Distributed Multi-Robot Localization Based on Mutual Path Detection, in Proc. of the 28th German Conference on Artificial Intelligence, Koblenz, Germany, 2005.


A. Ferrein, Ch. Fritz, and G. Lakemeyer: Using Golog for Deliberation and Team Coordination in Robotic Soccer, In KI Künstliche Intelligenz (1), 2005


G. Gans, M. Jarke, G. Lakemeyer, and D. Schmitz: Deliberation in a Metadata Based Modeling and Simulation Environment for Inter Organizational Networks., In Information Systems, Special Issue on Selected Papers From CAiSE03 Elsevier, 2005.


S. Jacobs, A. Ferrein, and G. Lakemeyer: Unreal Golog Bots., In IJCAI’05 WS on Reasoning, Representation, and Learning in Computer Games, 2005


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Overview

The Lehrstuhl für Informatik VI is concerned with research on advanced methods for statistical pattern recognition. The main application of these methods is in the field of automatic processing of human language, i.e. the recognition of speech, the translation of spoken and written language, the understanding of natural language and spoken dialogue systems.

The general framework for the research activities is based on statistical decision theory and problem specific modelling. The prototypical area where this approach has been pushed forward is speech recognition. Here, the approach is expressed by the equation:

\[
\text{Speech Recognition} = \text{Acoustic–Linguistic Modelling} + \text{Statistical Decision Theory}
\]

The characteristic advantages of the probabilistic framework and statistical decision theory are:

- The approach is able to model weak dependencies and vague knowledge at all levels of the system.
- The free parameters of the models can be automatically learned from training data (or examples), and there exist powerful algorithms for this purpose.
- Using the Bayes decision rule (as derived from statistical decision theory), the final decision is made by taking all available context into account. For example, in large vocabulary speech recognition, a sound is always recognized as a part of a word, which itself is part of a sentence. This allows the optimal feedback from the syntactic–semantic constraints of the language down to the level of sound recognition.

From speech recognition, we have extended and are still extending this approach to other areas, in particular the translation of spoken and written language and other tasks in natural language processing.

For language translation, the approach is expressed by the equation:

\[
\text{Language Translation} = \text{Linguistic Modelling} + \text{Statistical Decision Theory}
\]

This approach has been started in projects like VERBMOBIL (German project) and EUTRANS (European project). The experimental comparisons with traditional rule–based and other competing approaches show that the statistical approach is at least competitive in terms of performance, if not superior. In addition, it offers a couple of advantages like increased robustness and easy adaptation to a new task. In the final large–scale end–to–end evaluation of the VERBMOBIL translation project, the RWTH Aachen translation approach achieved a sentence error rate which was lower by a factor of two in comparison with three competing translation approaches.
In summary, the research activities of the *Lehrstuhl für Informatik VI* cover the following applications:

- speech recognition
  - large vocabulary recognition
  - multi-lingual speech recognition
  - speaker independent and adaptive speech recognition
  - robust speech recognition
- machine translation of spoken and written language
- natural language processing
  - document classification
  - language understanding
  - spoken dialogue systems
  - part-of-speech tagging and text annotation
- image recognition

Most of these research activities have been or are carried out in the framework of European projects (see below). In addition, there are bilateral research projects with companies.

**Selected Research Projects**

**Global Autonomous Language Exploitation (GALE)**

The goal of the GALE program is to develop automatic systems to extract information from a variety of sources, such as broadcast news, newswire text or Usenet newsgroup articles in the languages English, Chinese and Arabic. The *Lehrstuhl für Informatik VI* will contribute to GALE with the transcription of audio data into text (automatic speech recognition) and the translation of foreign language material into English (machine translation). The systems will pass along pointers to relevant source language data that will be available to humans and downstream processes. The distillation engine integrates information of interest to its user from multiple sources and documents.

**EU Project TC-STAR**

*(Technology and Corpora for Speech-to-Speech Translation)*

TC-STAR is a concentrated three year effort for advanced research in all core technologies for speech-to-speech translation: speech project targets at recognition, machine translation, and speech synthesis.

This EU integrated project is the first one world-wide that tackles the speech-to-speech translation of an *unconstrained* conversational speech domain, namely parliamentary debates in European English and European Spanish and broadcast news in Chinese, thus covering
a few languages relevant for Europe’s economy and society. The technical challenges and objectives of the project focus on the development of new algorithms and methods, integrating relevant human knowledge which is available at translation time into a data-driven framework. Examples of such new approaches are the integration of linguistic knowledge in the statistical approach of spoken language translation, the statistical modelling of pronunciation of unconstrained conversational speech in automatic speech recognition, and new acoustic and prosodic models for generating expressive speech in speech synthesis. This work is supported by the collection of language resources and the setup of an evaluation infrastructure.

The Lehrstuhl für Informatik VI is involved in several work packages of this project. We are building the European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation. The EPPS corpus consists of acoustic data, corresponding transcriptions, and parallel texts, i.e. translations of plenary sessions of the European Parliament in the languages English and Spanish. In the area of machine translation, we are involved in research on innovative translation methods, use of human-supplied knowledge, and on the integration of machine translation and speech recognition. We are work package leader and develop translation systems for Chinese-English, Spanish-English, and English-Spanish as well as automatic speech recognition systems for English and Spanish in the EPPS domain. Our work in the area of speech recognition covers lightly supervised transcription, new optimization criteria, and open vocabulary methods.

**EU Project TT2 (TransType2)**

The aim of TransType2 was to develop a computer-assisted translation system, which would help to meet the growing demand for high-quality translation. The innovative solution proposed by TransType2 was to embed a data-driven machine translation engine with an interactive translation environment. In this way, the system combined the best of two paradigms: the computer-assisted translation paradigm, in which the human translator ensured high-quality output; and the machine translation paradigm, in which the machine ensured significant productivity gains. Another innovative feature of the system was that it had two input modalities: text and speech. Six different versions of the system were developed for English, French, Spanish and German which were evaluated by two professional translation agencies. Lehrstuhl für Informatik VI contributed to improving the translation technology; and systems were set up for all six language pairs. Additionally, we extended the system by a speech interface for German to make the system more convenient for human translators. The project was completed in February 2005.

**EU Project LC-STAR (Lexica and Corpora for Speech-to-Speech Translation Technologies)**

The objective of the LC-STAR project was to improve human-to-human and man-machine communication in multilingual environments. LC-STAR was a joint European project lasting three years. It was completed in 2005. Within the project, lexica and corpora needed
for speech-to-speech translation were created. A speech-to-speech translation demonstrator for the three languages English, Spanish and Catalan was developed. The Lehrstuhl für Informatik VI concentrated on the investigation of speech centered translation technologies and on the creation of lexica for speech recognition in German. The research focused on the use of morpho-syntactically enriched language resources to improve speech translation.

**DFG Project Statistical Methods for Written Language Translation**

This project aims at the development and improvement of statistical machine translation. The following problems are tackled: large vocabulary translation, improvement of statistical alignment and lexicon models, integration of mono- and bilingual syntactic structures and morphological analysis, and adaption and improvement of training and search algorithms for statistical machine translation.

**DFG Project Statistical Modelling for Image Object Recognition**

The aim of the project is to investigate suitable statistical models for image object recognition on three levels: modelling of object appearance using maximum entropy models; modelling of the variability of image objects using hidden Markov models; modelling of complex scenes part-based models.

**RWTH Project IRMA (Image Retrieval in Medical Applications)**

The RWTH IRMA project is a joint project of the Institute of Medical Informatics, the Department of Diagnostic Radiology, and Lehrstuhl für Informatik VI. The goal of this project is the realization of a content-based image retrieval system suited for use in daily medical routine. At Lehrstuhl für Informatik VI, emphasis is put on the research in the domain of automatic image categorization and the evaluation of different features for medical image retrieval.

![Figure 10: Examples from the IRMA Database](image)

**National and International Evaluation Campaigns**

- **NIST 2005 Chinese–English Machine Translation Evaluation**

  In 2005, we took part in the NIST machine translation evaluation for translation of Chinese news text into English. Among leading research groups from all over the world, the RWTH system was ranked fourth of fourteen systems in this evaluation.
• **IWSLT 2005 (International Workshop on Spoken Language Translation)**

The C-STAR consortium organized the second evaluation campaign for speech translation. The task was the travelling domain, the translation directions were Chinese to English, English to Chinese, Japanese to English, Korean to English, and Arabic to English. The Lehrstuhl für Informatik VI took part in this evaluation and achieved first, second or third positions (depending on conditions and evaluation criterion) among 16 research groups.

• **CLEF/ImageCLEF Image Retrieval Evaluation 2005**

In 2005, we took part in the ImageCLEF content-based image retrieval evaluation for medical images. Among leading research groups from all over the world, our systems were ranked first and third in the medical automatic annotation task. In the medical retrieval task, we could strongly improve our results using a combination of text and image retrieval.

• **PASCAL Visual Object Classes Challenge 2005**

We participated in the PASCAL visual object classes challenge. Among leading research groups from all over the world, our part-based method obtained the second rank in the classification of objects in highly cluttered background.

• **Data Mining Cup 2005**

In 2005, a practical course for students held by Lehrstuhl für Informatik VI took part in the Data Mining Cup organized by the Chemnitz University of Technology, and prudsys AG. All students achieved a rank within the top 20 of over 140 international participants, including the 1st.

• **GfKl Datamining Competition 2005**

A team of three students from Lehrstuhl für Informatik VI participated in the Data Mining Competition held in the course of the annual meeting of the German Classification Society (Gesellschaft für Klassifikation, GfKl). They achieved two 2nd, the 6th, 7th, and 9th place out of 40 academic and professional participants.

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**Speech Recognition**

Today, state-of-the-art systems for automatic speech recognition are based on the statistical approach of Bayes decision rule. The implementation of Bayes decision rule for automatic speech recognition is based on two kinds of stochastic models: the acoustic model and the language model which together are the basis for the decision process itself, i.e. the search for the most probable sentence. These modules of an automatic speech recognition system (cf. Figure 11) are characterized as follows:
• The \textit{acoustic model} captures the acoustic properties of speech and provides the probability of the observed acoustic signal given a hypothesized word sequence. The acoustic model includes:
  1. The acoustic analysis which parameterizes the speech input into a sequence of acoustic vectors.
  2. Acoustic models for the smallest sub-word units, i.e. phonemes which usually are modeled in a context dependent way.
  3. The pronunciation lexicon, which defines the decomposition of the words into the sub-word units.

• The \textit{language model} captures the linguistic properties of the language and provides the a-priori probability of a word sequence. From an information theoretic point of view, syntax, semantics, and pragmatics of the language could also be viewed as redundancies. Statistical methods provide a general framework to model such redundancies robustly. Therefore state-of-the-art language models usually are based on statistical concepts.

• The \textit{search} realizes \textit{Bayes decision criterion} on the basis of the acoustic model and the language model. This requires the generation and scoring of competing sentence hypotheses. To obtain the final recognition result, the main objective then is to search for that sentence hypothesis with the best score, which is done efficiently using dynamic programming. The efficiency of the search process is increased by
pruning unlikely hypotheses as early as possible during dynamic programming without
affecting the recognition performance.

Figure 12: (a) Speech waveform of the utterance “Sollen wir am Sonntag nach Berlin
fahren”, (b) the corresponding FFT spectrum

At Lehrstuhl für Informatik VI, the following research directions related to all main areas of
automatic speech recognition were pursued in 2005:

- The generation of *European Parliament Plenary Session (EPPS) corpus* for speech-to-
speech translation between English and Spanish was continued. This corpus consists
of transcribed speech and parallel texts in the languages English and Spanish and is
based on corresponding TV broadcasts and internet publications.

- Extraction methods for *novel acoustic features* were developed to capture relevant
articulatory information not extracted by former extraction methods used in automatic
speech recognition. Also, investigations on different acoustic feature combination
methods were carried out.

- Different variants of *speaker adaptation* as well as methods for *speaker clustering*
were implemented and tested, and *speaker adaptive training* was prepared.

- In pronunciation modelling, methods for automatic phonetic transcription were
developed and applied to the detection of *out-of-vocabulary words*.

- *Discriminative model combination* using a variety of discriminative optimization
criteria was tested.

- Methods for discriminative training were investigated. Specifically, word error
minimizing criteria were developed and compared.
Transducer-based search architectures were investigated and compared to the standard search architecture.

A transducer-based approach for the integration of speech recognition and machine translation search for speech-to-speech translation was developed and tested.

Refinements of Bayes decision rule using a word error based cost function were investigated with special focus on analytic simplifications and reduction of complexity.

Machine Translation

The goal of machine translation is the translation of a text given in some natural source language into a natural target language. The input can be either a written sentence or a spoken sentence that was recognized by a speech recognition system. At Lehrstuhl für Informatik VI, we apply statistical methods similar to those in speech recognition. Stochastic models describe the structure of the sentences of the target language – the language model – and the dependencies between words of the source and the target language – the translation model (see Figure 13). The translation model is decomposed into the lexicon model which determines the translations of the words in the source language and the alignment model forming a mapping between the words in the source language string and the words in the target language string. These models are trained automatically on a corpus of bilingual source/target sentence pairs. In this approach, it is not necessary to manually design rules for the translation or the construction of sentences. A search algorithm determines the target language sentence that has the highest probability given the source language sentence.

The statistical approach to machine translation is particularly suitable for the translation of spontaneous speech, where the translation approach has to cope with colloquial language and speech recognition errors.
At *Lehrstuhl für Informatik VI*, the following research directions related to the main topics of machine translation were pursued in 2005:

- A new *phrase-based translation system* (PBT) was designed and implemented. The system is capable of translating text as well as lattices from automatic speech recognition systems. Constantly high translation quality was proven by top ranks in several international evaluations.

- A method for system combination for statistical machine translation, inspired from methods in speech recognitions was developed and yielded in an improved translation quality.

- A *computer-aided translation system* that aims at supporting human translators by an interactive machine translation environment was implemented. This system was enhanced with a speech interface and with methods that try to detect errors in automatically generated translations. This system was successfully tested in translation agencies in several evaluation rounds. It was shown that productivity of human translators increases through the use of this system.

- Furthermore, the integration of different types of language resources into a statistical machine translation was investigated. The focus was on translation from an inflected
language – like Spanish or German – into English. Knowledge about morpho-
syntax (such as part-of-speech tags and baseforms of words) was exploited to improve
translation quality.

• In the area of language modelling, we developed clustered language models for
different classes of sentences. This accounts for the fact that word order e.g. in
questions is different from that in declarative sentences.

• New reranking methods and features for machine translation were developed,
implemented, and tested. Among the features were improved language models,
syntactic features like parsing and tagging, and alternative translation models.
The methods improved translation quality and contributed to the good results in
international evaluations.

• Research efforts were extended in the area of automatic translation between German
written text and German Sign Language. Existing parallel corpora were augmented
in order to improve existing statistical machine translation systems. Combined with
speech input and a graphical output, the system aims at the support for deaf people.

• Since the output of machine translation systems often contain erroneous words, we
investigated so-called confidence measures that automatically detect mistakes made
by the system.

### Natural Language Processing

The goal of natural language processing is to design and build computer systems that are
able to analyze natural languages like German or English, and that generate their outputs in
a natural language, too. Typical applications of natural language processing are language
understanding, dialogue systems and text annotation.

The development of statistical approaches for these applications is one of the research
activities at the Lehrstuhl für Informatik VI.

In natural language understanding, the objective is to extract the meaning of an input
sentence or an input text. Usually, the meaning is represented in a suitable formal
representation language so that it can be processed by a computer. Usually, hand-
crafted grammars are used in order to parse input sentences and map them onto a formal
representation. The language understanding systems developed at the Lehrstuhl für
Informatik VI are based on statistical machine translation and learn dependencies between
source and target representations automatically from annotated texts. Because the usage of
hand-crafted grammars is reduced, the systems can be easily ported to other domains.

We developed a spoken dialogue system for the domain of a telephone directory assistance.
A large vocabulary continuous real-time speech recognition component as well as a natural
language understanding unit and a dialogue manager are integral parts of the system. The implementation of the dialogue system is independent from the application’s domain.

In part-of-speech tagging, each word is labeled with its word class (noun, verb, adjective, etc.). More generally, *tagging* is the task of labeling each word in a sentence with its appropriate tag; ”appropriate” being defined by the task. We developed a tagger using the maximum entropy framework which has been successfully evaluated on different tasks, like named entity recognition, part-of-speech tagging, shallow parsing, true casing and natural language understanding. The obtained results show a state-of-the-art performance.

In 2005, the maximum entropy framework developed for tagging was compared to standard machine translation approaches with respect to their performance in natural language understanding. The results showed that the discriminative maximum entropy approach clearly outperformed the source channel-based machine translation approach.

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**Image Recognition and Retrieval**

The experiences gained in human language technology and statistical pattern recognition are applied to the recognition of objects in images. So far, the main emphasis has been put on recognition of single objects using appearance-based methods (examples are shown in Figures 14 and 15). The main focus is modelling of variability and incorporation of invariances into the statistical model as well as the discriminative training of these models.

In 2005, the experiences gained in image processing and recognition were applied to content-based image retrieval tasks, and a quantitative evaluation of different aspects of image retrieval was performed. Classification of image objects using local patches in connection with statistical learning methods is another promising research topic.

Experiments in the domain of gesture and sign language recognition showed that the appearance-based approach is very competitive with other existing methods.

Figure 14: *Examples of single objects to be recognized (Caltech database)*
Other Activities

In the projects, various operational prototype systems have been set up, such as:

- Computer aided translation system TRANSTYPE2
- Speech-to-speech-translation system LC-STAR
- Image Retrieval Engine FIRE (Flexible Image Retrieval Engine)
  http://www-i6.informatik.rwth-aachen.de/~deselaers/cgi_bin/fire.cgi
Publications


F. Hilger, H. Ney, “Quantile Based Histogram Equalization for Noise Robust Large Vocabulary Speech Recognition”, In IEEE Transactions on Speech and Audio Processing, Accepted for future publication, 2005.


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**Dissertations**

M. Pitz: *Investigations on Linear Transformations for Speaker Adaptation and Normalization*
Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr. Christian Wellekens
March 2005

S. Vogel: *Statistical Machine Translation with Cascaded Probabilistic Transducers*
Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr.rer.nat. Alexander Waibel
December 2005
Logic & Theory of Discrete Systems

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Overview

Research

The research area of the group is automata theory and logic in connection with the specification, automatic verification, and automatic synthesis of programs. The focus of our present research is the evolving algorithmic theory of infinite graphs, with applications to model-checking, and the study of infinite games in various forms, e.g. as a model of reactive systems (research in the context of the EU project GAMES).

Highlights

• A new DFG project ("Algorithmic Theory of Automata over Unranked Trees") started, as well as a DAAD Procope Project “Finitely Presented Graphs: Structure, Behaviour, Algorithmics” for joint research with the group of D. Caucal, IRISA, Rennes.

• Within the European Science Foundation, the ESF Research Network AutoMathA ("Automata: From Mathematics to Applications") was granted and started its activities in July 2005; the international steering committee includes W. Thomas from Aachen.

• A new DFG-Graduiertenkolleg “Algorithmic Synthesis of Reactive and Discrete-Continuous Systems” (Speaker: W. Thomas) was granted in December (starting its work in July 2006).

• Wolfgang Thomas received the degree of doctor honoris causa from the Ecole Normale Supérieure de Cachan (18 November 2005).

• Stefan Wöhrle and Philipp Rohde finished their dissertations and obtained their doctoral degrees.

• As a special activity within the EU Training and Research Networks GAMES we organized a Spring School on Infinite Games and Applications at the B-IT Center in Bonn, visited by nearly 50 young researchers from 14 countries.
Research Projects

Automata and Languages

C. Löding, W. Thomas

The main focus of this research direction is to develop extensions of the fundamental model of finite automaton, enriching the expressive power but still keeping important properties of decidability. Results of such type are needed as a foundation of model-checking systems with infinite state spaces.

In recent years, the model of visibly pushdown automaton has been proposed with very good potential in this context. In two papers, C. Löding and co-authors obtained decidability results on this kind of automata: In [1] it was shown that the languages accepted by the visibly counter automata form a decidable subclass of the languages accepted by visibly pushdown automata. A second decidability result refers to the dynamic logic PDL extended by an infinitary component (given by visibly pushdown automata).

An application of language theoretical analysis to a problem in data base theory was found by C. Löding et al. in [2].

Algorithmic Model Theory

J. Altenbernd, C. Löding, W. Thomas, S. Wührle, together with A. Carayol (Rennes), funded by DAAD

One of the main challenges in model-checking is to extend the methodology to finitely presented infinite graphs. In this area, we focussed on properties which are expressible in monadic second-order logic (MSO) and developed new methods for the transformation of structures (MSO-transductions). Several results were obtained in the Procope collaboration with the group of D. Caucaq (Rennes). An integrated presentation of this research, focussing on higher-order pushdown systems and the combination of the structures by product operations, was completed in the dissertation of Stefan Wührle [14].

A different extension of pushdown systems is given by bifix rewriting systems. Ongoing work of Jan Altenbernd establishes decidability results for such systems.

Another track of research was pursued by W. Kariantjo: the integration of number theoretic conditions into the state-based framework. We obtained results on extensions
of the ‘Parikh automata’ as introduced by Klaedtke and Rueß; see the conference paper [4].

A more far-reaching perspective of the field was developed in the paper [13] (keynote speech at the 3rd conference “Automated Technology for Verification and Analysis”, Taipei).

Automata over Unranked Trees

C. Löding, W. Karianto, W. Thomas
funded by DFG

This project, funded by DFG in connection with another project at the University of Kiel, started in May 2005. The aim is to lift well-known results of the “classical” theory of tree languages to the case of “unranked” trees, which have finite but unbounded branching degree and arise in the context of XML-document processing.

The basis of our work are results as obtained by C. Löding in [6], which provide a new approach to infinite-state model checking. As initial results we found an effective characterization of top-down recognizable tree languages, as well as an efficient minimization algorithm for deterministic automata over unranked trees (see [3]).

ω-Automata and Algorithmic Game Theory

Ph. Rohde, W. Thomas, N. Wallmeier
funded by Graduiertenkolleg “Software für Kommunikationssysteme”

Infinite games and ω-automata are a subject which has been pursued by our group for several years. The aim of this research is to develop automata-based models of reactive nonterminating processes and to develop a framework for the automatic synthesis of controllers.

In connection with his doctoral project in the Graduiertenkolleg “Software für Kommunikationssysteme”, N. Wallmeier and the diploma student C. Schulte-Althoff provided the first case study of the literature which compares the two ω-automata minimization procedures due to Safra and Muller-Schupp. The results are documented in [12].

Regarding the game-theoretic framework, Ph. Rohde wrote a chapter [10] for a survey volume on algorithmic game theory.
In this research project we analyze problems over dynamically changing structures. This is in contrast to the classical framework of model-checking, where the underlying transition graphs are considered fixed. In our case, we determine procedures for “moving through a crumbling network”. The situation is modelled by a two person game over a (usually finite) graph, in which one player, called “runner”, tries to move via edges to a designated goal vertex, while the adversary, called “saboteur”, tries to prohibit this by deleting edges in the graph.

We investigated algorithmic problems in this dynamic scenario as well as logics for specification and their algorithmic properties (satisfiability, model-checking). For the latter problem, the logical framework of “sabotage µ-calculus” was introduced and characterized in a game-theoretic setting, involving so-called “back-up games” over dynamically changing graphs. This work is presented by Ph. Rohde in [11].

A comprehensive study including many more results was completed in 2005 (see the dissertation [9] of Ph. Rohde).

Other Activities

W. Thomas

- Dean of the Faculty of Mathematics, Computer Science, and Natural Sciences of RWTH Aachen
- Speaker of the DFG-Graduiertenkolleg “Algorithmic Synthesis of Reactive and Discrete-Continuous Systems”
- Member of the steering committee of the ESF Research Network AutoMathA
- Member of the Council of EATCS (European Association of Theoretical Computer Science)
- Member of the steering committee of the International Conference on Developments in Language Theory (DLT)
- Program Committee Member of the Conference “Foundations of Software Science and Computation Structures (FOSSACS)”, Edinburgh, March 2005
- Member of the Editorial Board of the following journals:
  - ACM Transactions on Computational Logic
– RAIRO Theoretical Computer Science and Applications
– Discrete Mathematics and Theoretical Computer Science

- Chairman of the German Section of the European Educational Forum (EEF)
- Member of external commissions (Promotion, Habilitation, Selection of Professors)

W. Oberschelp

- Member of the interdisciplinary working group “Karolingisches Aachen” at the RWTH Aachen
- Member of the preparing committee for the “Odysseum Cologne”, guided by FAW Ulm (F.J. Radermacher). Responsible for the topic “Computers” together with C. Drösser (Die Zeit)

V. Penner, Ph. Rohde

- Student Advisors for Curricula of Minor Subjects and for Teachers’ Curricula.

Talks and Publications

Talks
J. Altenbernd: Reachability over Bi-Stack Systems, First workshop of the PROCOPE project Aachen-Rennes, Aachen, April 2005


W. Karianto: Semi-Polynomial Sets and the Parikh Images of Level 2 Pushdown Automata, First workshop of the PROCOPE project Aachen-Rennes, Aachen, April 2005

W. Karianto: Adding Monotonic Counters to Automata and Transition Graphs, 9th International Conference on Developments in Language Theory (DLT 2005), Palermo (Italy), July 2005

W. Karianto: On the Parikh Images of Level-Two Pushdown Automata, 15. Theorietag der Fachgruppe 0.1.5 (Automaten und Formale Sprachen) der Gesellschaft für Informatik e.V., Lauterbad (Germany), September 2005

C. Löding: Entscheidungsprobleme für unendliche Graphen, Informatik-Kolloquium, University of Kiel, January 2005

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C. Löding: *Deterministic Transducers over Infinite Terms*, Workshop on Algorithmic Model Theory, Darmstadt, February 2005

C. Löding: *Regularity problems for visibly pushdown automata*, First workshop of the PROCOPE project Aachen-Rennes, Aachen, April 2005

C. Löding: *Synthesis from Scenarios*, Dagstuhl-Seminar on Synthesis and Planning, Dagstuhl, June 2005


Ph. Rohde: *On Games and Logics over Dynamically Changing Structures*, First workshop of the PROCOPE project Aachen-Rennes, Aachen, April 2005


Ph. Rohde: *On Games and Logics over Dynamically Changing Structures*, Informatik-Oberseminar, RWTH Aachen, December 8, 2005, Aachen, Germany

W. Thomas: *Automata on Unranked Trees: Restrictions and Extensions*, Dagstuhl-Seminar on Foundations of Semistructured Data, Dagstuhl, February 6-11, 2005


W. Thomas: *Automata Theoretic Foundations of Infinite Games*, Tutorial, Third International Symposium on Automated Technology for Verification and Analysis, October 4-7, 2005, Taipei, Taiwan

W. Thomas: *Some Perspectives of Infinite-State Verification*, Keynote speech, Third International Symposium on Automated Technology for Verification and Analysis, October 4-7, 2005, Taipei, Taiwan

W. Thomas: *When is S1S with an extra predicate decidable?*, Second workshop of the PROCOPE project Aachen-Rennes, Rennes, France, October 2005

W. Thomas: *Perspectives in algorithmic model theory*, Workshop on Perspectives in Verification, Cachan, France, November 17-18, 2005

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N. Wallmeier: *Observations on Determinization of Büchi Automata*, 10th International Conference on Implementation and Application of Automata, CIAA 2005, Sophia Antipolis (France), June 2005

S. Wöhre: *Synchronized Products of Graphs*, First workshop of the PROCOPE project Aachen-Rennes, Aachen, April 2005

**Publications**


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Overview

The research group on Mathematical Foundations of Computer Science is part of the Department of Mathematics, but there is a very intensive collaboration, both in research and teaching, with the Department of Computer Science, most notably with the research group Computer Science VII (Prof. Wolfgang Thomas).

The main research areas of the group are logic, the theory of infinite games, and complexity, with particular emphasis on logic for computer science, algorithmic issues in logical systems, computational model theory, and descriptive complexity. On the methodological side, fixed point logics, games, and automata play a central role in our research.

Research Projects

Games and Automata for Synthesis and Validation (GAMES)

www.games.rwth-aachen.de

E. Grädel, V. Barany, D. Berwanger, H. Björklund, T. Ganzow, L. Kaiser,
(and Research Group Computer Science VII of Prof. W. Thomas)

GAMES is an EU Research Training Network (RTN), co-ordinated by E. Grädel, which includes seven European sites (Aachen, Bordeaux, Edinburgh, Paris, Uppsala, Vienna, Warsaw) and one site from the USA (Rice). The Aachen node of the network includes our research group and the one led by Prof. W. Thomas.

The goal of the network is the development of specification and validation methodologies that are based on games and automata, for guaranteeing the reliability, correctness, and efficiency of large computing systems. More specifically, the research objectives are the following.

A. Foundations: Games, automata, and logic. The combination of automata, game theory, and applied logic constitutes a powerful theory with important practical applications. However, the present state of the theory still has essential gaps in central issues. Challenging problems concerning the mathematical foundations of infinite games and the interplay between automata, games, and logics have to be solved and a deeper integration of concepts from automata, games, and logics is needed for obtaining wider applications.

B. Reactive computation. We want to make progress in a so-far unexploited potential of infinite games, namely to develop them as a model of reactive computation. Our aim is to devise game-based methods for the automatic synthesis and testing of reactive controllers.
C. Verification: New Frontiers. Model checking techniques have been applied with great success to the verification of hardware. One of the big challenges for this network is to extend the verification methodology so as to deal with broader classes of systems, including important classes of software systems.

D. Web Technologies: Queries and Protocols. Mobile Computing, e-Business, and the World Wide Web have dramatically changed the way in which data are stored and manipulated. New technologies have emerged, with a strong demand for better foundations and efficient algorithmic strategies, and with new validation and security problems. We will exploit the methodological proximity between databases and verification to develop game and automata based techniques for query evaluation and for the new validation tasks in this area.

Algorithms and Complexity for Logic Problems

E. Grädel, D. Berwanger

The goal of this research is the design and analysis of decision algorithms and complexity issues for logic problems that are relevant for computer science. Application areas where these problems arise include, for instance, the specification and verification of hardware and software, databases, and knowledge representation.

Recently, substantial progress has been made concerning the algorithmic properties of modal logics (in the broad sense, including temporal logics, dynamic logics, the modal μ-calculus etc.), two-variable logics, and guarded logics. A key issue in this context is the relationship of algorithmic and model-theoretic properties of logical systems and the use of automata-based methods.

Computational Model Theory and Descriptive Complexity

E. Grädel, D. Berwanger, V. Barany, T. Ganzow

Finite model theory studies the relationship between logical definability and computational complexity on finite structures. A particularly important aspect concerns logical descriptions of complexity classes. Our research group has made significant contributions to this area.

A newer development in this field is the extension of the approach and methodology of finite model theory to (particular classes of) infinite structures. Algorithmic issues on infinite structures are of increasing importance in several areas of computer science. In databases, the traditional model based on finite relational structures has turned out to
be inadequate for modern applications (like geographic data, constraint databases, data on the Web). Also in verification, infinite (but finitely presentable) transition systems become more and more important, in particular for applications to software.

We investigate several directions, for making the methodology developed in finite model theory applicable to infinite structures. Of particular importance are, again, the connections between algorithmic issues and logical definability.

We have developed a model theory of metafinite structures that combine finite structures with arithmetic operations on infinite numerical domains. Applications of metafinite model theory have been studied in the following domains: descriptive complexity on real numbers, approximation properties of optimization and counting problems, databases with uncertain or unreliable information, and database query languages with aggregates.

We study algorithmic and definability issues on various classes of infinite structures that are presentable by automata and interpretations. The work by A. Blumensath, V. Barany, and E. Grädel on automatic structures has been very influential for the development of this field.

Abstract State Machines

E. Grädel, A. Nowack

Abstract State Machines (ASM) are a successful formalism for the specification of large discrete systems. The success of ASM is based on several properties. ASM bridge the gap between formal models of computation and practical specification methods, they can model any algorithm at its natural abstraction level, and they provide executable specifications. (For background on ASM, see www.eecs.umich.edu/gasm.)

The goals of our project are on the one hand a systematic study of the applicability of model checking methods for ASM. We want to identify classes of ASM and specification logic for which automatic verification algorithms are possible. On the other hand, we want to provide model-theoretic and complexity-theoretic foundations of the ASM methodology. In particular we aim at

- The classification of the fundamental algorithmic problems related to ASM according to their complexity.
- The systematic development of a complexity theory for ASM,
- Definability issues for ASM in suitable specification logics,
- The development of model-theoretic tools for ASM, in particular a composition theory.
Other Activities
Erich Grädel

- Co-ordinator of the European Research Training Network *Games and Automata for Synthesis and Validation* (GAMES).

- Member of the Editorial Board of The Bulletin of Symbolic Logic, (Reviews Editor for Logic in Computer Science).

- Member of the Editorial Board of *Logical Methods in Computer Science*


- Member of the Programme Committee of the 11th International Conference on Logic for Programming, Artificial Intelligence and Reasoning LPAR 2005, Montevideo.

Talks and Publications

Talks


E. Grädel: Positional Determinacy of Games with Infinitely Many Priorities, 7th Augustus de Morgan Workshop on Interactive Logic: Games and Social Software, King’s College London, November 2005.


E. Grädel: Complexity Measures for Directed Graphs, Workshop on Perspectives in Verification, in honour of Prof. Dr. Wolfgang Thomas (RWTH Aachen), on the occasion of his doctorate honoris causa, awarded by ENS Cachan, November 2005.

Publications


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D. Berwanger, E. Grädel, and G. Lenzi: *The Variable Hierarchy of the Mu-Calculus is Strict.*, Theory of Computing Systems - special issue dedicated to selected papers from STACS 2005. Accepted for publication.


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Overview

The Computer Graphics and Multimedia group at the RWTH is focussing on research projects in the areas of Geometry Processing, 3D Reconstruction, and Interactive Visualization but it is also active in areas such as High Quality Image Synthesis, Computer Vision, Point-based Graphics and Multimedia Data Transmission. Our research projects and collaborations are funded by the Deutsche Forschungsgemeinschaft (DFG), the Federal Ministry of Education and Research (BMBF), the German-Israelian Foundation (GIF), and the European Union (EU). Moreover, we are cooperating with various companies in the automotive and automatization industry as well as with academic research groups around the world (North America, Europe, Asia). We consider our research field as applied basic research since even if the methods and techniques that we are developing often address fundamental and abstract problems we are nevertheless aiming at the application and evaluation of our solutions in real world scenarios.

A fully automatic Geometry Processing Pipeline is one of the long term goals on our research agenda. This requires methods for capturing the shape and texture of real objects, turning them into efficient computer models and enhancing the quality of the raw data with respect to surface roughness, sharp feature preservation and topological consistency. More sophisticated algorithms are able to even detect and extract structural information (e.g. in technical objects composed by shape primitives such as cylinders and spheres). Eventually we also need algorithms for the interactive visualization of the potentially massive datasets. To achieve this goal we are investigating new techniques to measure three dimensional data with digital cameras and laser range scanners. Once this data is obtained we have to integrate measurements from several sources into a single 3D computer model and thereby remove erroneous and redundant data. Recently, hybrid geometry representations (which combine surface and volume representations) have attracted our interest since they allow for more robust and more efficient algorithms for various geometry processing tasks. In the area of mesh generation we made significant advances in quad-dominant meshing for arbitrary input geometries.

In the past year we have started to look more closely into volumetric reconstruction techniques from pre-calibrated video footage. Here we could successfully extend the current state of the art by developing a new and very robust photo-consistency measure, which can be evaluated efficiently on a graphics processor. Moreover we came up with a new algorithm for optimal surface extraction based on a global graph cut computation.

The processing of 3D geometry data is becoming more and more important in industrial product design and development. Typical applications go way beyond classical CAD/CAM tasks. Through the availability of high performance computer hardware and highly efficient numerical algorithms, various phases of the industrial development process are being based on computer simulations today. In order to guarantee the reliability of these simulations one needs very detailed 3D models. Well known examples for this scenario are the flow or crash simulation in the early stages of automotive and airplane development. Further applications are reaching from bio-medical engineering to rapid prototyping and to multimedia data
archives. Especially in 3D medical image processing, geometric algorithms gain increasing relevance. In all these applications the cost efficient generation and modification of complex 3D models is essential for the successful use of computers.

To promote this fresh and highly relevant research area we have started an international symposium series on Geometry Processing which after its successful start in Aachen in 2003 has now established as the major international forum specialized to this field. On the national level, we founded a “Geometry Processing” section as a sub-organization of the national Gesellschaft für Informatik. As the speaker of this section, Leif Kobbelt’s goal is to join the forces of the various research groups in industry and academia.

Our teaching curriculum currently comprises the sequel Computer Graphics I/II and the sequel Geometric Modeling I/II. Both sequels are taught in parallel with their first parts in the winter term and their second parts in the following summer term respectively. In the Computer Graphics courses we cover the basic as well as the advanced techniques for image synthesis and lighting simulation, image based rendering techniques, and polygon mesh processing. The Geometric Modeling courses are more focused on techniques and algorithms to efficiently process freeform curves (part I) and surfaces (part II). In addition to the courses, we offer a practical exercise project on Special Effects. Our goal in this project is to develop a software system that processes video streams from 20 digital cameras filming the same scene from different viewpoints such that arbitrary new views can be generated synthetically. On the undergraduate level we offered an introductory seminar and practical exercises on topics in Computer Graphics.

In the fifth year after our group started, the number of students working on their diploma thesis in our lab is constantly increasing. Some of the projects presented on the following pages are actually based on results emerging from thesis projects. More exciting topics are permanently offered to interested students.

On the following pages, we are going to give a brief overview on our current research projects. These range from sophisticated 2D image processing tools, via VR applications to computer vision, mesh optimization and interactive shape modeling. This year our group was again able to publish innovative research papers on many internationally recognized conferences and journals in Computer Graphics. For example, even though the Eurographics 2005 conference had an acceptance rate of only about 15% this year, all our four submission were accepted, which means that papers from our group provided about 10% of the entire conference program.
A common dilemma in today's CAM production environments are the different geometry representations that are employed by CAD systems on the generation and design side and downstream applications on the analysis and visualization. While CAD systems usually represent a 3D model by a set of trimmed NURBS patches, downstream applications like computational fluid- or structure simulation, rapid prototyping, and numerically controlled machining rely on closed and consistent manifold triangle meshes as input. The conversion from one representation into the other is not only a major bottleneck in terms of time, but also with respect to the accuracy and quality of the output and thus directly impacts all subsequent production stages.

Common tessellation algorithms are able to efficiently and accurately convert single patches into triangle meshes, but usually cannot properly handle continuity constraints between different patches or detect and resolve self-intersecting geometry. This leads to artifacts like gaps, overlaps, intersections, or inconsistent orientations between the tessellated patches, which often have to be repaired in a manual and tedious postprocessing step. For this reason, quite some effort has been put into algorithms that are able to automatically repair such models.

Surface oriented algorithms fix the inconsistencies by perturbing the input only slightly, but they cannot handle all special cases. Volumetric algorithms produce guaranteed manifold meshes but destroy the structure of the input tessellation due to global resampling. In this project we combine the advantages of both approaches: We exploit the topological simplicity of a voxel grid to reconstruct a cleaned up surface in the vicinity of intersections and cracks, but keep the input tessellation in regions that are away from these inconsistencies. We are thus able to preserve the characteristic structure of the input tessellation, close gaps up to a user-defined maximum diameter, resolve intersections, handle incompatible patch orientations and produce a feature-sensitive, manifold output that stays within a prescribed error-tolerance to the input model.
In recent years the visualization and processing of structural magnetic resonance imaging data sets of human organs like the heart has become an important tool for anatomists and scientists alike. Extracting the interfaces between different tissue types of such datasets is not only important for indirect volume visualization but in particular is an integral part of many downstream applications, like, e.g., segmentation or tracing of anatomical structures by active contour models. Typically these interfaces are represented as triangle meshes that have to satisfy certain quality criteria:

1. Each triangle mesh should be a 2-manifold with boundary. The boundaries of the triangle meshes should consistently fit together, i.e. no gaps, T-junctions or other artifacts should occur.

2. The triangles should be well-shaped in order to facilitate robust numerical evaluation.

3. The triangle meshes should reflect user-specified a-priori knowledge about the anatomical structure.

In this project we develop algorithms to automatically construct such a set of interfaces from a multi-valued volume dataset. While each single interface is generated independently, two or more interfaces may join consistently along their common boundaries. In contrast to previous work, our algorithm classifies and removes the topological ambiguities from the volume before extracting the interfaces. This not only allows for a simple and stable extraction algorithm, but also makes it possible to include user constraints.
In recent years, significant progress has been made in establishing triangle meshes as a representation for advanced geometric modeling, where one of the most complex and challenging operations is interactive shape deformation. High quality surface-based approaches deform a surface $S$ to $S'$ using a smooth displacement function $d : S \rightarrow \mathbb{R}^3$, which is derived from a constrained energy minimization on the surface $S$. As a consequence, these techniques are highly flexible and powerful, but at the same time require a certain minimum tessellation quality in order to guarantee sufficient numerical robustness.

In contrast to this, space deformation approaches implicitly deform objects by warping their whole embedding 3-space. The corresponding displacement field $d : \mathbb{R}^3 \rightarrow \mathbb{R}^3$ does not depend on the underlying surface representation and hence is affected neither by its complexity nor by its quality aspects. Analogously to surface-based methods, high quality space deformations can be derived from a variational minimization, although at a higher computational cost.

We developed all required technical ingredients to use triharmonic radial basis functions for real-time freeform shape editing, which improves the performance compared to existing techniques by up to three orders of magnitude. An incremental least-squares method enables us to approximately solve the involved linear systems in a robust and efficient manner and by precomputing a special set of deformation basis functions we are able to significantly reduce the per-frame costs. Moreover, evaluating these linear basis functions on the GPU finally allows us to deform highly complex polygon meshes at a rate of 60M triangles per second.
Iterative Multi-View Plane Fitting
Martin Habbecke, Leif Kobbelt

With the increasing performance of computer graphics applications, like interactive visualization and simulation, the need to automatically generate 3D models of real objects has become more and more urgent. Due to the availability of digital imaging equipment in every price range, the 3D reconstruction from images has received particular attention in recent years.

Many existing techniques are based on the reconstruction of 3D points or depth values by detecting features and comparing single image pixels or small image areas. Due to the inevitable noise in digital images, imperfect calibration and overly simplified illumination models, this is an error-prone procedure often leading to reconstructions of low accuracy. To overcome these difficulties, we developed an alternative method which reconstructs planar regions in object space from calibrated 2D images. While preserving a minimal parametrization of planes in space with only three degrees of freedom, our method is not restricted to the comparison of a few pixel values, but rather integrates over large areas in an arbitrary number of input images. The increased amount of redundant information results in improved stability of the reconstruction with respect to image noise and camera calibration errors. In addition, planes have the advantage of being more powerful than points and lines in terms of surface approximation and are thus the primitive of choice in recent geometry representations.

One of five input images with manually specified 2D polygons (left). Reconstructed planes (center left), reconstructed planes together with proxy geometry (center right) and proxy geometry alone for reference (right).
Robust 3D Reconstruction from Calibrated Images using Planar Primitives

Martin Habbecke, Leif Kobbelt

Based on our multi-view plane fitting algorithm, we developed a novel technique for the 3D reconstruction of real-world objects from calibrated images. The algorithm approximates an object or a whole scene by a set of planar discs. Starting from a single disc, we run a region-growing strategy on the unknown 3D surface until all visible parts of the scene are covered. We choose discs because of their rotational invariance: their 3D orientation can uniquely be defined by a normal vector. Furthermore, discs have the advantage that they do not need the enforcement of strict neighborhood constraints. Similar to splat-based object representations, loose neighborhood relations are sufficient to perform all required surface operations. A simple relaxation scheme based on particle repulsion yields a highly uniform distribution of the discs on the 3D surface.

A common problem of image-based reconstruction methods is the visibility determination. Because the scene’s geometry is unknown, it is difficult to determine in which images a certain disc is visible. We solve this problem with an effective image selection mechanism that, for each disc, finds a set of images with the highest likelihood of “seeing” the disc. Since our algorithm reconstructs a dense set of position and normal samples on the scene’s surface, its results are perfectly suited for standard algorithms that generate closed manifold meshes from this type of input.

First and last image of the input sequence that consists of 76 images in total (left). Dense rendering of reconstructed discs (center) and rendering of a closed manifold mesh generated from the point and normal information of the discs.
The faithful reconstruction of three dimensional real world objects remains a great challenge in computer graphics and computer vision. Although established technologies such as laser scanning are able to produce high quality 3D reconstructions, they still lack flexibility with respect to material and lighting conditions and are relatively expensive. Hence the idea of reconstructing 3D objects from photos or video is not only of scientific importance but would also be an economically relevant alternative to specialized 3D scanning devices.

A particularly promising direction is image-based reconstruction of 3D objects using volumetric approaches. One of the central question for these methods is whether the object surface passes through a specific region in space or not, based on the so called photo-consistency. In this project we develop a new, illumination invariant photo-consistency measure for high quality, volumetric 3D reconstruction from calibrated images. In contrast to current standard methods such as normalized cross-correlation it supports unconstrained camera setups and non-planar surface approximations. Our measure can be embedded into a highly efficient, completely GPU hardware accelerated volumetric reconstruction pipeline by exploiting the programmability of current graphics processors. This allows us to generate high quality 3D reconstructions with computation times of only a few seconds to minutes, even for large numbers of cameras and high volumetric resolutions.

The above images show a reconstruction of the Bahkauv-statue in the city of Aachen from a set of only 27 photos using our volumetric reconstruction technique.
The digitization of 3D human motion data plays a central role in a variety of applications, such as immersive interfaces for virtual environments, motion analysis in medical contexts, or character animation in movies or games. The process of capturing and processing motion data is a computationally complex task which usually requires a significant amount of manual pre- and post-processing even for established techniques such as optical motion capture systems. This necessity for expert knowledge makes current motion capturing techniques too inflexible in many potential application scenarios.

In this project we develop techniques to support the use of motion capture as a general, flexible input device without the above mentioned restrictions. We implement a self-calibrating framework for optical motion capture, enabling the reconstruction and tracking of arbitrary articulated objects in real-time. Our method automatically estimates relevant model parameters on-the-fly without any information on the initial tracking setup or the distribution of optical markers, and computes the geometry and topology of multiple tracked skeletons. Furthermore we provide algorithms to normalize the recorded motion data yielding a common and intuitive data basis across different recording sessions. A final parameterization step based on automatically extracted main movement axes is used to generate a compact motion description, which allows for flexible modification and retargeting of the motion to, e.g., 3D avatars in VR applications.

These images show different phases of our algorithm. From the recorded motion of a subject equipped with cliques of optical markers (left image) our method computes a normalized skeleton structure (middle image) which can be used for animating arbitrary 3D models (right image).
Because of their conceptual simplicity and superior flexibility, point-sampled surfaces have evolved into a valuable alternative to surface representations based on polygonal meshes. The current state-of-the-art for representing and rendering point-based models is the use of elliptical surface splats, which allow for anisotropic surface approximation, combined with sophisticated EWA filtering. These methods allow for high-quality anti-aliased rendering, but cause a significant computational overhead. Since standard graphics hardware is specialized to polygonal geometry representations, high-quality point-based rendering either has to fall back to less efficient software implementations, or has to find an acceptable trade-off between rendering quality and rendering performance.

In this project we present a new approach to exploit the capabilities of today’s GPUs for hardware-accelerated surface splatting. Our approach achieves a quality comparable to the original EWA splatting at a rate of more than 20M elliptical splats per second. In contrast to previous GPU renderers, our method provides per-pixel Phong shading even for dynamically changing geometries and high-quality anti-aliasing by employing a screen-space pre-filter in addition to the object-space reconstruction filter. The use of deferred shading techniques effectively avoids unnecessary shader computations and additionally provides a clear separation between the rasterization and the shading of elliptical splats, which considerably simplifies the development of custom shaders.

The images above show a Phong-shaded octopus model and NPR-shaded renderings of the dinosaur model, the Igea artifact, and the Lucy statue.
Interactive mesh editing has become an essential component of most modern CAD systems because the conceptual simplicity and algorithmic efficiency of processing triangle meshes established their effective application in various geometry processing areas, ranging from early product development phases, such as rapid prototyping, to character animation and rendering in movies and 3D games.

Among the variety of existing shape deformation approaches, multiresolution modeling appears to be one of the most powerful paradigms: Decomposing the geometry into a low frequency base surface and high frequency detail coefficients allows for global deformations with natural fine-scale detail preservation. This enables editing of a fully detailed mesh by manipulating the coarse scale control handles available on the base surface.

Especially in the context of engineering applications, meshes have to represent sufficiently accurate approximations of the true surface. As a consequence, models often consisting of millions of triangles have to be processed. To improve the performance of such modeling frameworks, we developed a new technique for multiresolution editing of meshes which allows for outsourcing as much as possible of the deformation’s computation to the high-performance graphics processor unit (GPU) of the PC. By exploiting the specialized, highly parallel design of the GPU, our algorithm accelerates more than five times the multiresolution modeling of meshes in comparison to an optimized CPU implementation. Moreover, since the GPU performance grows at a much faster rate than the performance of the CPU, the benefit from our technique will even increase in the future.

A car model (left) is represented as normal displacement with respect to a smooth Catmull-Clark surface (middle). Manipulating the vertices of its control mesh, a large scale deformation is performed on the mesh (right). Our algorithm allows such global deformations to be performed in real-time on the GPU. In comparison, computing the same deformation on the CPU is five times slower, which does not allow for real-time feedback during editing.
A Robust Two-Step Procedure for Quad-Dominant Remeshing

Martin Marinov, Leif Kobbelt

Remeshing algorithms are considered a fundamental component of the contemporary geometry processing pipeline. Traditionally, the focus of their development was mostly the quality of the mesh elements, i.e., shape and regularity. Indeed, various CAD and CAE applications would perform poorly, or even crash, if a bad mesh was fed to them as input. Hence, improving solely the performance with respect to this local quality criterion was the predominant goal several years ago. To satisfy the requirements, compromises were made both with regards to the complexity of the output, i.e., dense remeshes were needed to provide enough degrees of freedom for the optimization, as well as with the alignment of the mesh faces to the structure of the input model.

Recently, the focus of the research in this area has shifted to a more challenging problem setting: Is it possible to remesh the input surface producing sufficiently regular faces, and at the same time, preserve its structural characteristics? A crucial factor for this change was the observation that such properties can significantly reduce the production time and expense in several CAD domains, e.g., rapid prototyping, reverse engineering and conceptual design. Therefore, we developed a novel remeshing algorithm which separates the local regularity optimization from the global alignment requirements by splitting the process into two steps: In the first step we segment the input mesh into a set of structure-preserving regions. In the second step we generate a quad-dominant mesh inside a 2D parameter domain for every region. These meshes conform to a set of automatically defined constraints (vertices & edges) at the boundaries of the regions, which enables their seamless composition on the input 3D surface.

Left: The input CAD mesh exhibits high irregularity and significant amount of noise. Middle left: The segmentation of the mesh highlights the important structural features of the model. Middle right: A set of smooth curves, connecting constrained samples at the region boundaries, is selected to form an as regular as possible quad-dominant mesh in the parameter domain of every region. Right: The quad-dominant meshes are composed together to form the final output mesh.
Fast Fragment-Based Image Completion  
Darko Pavic, Leif Kobbelt

If the processing of digital images is supposed to go beyond mere filtering, one of the most basic operations is to add or remove objects from a given image. While adding an object to the foreground of an image is comparably easy (if we ignore relighting issues), removing an object is usually quite difficult because the now-visible background has to be reconstructed properly in order to hide the modification to the viewer.

Besides image completion approaches that are based on filtering or texture-synthesis, the fragment-based approaches have been shown to lead to the most convincing results. In these approaches the image regions, where foreground objects have been removed, are filled by iteratively copying small patches (source fragments) of the input image to the boundary of the unknown region (target fragment) until they completely cover the unknown region.

Although existing fragment-based image completion techniques lead to acceptable completion results in most cases, one has to deal with rather high computation times of several minutes to hours. This makes such techniques impractical as an interactive tool. We have developed a new approach for computing fragment-based image completion which reduces the computation time to a few seconds and hence enables its integration into an interactive inpainting tool. Exploiting Fourier techniques accelerates the query process by one to two orders of magnitude compared to previous solutions.
Geometry processing plays a very important role in computer graphics. As a generic term it includes mathematical methods and algorithms for the generation, optimization, modification, storage and production of geometric 3D models. A well-known example of such an application is Computer Numerically Controlled (abbr. CNC) milling. The standard processing pipeline for manufacturing physical objects consists of first creating a digital 3D model of the target object by using some CAD software. The next step is the generation of toolpaths which are then finally used for CNC milling.

CNC mills are classified according to the number of free axes they possess. Usually, in the three-axis CNC milling, material is removed slice-by-slice. In each slice we have to move the milling tool across the whole outer part of the slug. Different strategies are applied and each of them has its advantages and drawbacks regarding the stress of the milling machine. The most promising strategies are contour based, i.e. for each 2D contour, which describes the 3D model in a slice, offset curves are computed and interconnected. Classical approaches for computing offset curves have numerical problems, e.g. when the offset becomes greater than the distance to the contour’s medial axis, leading to a number of special cases we have to consider.

We follow an alternative approach which exploits the GPU computing power. For a given contour an unsigned distance field is computed. From such a distance field the offset curves can be extracted robustly as iso-contours. The main advantage of using the GPU in this case is its capability of parallel processing. Additionally we avoid handling of any kind of special cases.
Global Illumination describes how light propagates through a scene. To synthesize an image that looks like a photo, we have to simulate all kinds of global illumination effects such as shadows, reflections, and caustics. For example, in the real world, shadows are never pitch black, but they receive some indirect lighting. Objects made of glass can transmit and refract light, which gives rise to effects like distortions and caustics. Objects made of metal can act as mirrors and also produce different visual effects. The phenomenon of global light transport is very complex and can be described by the general Rendering Equation. This integral equation is very hard to solve exactly and our goal is to find efficient and good algorithms to approximate its solution. To analyse and synthesise the lighting of a scene is of importance not only for engineering, designing and architectural purposes (a), (b), but Global Illumination is also used in movies, advertisement, video games, art and many other areas. In fact every computer generated photorealistic picture uses Global Illumination in some way.

In order to evaluate our algorithms we want to be able to take a photo (c) and generate an image that is as similar as possible (d) to the original. To do this efficiently we develop new algorithms and data structures that model all the complex visual phenomena that are possible.

Also the inverse problem statement of deriving the lighting from a photo is of importance, too. This is called Inverse Global Illumination and allows to show existing images under new and different lighting conditions. In this area there are also many open questions and our goal is to find new solutions.

And finally doing all this in real time, that is in an interactive program, is the most difficult problem but at the same time the most wanted application at Global Illumination. There are already some aspects solved, for example by using precomputed radiance transfer, but still scenes with dynamically moving objects cannot be displayed correctly in real time. Up to now only rough approximations could be made.
In wireless network planning, much effort is spent on the improvement of the network and transport layer – especially for Mobile Ad Hoc Networks. Although in principle real-world measurements are necessary for this, their setup is often too complex and costly. Hence good and reliable simulation tools are needed. Also for placement of transmitters in cities, simulations can help to locate the spots of highest availability.

In this work we have developed a new physical layer simulation algorithm based on the extension and adaptation of recent techniques for global illumination simulation. By combining and improving these highly efficient algorithms from the field of Computer Graphics, it is possible to build a fast and flexible utility to be used for wireless network simulation. Instead of the wave nature of EM radiation we rather use the particle nature of waves to compute a discrete sampling of the volumetric electromagnetic field by tracing stochastically generated photon paths through the scene. This so called Photon Path Map is then used to estimate the field density at any point in space. One has to take several physical effects into account when dealing with electromagnetic radiation, such as absorption, transmission, refraction and diffraction of the rays. This can all be modeled by the ray-path model we chose for our approach. The algorithm can be applied to three dimensional indoor (e) as well as outdoor (f) scenarios without any changes and it scales logarithmically with the growing complexity of the underlying scene geometry. The pictures show the resulting volume images produced by our algorithm. These images can be used to visually inspect the wave propagation or they can be used as an input to a network simulator. The more exact the physical model used by the network simulator, the better are higher level simulations. So our algorithm helps to gain a better insight not only on the physical level, but also on the level of routing or transport protocols.
Point-based graphics receives more attention in recent years and much work has been dedicated to the efficient acquisition, modeling, processing and rendering of point-sampled 3D models. In order to visually fill the gap between point samples, point-based models are usually generalized to splat representations that sample and approximate the original surface geometry. The resulting surface splatting techniques enable high quality and efficient rendering algorithms for dense point-sampled datasets.

However, with increasing model complexity, the need for multiresolution point/splat models becomes evident. For triangle meshes, progressive or continuous level of detail hierarchies have proven to be very effective when it comes to (locally) adapt the resolution level of the 3D model to the application-dependent quality requirements. In this project we transfer this concept to splat-based geometry representations to produce progressive splat models (see below figure of the Charlemagne model with increasing level of details from left to right).

Our progressive splat decimation procedure uses the standard greedy approach but unlike previous work, it uses the full splat geometry in the decimation criteria and error estimates, not just the splat centers. With two improved error metrics, this new greedy framework offers better approximation quality than other progressive splat decimators. It comes even close to the recently proposed globally optimized single-resolution sub-sampling techniques while being faster by a factor of 3. Moreover, we have conducted thorough comparisons and analysis of diverse typical splat decimators currently available, such that we can derive a practical guide to choose the optimal splat decimation strategy for a specific quality-time tradeoff.
Allowing for copyright protection and ownership assertion, digital watermarking techniques, which have been successfully applied for classical media types like audio, images and videos, have recently been adapted to the newly emerged multimedia data type of 3D geometry models. In particular, the widely used spread-spectrum methods can be generalized to 3D datasets by transforming the original model to the frequency domain and perturbing the coefficients corresponding to the most dominant basis functions. Previous approaches employing this kind of spectral watermarking are mainly based on multiresolution mesh analysis, wavelet domain transformation or spectral mesh analysis. Though they already exhibit good resistance to many types of real-world attacks, they are often far too slow to cope with very large meshes due to their complicated numerical computations.

In this project, we have developed a novel imperceptible spectral watermarking scheme to support ownership claims on triangle meshes of given 3D shapes (cf. right figure, where the Iphigenie model (left) is watermarked with a 24 bits signature (middle) and the right image shows their differences). To span the spectral domain for watermarking, we use a new set of orthogonal basis functions derived from radial basis functions (RBFs), which lead to optimal concentration of the shape information to just a few (low-frequency) modes. Our watermarking scheme exhibits almost the same watermarking quality and robustness against various real world attacks as other related spectral approaches. On the other side, by utilizing a fast basis function orthogonalization algorithm, our watermarking scheme runs much faster by two orders of magnitude, and hence can process and watermark very large models more efficiently.
Other Activities

Committees and Organization:

- Member of the internat. Program Committee of the SIGGRAPH conference 2005, Los Angeles, CA, USA
- Member of the internat. Program- and Organization Committee of the 9th SIAM conference on Geometric Design and Computing 2005, Phoenix, AZ, USA (also: co-organizer of two mini-symposia)
- Member of the internat. Program Committee of the Pacific Graphics Conference 2005, Macao, China
- Program Chair of the internat. Program Committee of the Solid and Physical Modeling Conference 2005, Boston, USA
- Member of the Organization Committee of the European Mathematical Society Summer School on Subdivision Schemes in Geometric Modeling (sponsored by the EU), Pontignano, Italy, June 2005
- Member of the internat. Program Committee of the Interactive 3D Graphics and Games Conference 2005, Washington D.C., USA
- Editor for a Special Issue on Geometry Processing of the CAGD Journal
- Member of the internat. Program Committee of the Shape Modeling International Conference 2005, Boston, USA
- Co-Chair of the Program and Organization Committee, GI-Workshop on Virtual and Augmented Reality 2005, Aachen, Germany
- Member of the internat. Program Committee of the Computer Graphics International Conference 2005, Stony Brook, NY, USA
- Member of the internat. Program Committee of the Symposium on Geometry Processing 2005, Vienna, Austria
- Member of the internat. Program Committee of the 13-th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision, WSCG 2005, Pilzn, Czech Republic
- Member of the internat. Program Committee, Conference on Vision, Modeling and Visualization, VMV 2005, Erlangen, 2005
- Member of the internat. Program Committee of the Symposium on Point-Based Graphics 2005, Stony Brook, NY, USA
- Member of the internat. Program Committee of the 9th International Conference on Computer-Aided Design and Computer Graphics, CAD/CG 2005, Hong Kong, China
- Co-Organizer, Symposium “Graphische Datenverarbeitung” at the GI-Jahrestagung 2005, Bonn
- Co-Editor of the Special Issue on the Symposium on Solid and Physical Modeling 2005 of the Journal of Computational Geometry
- Co-Editor of the Special Issue on the Symposium on Solid and Physical Modeling 2005 of the Computer Aided Design Journal
• Co-Editor of the Special Issue on the Symposium on Solid and Physical Modeling 2005 of the Journal of Graphics Models

Offices:

• Organizational Member of the Eurographics Association
• Chair of the Computer Science Department
• Head of the Bachelor/Master Commission
• Head of the Examination Commission
• Speaker of the GI section “Geometry Processing”
• Scientific Advisor, German-Israeli Foundation for Scientific Research and Development
• Member of the scientific board, Virtual-Reality Center Aachen (VRCA)
• Member of the regional industry club REGINA e.V.
• Director of the Steinbeis Transfer Center “Geometry Processing”
• Reviewer:
  – DFG
  – Humboldt-Stiftung
  – German-Israelian Foundation
  – Studienstiftung des Deutschen Volkes
  – Deutscher akademischer Austauschdienst
  – Norwegian Research Council
  – Various tenure procedures
• Stephan Bischoff: Student Advisor, main study period computer science

Talks and Publications

Invited talks

Leif Kobbelt: Efficient Linear System Solvers for Mesh Processing, 11-th IMA Conference on the Mathematics of Surfaces, Loughborough, UK

Leif Kobbelt: Recovering Global Features on Meshes, Minisymposium on Feature Sensitive Mesh Processing, SIAM Conference on Geometric Design and Computing, Phoenix, USA, November 2005

Leif Kobbelt: Structure Recovery for Geometric Models, Hong Kong University, October 2005

Leif Kobbelt: Geometry Processing at the RWTH Aachen, PhilipResearch Labs, Hamburg, April 2005

Leif Kobbelt: Interactive High-Quality Shape Modeling, Oberwolfach Seminar on Analytical and Numerical Methods in Image and Surface Processing, February 2005

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Conference presentations

Stephan Bischoff: Structure Preserving CAD Model Repair, Eurographics, Dublin, Ireland, August/September 2005

Stephan Bischoff: Active Curves and Surfaces with Topology Control, SIAM Conference on Geometric Design and Computing, Phoenix, USA, October/November 2005

Stephan Bischoff: CAD Model Repair, Workshop on Industry Challenges in Geometric Modeling and CAD, Darmstadt, Deutschland, März 2005

Mario Botsch: High quality surface splatting on today’s GPUs, Symposium on Point-Based Graphics 2005, Stony Brook, NY

Mario Botsch: Progressive Splatting, Symposium on Point-Based Graphics 2005, Stony Brook, NY

Mario Botsch: Real-time shape editing using radial basis functions, Eurographics 2005, Dublin, Ireland

Alexander Hornung: Self-Calibrating Optical Motion Tracking for Articulated Bodies, IEEE VR 2005, Bonn, Germany, March 2005

Martin Marinov: Automatic Generation of Structure preserving Multiresolution Models, Eurographics, Dublin, Ireland, August/September 2005

Sandip Sar-Dessai: Automatic Data Normalization and Parameterization for Optical Motion Tracking, 2ter Workshop “Virtuelle und Erweiterte Realität” der GI-Fachgruppe VR/AR, Aachen, Germany, September 2005


Jianhua Wu: Efficient Spectral Watermarking of Large Meshes with Orthogonal Basis Functions, Pacific Graphics 2005, Macau, China, October, 2005

Publications

A. Hornung, S. Sar-Dessai, L. Kobbelt: Self-Calibrating Optical Motion Tracking for Articulated Bodies, IEEE Virtual Reality Conference VR, 75-82, 2005

L. Kobbelt, V. Shapiro, eds: Symposium on Solid and Physical Modeling, ACM SPM 2005 Proceedings, Boston

L. Kobbelt, ed.: Special Issue on Geometry Processing, Computer Aided Geometric Design, Elsevier


J. Wu, L. Kobbelt: *Efficient Spectral Watermarking of Large Meshes with Orthogonal Basis Functions*, The Visual Computer, Pacific Graphics 05 special issue, Vol. 21(8-10), 848-857


S. Sar-Dessai, A. Hornung, L. Kobbelt: *Automatic Data Normalization and Parameterization for Optical Motion Tracking*, Workshop “Virtuelle und Erweiterte Realität” der GI-Fachgruppe VR/AR, Shaker Verlag, Best Paper Award


L. De Floriani, L. Kobbelt, E. Puppo: *A Survey on Data Structures for Level-Of-Detail Models*, Advances in Multiresolution for Geometric Modeling, N.A. Dodgson, M.S. Floater and M.A. Sabin (eds.), Springer Verlag

L. Barthe, C. Gerot, M.A. Sabin, L. Kobbelt: *Simple computation of the eigencomponents of a subdivision matrix in the Fourier domain*, Advances in Multiresolution for Geometric Modeling, N.A. Dodgson, M.S. Floater and M.A. Sabin (ed.), Springer-Verlag

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Data Management and Exploration

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  Dipl.-Inform. Achim Schlosser (April - June)
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  Dipl.-Inform. Nicole Schneider (until March)

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Overview

Research at Computer Science 9 focuses on the aspects of data management and data exploration. In our modern world, more and more digital information is stored and processed. Telecommunication data, medical diagnostic data, environmental data, gene pools, structures of proteins and digital multimedia data are only a few of many examples for large databases storing complex objects. Concerning the aspect of data management, we investigate the problem of storing large sets of complex objects in a way that the data can be searched and retrieved very efficiently. Our research in this direction focuses on Relational Indexing where built-in index structures of Relational Database Management Systems are exploited for efficient and robust data management.

A central question our research group is interested in is how to find and extract the hidden knowledge from large databases. At this point we encounter the problem of Data Mining or Knowledge Discovery in Databases. To establish content based retrieval and similarity search, appropriate data structures are needed to represent the complex objects. Depending on the chosen data model it is possible to develop effective data management techniques while simultaneously achieving interactive response times for queries.

In addition to completely automatic methods, it is necessary to support data mining by interactive techniques. Interactive data mining methods help to improve the results by using visual representations and by taking relevance feedback into account in order to include the cognitive abilities of human experts.

The activities on the field of scientific research have been reinforced in 2005 yielding a new German Research Foundation (DFG) project on fast Earth Mover’s Distance (EMD) searches and various new diploma theses concerning relational indexing, multimedia retrieval and clustering. Projects and cooperative work with industrial partners including CIM, Daimler Chrysler, ExaConsult, Gevas, Inform, IBM, Oracle were also started and deepened. Several projects were addressed in collaboration with scientific institutes such as the Section of Engineering Hydrology, the Department of Medical Informatics, the Institute for Biomedical Engineering -Cell Biology- and the Virtual Reality Center Aachen (VRCA) at the RWTH Aachen.

Besides that, the chair further extended the offered lecture courses concerning the topics Data Mining Algorithms, Models for Data Exploration and Index Structures for Databases. In our seminars offered last year we especially focused on complex objects in databases, a field appealing to many industries, and on other current hot topics of Data Management and Data Mining. The related lab course on data structures offered an opportunity to interested students to implement some indexing structures and algorithms and to gain experience in handling various data mining tools and database systems.
Research Projects

Data Exploration

Similarity search in database systems is becoming an increasingly important task in modern application domains such as multimedia, molecular biology, medical imaging, computer-aided engineering and many others. The major reasons to research efficient algorithms for knowledge discovery in large databases are the huge amount of data and the need to turn such massive data into useful information and knowledge. Especially for CAD (Computer-Aided Design), suitable similarity models and a clear representation of the results can help to reduce the cost of developing and producing new parts by maximizing the reuse of existing parts and thus increasing productivity of manufacturers and subcontractors e.g. in the hard-fought automobile and plane market.

The goal of data exploration is to develop and study algorithms for similarity search in modern databases. Often the complexity of traditional algorithms to analyze the similarity between objects is too high to apply them to huge amounts of objects. To obtain acceptable response times for similarity queries many different techniques must be combined. For example, multi-dimensional indexing structures like R-trees or X-trees are very useful for the retrieval of the required information.

Efficient techniques for similarity search are the basics for many algorithms in the field of Data Mining. Classification and clustering, for instance, are two tasks out of the wide range for various data mining problems. Developing new algorithms for these purposes is especially necessary to meet the different requirements of the respective applications. Marketing, electronic commerce, fraud detection, astronomy, biomolecular and other multimedia data to name only a few of many applications which need special data exploration algorithms.

One application investigated by our team is the prediction of flight delays. Extensive flight data is recorded by flight information systems at all major airports. Using such databases, we aim at providing estimations for future flight delays which are essential in refining robust scheduling methods for airport resources and ground staff. Many attributes may be considered for the prediction of flight delays which leads to the problem of classifying high-dimensional data. When considering high dimensional data classification accuracy may drop below acceptable levels because of noisy or locally irrelevant attributes. To detect locally meaningful patterns, we built a novel framework combining classification with subspace clustering. Subspace clustering has proved to work well in high-dimensional and noisy domains, yet does not utilize class labels and thus does not provide appropriate groupings. We overcome this difficulty by incorporating class information into subspace search. A subspace classifier is developed which is validated on both synthetic and real datasets in thorough experiments.
Geometry-based Similarity Search

In many applications the original representation of objects cannot be used to find similarities or to discover hidden information. Therefore complex objects have to be transformed into a suitable representation. A very successful approach is to map the objects into high-dimensional feature spaces. An example is the shape histogram technique applied to a 3D molecule representation as displayed in figure 16. Additionally, approximation techniques may be used to reduce the dimensionality.

Figure 16: Computation of a 3D shape histogram for a molecule as an example of high dimensional feature extraction

The suitability of object representations highly depends on the individual applications and algorithms. Furthermore, similarity often has quite subjective characteristics, so similarity models have to be adaptable to application specific requirements and individual user preferences. Examples include pixel-based shape similarity model as well as 2D and 3D shape histograms, applied to biomolecular and image databases or the above mentioned CAD data collections.

Index Support for CFD Data Post-Processing

High performance computing clusters similar to the one installed at the RWTH Center for Computing and Communication are utilized to execute complex simulations (e.g. from the field of computational fluid dynamics, CFD) delivering enormous amounts of data, often covering the range of many gigabytes of hard disc space. In order to produce significant visualizations and meaningful results, a post-processing step is inevitable to extract the desired knowledge from the raw data and to transform this information to the required format required by the visualization engines of the virtual reality environment. This post-processing is mainly done by standard PC hardware due to their low cost. Current methods require the raw data to be held in main memory completely, thus limiting the size of the raw data and therefore restricting the level of detail of the simulation depending on the size of available main memory.
To break this restriction, we develop out-of-core techniques to enable efficient access to the data which is held on secondary storage. Research on these techniques include customizing and streamlining existing geometric index structures as well as developing new methods to store and access the data in real-time virtual reality environments. These index structures enable a variety of access and query methods, e.g. view-dependent isosurface or cutplane extraction (cf. figure 17). This allows for the use of a very high level of detail of the simulation combined with real time user interaction in virtual reality environments, e.g. the CAVE or HoloBench installed at the VRCA (Virtual Reality Center Aachen). 

![Figure 17: Isosurface extraction (left) and cutplane extraction (right)](image)

Fast Nearest Neighbor Search

Utilizing spatial index structures on secondary memory for nearest neighbor search in high-dimensional data spaces has been the subject of much research. With the potential to host larger indexes in main memory, applications demanding a high query throughput stand to benefit from index structures tailored for that environment. “Index once, query at very high frequency” scenarios on semi-static data require particularly fast responses while allowing for more extensive precalculations. One such precalculation consists of indexing the solution space for nearest neighbor queries as used by the approximate Voronoi cell-based method. We research methods to overcome the difficulties faced (support of dimensionality reduction, indexability) for normalized data and aim at significantly improving response times through limiting the dimensionality of both the data and the Voronoi cell approximations. The latter allows for fast Nearest Neighbor retrieval without any further loss of accuracy. Our prototype system shows speedup factors of up to five compared to other indexing structures for real world data sets.
Figure 18: A Voronoi diagram for 6 points in the plane, a tight and a non-tight cuboid-shaped approximation of the Voronoi cell for point \( p \)

**Fast EMD Search**

In virtually any scientific or commercial application such as medical and biological imaging or music archives users deal with tremendous quantities of images, videos or audio files stored in large multimedia databases. For content-based data mining and retrieval purposes suitable similarity models are crucial. The Earth Mover’s Distance (EMD) was introduced in Computer Vision to better approach human perceptual similarities. Its computation, however, is too complex for usage in interactive multimedia database scenarios. In order to enable efficient query processing in large databases, we propose an index-supported multistep algorithm. We therefore develop new lower bounding approximation techniques for the Earth Mover’s Distance which satisfy high quality criteria including completeness (no false drops), index-suitability and fast computation. We demonstrate the efficiency of our approach in extensive experiments on large image databases.

Figure 19: Multistep filter concept with low-dimensional index on high efficiency filter, followed by high selectivity filter; thus avoiding most expensive EMD computations
Data Management: Complex Objects in Relational Databases

There is a growing demand for database applications to handle complex objects including time spans for the validity of stored facts, tolerance ranges for imprecisely measured values in scientific databases, or approximate values in local caches of distributed databases. Furthermore, many topics of data mining have to solve the problem of querying high dimensional data or of effectively executing range queries. In order to obtain industrial strength, query processing has to be integrated into existing robust database systems.

Figure 20: Query using a relational interval tree

Intervals represent a fundamental data type for temporal, scientific, and spatial databases where time stamps and point data are extended to time spans and range data, respectively. For database applications on large amounts of data, not only intersection queries have to be processed efficiently but also general interval relationships including before, meets, overlaps, starts, finishes, contains, equals, during, startedBy, finishedBy, overlappedBy, metBy and after. Our new algorithms use the Relational Interval Tree, a purely SQL-based and object-relationally wrapped index structure for managing interval data. This technique therefore preserves the industrial strength of the underlying RDBMS including stability, transactions, and performance. The efficiency of our approach has been demonstrated by experimental evaluations on large sets of generated as well as real-life data. In order to support broader ranges of data with our approach, we will extend our algorithms to support intervals with floating-point valued endpoints. Furthermore, we plan to adopt the newly developed methods to similarity search as well as to various application domains.

The increasing use of temporal and spatial data in present-day relational systems necessitates an efficient support of joins on interval-valued attributes. Standard join algorithms do not support those data types adequately, whereas special approaches for interval joins usually require an augmentation of the internal access methods which is not supported by existing relational systems. To overcome these problems we introduced new join algorithms for interval data.
Based on the Relational Interval Tree, these algorithms can easily be implemented on top of any relational database system while providing excellent performance on joining intervals. As experimental results on an Oracle9i server have shown, the new techniques outperform existing relational methods for joining intervals significantly. Furthermore, we enhanced our algorithms to support additional selection predicates on scalar and temporal attributes as well as additional join predicates on scalar attributes. We also investigated the applicability of our join algorithms to scenarios where one of the joining relations is provided by a stream.

In order to integrate the RI-tree in present-day object-relational database systems, we use their extensible indexing frameworks that enable developers to extend the set of built-in index structures by custom access methods. Although these frameworks permit a seam-less integration of user-defined indexing techniques into query processing they do not facilitate the actual implementation of the access method itself. In order to leverage the applicability of indexing frameworks, relational access methods such as the Relational Interval Tree (RI-tree), an efficient index structure to process interval intersection queries, mainly rely on the functionality, robustness and performance of built-in indexes, thus simplifying the index implementation significantly. To investigate the behavior and performance of the recently released IBM DB2 indexing framework we use this interface to integrate the RI-tree into the DB2 server. The standard implementation of the RI-tree, however, does not fit to the narrow corset of the DB2 framework which is restricted to the use of a single index only. We therefore adapt the originally two-tree technique to the single index constraint. As experimental results with interval intersection queries show, the plugged-in access method delivers excellent performance compared to other techniques.
Other Activities

Courses

Lectures:

- Data Mining Algorithms (summer 05)
- Data Mining Algorithms B-IT Bonn (summer 05)
- Index Structures for Databases (winter 05/06)
- Models for Data Exploration (winter 04/05)
- Interdisciplinary team-taught lecture series for Medical Image Processing (with Priv.-Doz. Dr.rer.nat. Thomas Lehmann et al., winter 04/05 and winter 05/06)
- Interdisciplinary team-taught lecture series for Bionics (with Priv.-Doz. Dr.rer.nat. Harald Luksch et al., winter 04/05 and winter 05/06)
- Interdisciplinary team-taught lecture series for “Faszination Technik” (with Lehrerbildungszentrum Dr. Boelhauve, Meier et al., winter 05/06)
- Programming (winter 05/06, undergraduate service)

Seminars:

- Algorithms for Data Mining (winter 04/05)
- Algorithms for Data Mining B-IT IPEC (winter 05/06)
- Complex Objects in Databases (summer 05)
- Medical Image Processing (with Priv.-Doz. Dr.rer.nat. Thomas Lehmann et al., summer 05)
- Methods and Tools (winter 04/05 and winter 05/06, undergraduate)

Lab Courses:

- Data Structures (summer 05, undergraduate)
- Data Mining Algorithms (winter 04/05)
Reviewing

Membership in program committee:

- ACM International Conference on Knowledge Discovery and Data Mining (KDD 2005)
- ACM International Conference on Management of Data (SIGMOD-2006)
- IEEE International Conference on Data Engineering - Demo program (ICDE-DEMO-2005)
- IEEE International Conference on Data Engineering (ICDE-2006)
- International Conference on Very Large Data Bases (VLDB-2005)
- International Conference on Database Systems for Advanced Applications (DASFAA 2006)

Journals:

- The VLDB Journal The International Journal on Very Large Data Bases (VLDB J.)
- IEEE Transactions on Knowledge and Data Engineering (TKDE)
- Information Processing Letters (IPL)
- Information Visualization (IVS)

Diploma Theses

Finished diploma theses:

- Eric Camen: Concepts for Region-Based Similarity Search in Image Databases by Using the Earth Mover’s Distance
- Boris Glavic: Subspace Clustering for Sequences of Ordered Categorical Data
- Boris Kaiser: A Mapping and Validation Concept for Data Exchange in E-Business Applications
- Liviu Munteanu: Dimensionality Reduction for Accelerating EMD-based Image Retrieval in Large Databases
• Gunter Ohrner: Database-supported consistency checks for electronic communication systems Multimedia-Databases

• Achim Schlosser: Single index based interval management in relational databases

• Jochen Schlosser: Stream-Based Processing of Interval Joins

• Andrea Wenning: Approximation and Indexing of the Earth Movers Distance for Efficient Contentbased Search in

• Marc Wichterich: Approximation of Voronoi Cells for Nearest Neighbor Search

Diploma theses in progress:

• Christian Klaus: Indexunterstützung für das Postprocessing von CFD-Datensätzen (working title)

• Ansgar Prüne: Unterstützung der Bayes-Klassifikation durch hierarchische Indexstrukturen

• Petra Welter: Lokal selektive Klassifikation mit Subspace-Clustern

• Afzal Zubair: Retrieval of Spoken Documents Using Fuzzy Keyword Search in Syllable Transcript

Industrial and Academic Collaboration

• CIM-Aachen GmbH: Data Mining for databases in manufacturing.

• Daimler Chrysler AG: Database-supported consistency checks for electronic communication systems.

• IBM Germany: Single index based interval management in relational databases.

• GEVAS GmbH: Interval Management for Traffic Monitoring.

• ExaConsult: Data Mining Applications.

• INFORM GmbH: Data Mining concepts for the prediction of delays in flight traffic.

• Oracle Corp. USA: Relational Interval Tree.

• RWTH Faculty of Civil Engineering, Section of Engineering Hydrology (Prof. Dr. Nacken): Data Mining for decision support in hydrology

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• RWTH Faculty of Medicine, Department of Medical Informatics (PD Dr. Lehmann): Similarity Search in medical image databases

• RWTH Faculty of Medicine, Institute for Biomedical Engineering - Cell Biology (Prof. Dr. Zenke): Data Mining in Gene Expression Databases

• Virtual Reality Center Aachen (Dr. Gerndt): Index support for a graphics data server

• Working visit of Dr. Meyer-Baese, professor of electrical and computer engineering at the Florida A&M University - FSU College of Engineering

Publications


Assent I., Wenning A., Seidl T.: Approximation Techniques for Indexing the Earth Mover’s Distance in Multimedia Databases, Proc. IEEE 22nd Internat. Conf. on Data Engineering (ICDE 2006), Atlanta, GA, USA.


Enderle J., Schneider N., Seidl T.: Efficiently Processing Queries on Interval-and-Value Tuples in Relational Databases, Proc. 31st Internat. Conf. on Very Large Data Bases (VLDB 2005), Trondheim, Norway, 385-396.


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Overview

The group’s focus in research and teaching covers various topics in computer-supported learning, among them

- software engineering methods and tools for the analysis, specification, design and implementation of eLearning scenarios, components, contents, and systems,

- informative, individualized and semi-automatic feedback in eLearning systems,

- frameworks for the implementation of innovative instructional theories and development of sophisticated learning and authoring tools,

- didactics of computer science, and

- the role of IT and media competencies in teachers’ education.

Prof. Schroeder took a sabbatical leave during the summer term. Most of this time he spent at the Chair of Information Technology and Education of the ETH Zürich where his focus in research was on didactics in computer science. The results of this joint research on computer science teachers’ education will be integrated into the curriculum of RWTH teachers’ education. Specifically, two new seminars about instructional methods and their utilization in computer science lessons have been designed and successfully conducted in the following winter term.

Another research work focused on the informative, individualized and semi-automatic feedback in eLearning systems. This research will be the basis for the main project work of computer-supported learning group for the next years.

Furthermore, this year’s activities were dominated by the constitution and development of the Center for integrative eTeaching and eLearning concepts (CiL). CiL as the central eLearning competence center of RWTH Aachen university, develops supporting structures for a sustainable introduction of eLearning elements into the universities study programs. CiL designs the technological, instructional and administrative framework for blended learning at RWTH Aachen university. CiL’s main objectives are:

- development and maintenance of the central eLearning platform of RWTH Aachen university

- integration of university administrative software platform with the eLearning platform in order to implement seamless processes of study program administration with teaching and learning

- identification of blended learning scenarios and choice of adequate eLearning tools for their implementation
• development of a qualification programme for university teachers to integrate eLearning tools into the normal study offerings

• consulting and project support for eLearning projects

Prof. Schroeder also used his sabbatical leave to expand the teaching curriculum consisting of the lectures eLearning, Fachdidaktik 1 and Fachdidaktik 2 by a lecture on Web Engineering. Furthermore, the group offers a seminar for students of the “Lehrmatsstudiengang Informatik” every semester, and is establishing the eLearning Engineering Lab as a lab offered every semester too.

Tim Paehler concluded his dissertation “Design, Implementation and Application of a Reusable Component Framework for Interactive Mathematical eLearning Sites”, which he developed as part of the Mumie project (http://www.mumie.net/). His main contributions were designing for reuse of highly interactive and exploratory components for learning mathematical content. The framework allows for adaption without programming knowledge.
Research Projects

**eSWES (eLearning Systems for Water and Environmental Studies)**

*Ulrik Schroeder – with Heribert Nacken (RWTH Aachen university), Laura Farinetti (Politecnico di Torino), Kamal Ewida (Zagazig University)*

Egypt is facing many challenges due to its increasing population, limited water resources and serious environmental problems. Therefore, among the Egyptian universities, water and environmental studies are becoming a vital issue. The need for highly qualified graduates and improving the education methods in Egypt has forced the Egyptian ministry of higher education and universities to look for new educational solutions in these areas. The three year EU TEMPUS project has the intention to improve the teaching and learning processes by introducing eLearning at both the department of water & water structures and the department of environmental engineering, faculty of Engineering, Zagazig University (Egypt). The project will result in the first eLearning model to the whole Zagazig university to ensure its advanced position among Egyptian universities. The success of this model will encourage other departments to move towards eLearning to enhance the quality of education and in turn the qualification of graduates.

**BLEND-XL - Finding a Balance in Blended Learning with eXtra Large Student Groups**

*Ulrik Schroeder, Eva Giani – with partners from Delft University of Technology, University of Northumbria at Newcastle, University of Zilina, RWTH Aachen University, and Academy of Humanities and Economics in Lodz*

Teaching large groups of students is an increasingly common phenomenon in higher education, especially in the first year of study, when many students follow introductory courses or core modules. These courses are often taught in large groups in big lecture theatres, which is found de-motivating by both students and teachers because of the lack of communication. As a consequence, there is a higher attrition rate and a lower success rate on the exams than in small-scale education, especially in technical studies where a high dropout rate is common and is leading to a shortage of engineers at a European level.

This three year EU-project started in October 2005 and is coordinated by the Centre for Education and Technology of Delft University. The idea behind this project is that large-scale education can be made more motivating and more personal through the
effective use of ICT. This project focuses on the design of useful pedagogical models for learning situations in which face-to-face activities are mixed with online activities, often referred to as “blended learning”.

**Clever - Capture, Log, Edit, Visualize, Evaluate, and Replay**

*Interaction with programs in order to foster action-oriented learning*

*Ulrik Schroeder, Christian Spannagel*

The Clever application with the underlying Jacareto framework is a flexible tool for capturing user interaction on graphical user interfaces written in Java. In contrast to other capture&replay tools, Jacareto replays recorded interactions on new instances of the observed software itself. This form of replaying has many advantages. In this project the tool has been used for the implementation of various action-oriented learning scenarios, such as the cognitive apprenticeship model for programming classes.

**FiLM - Fachintegratives Lernen mit digitalen Medien**

*(Integrated Learning with digital media)*

*Ulrik Schroeder, Christian Spannagel - Graduiertenkolleg with Raimund Girwidz, Franz-Xaver Bogner, Joichim Engel, Herbert Löthe*

The project FiLM develops concepts and implementations for integrated cross-domain instructions in mathematics, natural & computer sciences. Natural phenomena and environmental processes, daily life, and technology are specified by domain-specific methods from biology, physics, mathematics and computer science. Therefore, a concrete example of each field is illustrated from diverse perspectives by means of new media and worked out by students in cross-domain projects. New information and communication technologies thus serve as facilitators for cross-domain learning based on new findings in learning psychology such as

- contextualization with links to practice and everyday life,
- concepts of processing depth,
- cognitive flexibility and variable accessibility of knowledge.
The purpose of this pilot project is to objectify some subjects beyond the boundaries of individual classes and to create transparency for teachers, pupils and their parents. Currently, the pilot project is implemented at the Inda Gymnasium at grades 5 and 6 for English and mathematics. On a weekly basis, additional exercises are developed in cooperation with the responsible teacher and corrected manually. This training system supports pupils in their preparation for exams. The results show that all learners could significantly increase their performance.

Within the scope of a diploma thesis the exercises are gradually transformed into eLearning units with a complete set of exercises and further material. The aim is to automatize the time-consuming manual corrections with the help of eLearning systems to a large extent, such that these exercises can be easily created and used by teachers. In this context a guideline for teachers will be developed.

Other Activities

In cooperation with the GI-Fachgruppe “Informatische Bildung in NRW”, our group organized the “4. Informatiktag NRW for Teachers”. 15 workshops, talks and discussions provided around 190 participants with information on the current evolution of computer science in school and the general education in informatics.

In conjunction with the CiL, Prof. Schroeder organized the official opening of the CiL of the RWTH Aachen University that deals with the question whether German universities are fit for the digital age. Well-known experts from politics, economy and science discussed the relevance of eLearning as a strategic element of the evolution of universities. Among others Prof. Dr. Weiler from Stanford University and Prof. Dr. Plattner, prorector of the ETH-Zürich, approved of the orientation of the CiL as an integrating organization that is to coordinate existing organizations of the RWTH Aachen University concerning the implementation of eLearning and the problems arising from that.

Organization of Workshops

- *Strategien der nutzerorientierten Informationsversorgung für Forschung und Lehre*, RWTH Aachen, Juni 2005

- *Urheber- und Verwertungsrechte bei elektronischen Dokumenten*, RWTH Aachen, September 2005
U. Schroeder:

- Scientific leader of the newly founded eLearning Center of RWTH Aachen University: Center for integrative eTeaching and eLearning Concepts (CiL) (see http://www.cil.rwth-aachen.de);
- Head of the eLearning working group of RWTH Aachen University;
- Member of the committee for the education of secondary school teachers of RWTH faculty 1, which defined new curricula and regulations for examinations and the organization of courses (see http://lehramt.informatik.rwth-aachen.de);
- Head of the committee for studies in Computer Science, currently discussing the introduction of Bachelor / Master degrees in Computer Science;
- Contribution to the evaluation of CeC;
- Reviewer for the Workshop “Mobiles Informationsmanagement und seine Anwendungen”, GI-Jahrestagung 2005;
- Referee for the “eLearning Kompetenzzentrum (elc)”;
- Referee for applications for filep-projects at the ETH-Zürich;
- Cooperator in the swiss committee for the formulation of a computer science curriculum for schools.

E. Giani:

- Member of the eLearning working group of RWTH Aachen;
- Co-organizer of the “Girls Day” and the “Schnupperstudium” for Computer Science.

Talks and Publications

Talks

U. Schroeder: The Role of Interaction Records in Active Learning Processes, IADIS Virtual Multi Conference on Computer Science and Information Systems, 2005


U. Schroeder: *Initiieren - Beraten - Begleiten - Integrieren - Das CiL der RWTH*, Eröffnungsveranstaltung des CiL der RWTH Aachen

U. Schroeder: *Informatik in der Schule - Objektorientiertes Programmieren*, Didaktisches Kolloquium der ETH-Zürich

**Publications**


Media Computing

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Overview

The Media Computing Group at RWTH Aachen University conducts research in Media Computing and Human-Computer Interaction (HCI) that goes beyond today’s graphical user interface and desktop metaphor. Grounded in computer science, we develop and study new interaction theories, techniques, and systems in the areas of interaction with multimedia, ubiquitous computing environments, tangible user interfaces, and HCI design patterns. Our goal is to make the Brave New World of ubiquitous multimedia technologies useful by making it usable.

New media technologies, such as interactive TV or electronic books, often distinguish themselves through their capability for interaction. Their user interface, however, lags far behind its technological potential: today’s “media players” still largely resemble a 1950’s tape recorder. Multimedia interaction is stuck in the 30-year-old desktop metaphor—perfect for document work, but not for media processing. This bottleneck is giving HCI a significance push similar to the explosion of Computer Graphics in the 1990’s. It enables, but also requires us to rethink some central paradigms of interacting with information, especially time-based media.

New interaction techniques can re-enable established routines from the pre-digital world, or create new ones unique to the interactive medium. Our interactive exhibits, for example, enable users to interact with the rich structure of musical data streams—to find a piece in a musical database by humming it, improvise to a piece with computer support, or conduct an actual audio and video recording of the Vienna Philharmonic. This inevitably leads to fundamental research questions in computer science, such as real-time time stretching of A/V streams, conducting gesture recognition, and cognitive modeling of the human conducting process.

Beyond such individual systems lies the realm of media spaces, entire environments in which several key dimensions of complexity increase—multiple users interact with multiple media, using multiple systems, devices, and applications. History has shown that, as technology matures, it fades into the background of a newly augmented reality, instead of leading to virtual realities. But which devices and interaction modalities, if any, will be playing an equally dominant role in this post-desktop scenario as mouse, keyboard, and monitor in today’s desktop-centered systems? We have built the Aachen Media Space at our department, a next-generation interactive environment, to further explore this exciting new area of research.

Trying to prototype new, physical post-desktop user interfaces for such interactive spaces has led us to the development of the iStuff toolkit. As a result, questions such as how to handle inevitable latency in a decentralized user interface, new forms of feedback, and preferred modalities when interacting with media in such environments, have become better understood.

The increasing momentum in this field also calls for new, more efficient ways to capture, structure, discuss, and ultimately formalize and standardize the rapidly growing body of knowledge and experience in interaction technologies and techniques.
with multimedia. One way to express and distribute this kind of knowledge are our *Interaction Design Patterns*, combining the advantages of existing widely used formats such as general design guidelines, design rationale, and specific style guides.

Our group builds upon these results and continues to chart new territory in interactive multimedia research, in collaboration with international partners in research and industry, including Stanford University, KTH Stockholm, ETH Zürich, UCSD, and others. We are a member of the international RUFAE network that conducts research on user-friendly augmented environments. We also offer courses and research opportunities within the Media Informatics Master’s Programme at the Bonn-Aachen International Center for Information Technology (B-IT). This center, established in 2002 and located in Bonn, offers highly selective International Master’s Programmes in Applied Information Technology as well as summer/winter schools to qualified Computer Science students.

## Research Projects

### The Aachen Media Space

*Jan Borchers, Eric Lee, Rafael Ballagas, Daniel Spelmezan, David Holman*

The Aachen Media Space is a new interactive room, a computer-augmented environment for collaborative media-based activities, that our group is currently creating as part of our infrastructure. It features a notable non-presence of computers in their traditional form. Instead, it has the general atmosphere of a relaxed environment that invites collaborative activities. Its primary users are the research group members and senior students working on projects in the group. Typical tasks include interaction with multiple media, but also brainstorming, meeting, and presentation activities.

The space serves several functions: It provides an everyday social space to meet, discuss, and present work. It also serves as a test bed for new developments in multimedia computing done by students and researchers. Finally, it houses a gallery of outstanding projects (such as various interactive exhibits) that can be demonstrated directly in the Media Space, or moved out to external venues (conferences, etc.).

This makes the Media Space not only a crucial “melting pot” providing an integrating theme and focus for the work of the group, but also turns it into an excellent environment to demonstrate our research projects (and possibly those of other interested CS groups) to visiting academic peers and current and future industrial partners. Experience from working at several prior universities has shown that, as project artifacts, these running systems frequently become highly sought after by the institution in order to serve as a showcase during public-relations events and on similar occasions, helping
to attract prospective students, researchers, and support from funding agencies and industry, and even to give the institution a more interesting profile among the local community.

The room design is centered around eight mobile 40” high-contrast, high-resolution interactive wall displays distributed around the room that can be read conveniently despite daylight conditions, several group tables with built-in displays that can be joined into a large structure, and informal seating in a corner. Research shows that having these amounts of display real estate fundamentally changes how people interact with information.

A video conferencing unit links the space to research institutions around the world, fostering the continuation of existing international collaborations with institutions such as the Royal Institute of Technology Stockholm and Stanford University, and the establishment of new research contacts. Several untethered tablets are available for sketching, browsing, and interacting with multimedia data streams within the Media Space.

A speaker array allows for localizable audio signals at high quality. The array is handled by a room-wide audio server that any machine in the room can access to route its acoustic output to the array. This is achieved using our Audiospace middleware.

The room features raised floor and ceiling cable trays to facilitate cabling, installing sensors, cameras, microphones, and other technology necessary for a multimedia environment. It distinguishes itself from our Laboratory through the tasks it is designed for. Basic everyday development is not an activity to happen in the Media Space since by definition it hides that technology (no access to multiple keyboards, mice, monitors, CPUs, etc.). In the final setup the two rooms will be adjacent to each other to ensure that the development-oriented work in the Laboratory and the activities in the Media Space evolve in tight coupling with each other. Students can also go to the Laboratory in order to access a Media Space machine for administrative tasks. Media Space and Laboratory are based on Apple Power Mac G5 computers.
During the last year, the Media Space has been used for regular group meetings, presentations, video conferences and student projects.

iStuff
Rafael Ballagas

iStuff is a toolkit of physical input and output devices, such as buttons, sliders, and sensors, that can be used to quickly prototype tangible user interfaces (TUIs). This can dramatically improve the quality of tangible interface design by allowing for many iterations in the design process, similar to the way graphical user interface (GUI) toolkits have improved the development lifecycles of application GUI development. The iStuff toolkit is designed specifically to support prototyping multi-modal, multi-user interaction in ubiquitous computing (ubicomp) environments. It leverages a proven ubicomp infrastructure known as the Event Heap. Another strength of the iStuff project lies in its facilities for interoperability and reconfiguration provided by the Patch Panel middleware. The Patch Panel allows users to map devices to actions in the room, and thereby to incrementally integrate physical interfaces into a larger interactive system without changing any code. We are continuing to research and improve different aspects of the toolkit. Our goals are to understand and deal with the latency inherent in distributed ubicomp user interfaces, to help bridge the gap between the crossover from tangible prototype to final product, and to understand how important desktop interface concepts like focus and selection translate to the ubiquitous computing domain. The toolkit also helps us and our students to explore novel post-desktop user interfaces.

iStuff Mobile is an extension to the iStuff toolkit. It is a rapid prototyping platform that helps explore novel interactions with mobile phones. It combines sensor network platforms, mobile phone software with the existing iStuff framework. Interaction designers can use the framework to quickly create and test novel sensor-based interactions without making internal hardware modifications to the mobile phone handset.
Our goal is to use this extension to explore novel interactions that combine mobile phones and ubiquitous computing, as well as to provide a design tool for ubiquitous computing research.

Central to the question of rapid prototyping, is how designers specify the different interactions and their intended results. We are experimenting with a new Patch Panel GUI that extends Apple’s Quartz Composer as an intuitive visual interface to establish relationships between user actions and application feedback. We are researching how these visual programming environments compare to other programming environments such as scripting languages and how these different approaches effect the design process.

### Phonecam-based interactions with Large Public Displays

*Rafael Ballagas, Jan Borchers*

Interaction with large public displays presents unique challenges, particularly with physical interaction. Using personal devices as tools for interaction satisfies the major design considerations for this domain. We have developed a set of direct manipulation interfaces based on camera-enabled mobile phones that use both visual codes and optical-flow processing to support serendipitous interaction with large public displays. The “Point & Shoot” technique allows users to select objects on a large display by aiming through the camera viewfinder. This technique uses visual codes to set up an absolute coordinate system on the display surface instead of tagging individual objects on the screen. The “Sweep” technique enables users to wave the phone in the air to control a large display application with three degrees of freedom using optical-flow processing.
Our research goals are to create intuitive and fluid interaction techniques that allow people to serendipitously interact with the resources in their immediate environment. These techniques help enable new classes of large public applications including interactive art, games, bulletin boards, and advertising.

**Personal Orchestra: A Family of Interactive Conducting Systems**

*Eric Lee, Jan Borchers*

Our work in interactive conducting attempts to break the mold of current multimedia interfaces which are largely limited to the decades-old metaphors of play, stop and rewind. Embedded in multimedia is a rich set of semantics; for example, music is vertically composed of chords, voices and instruments and horizontally composed of notes, beats and bars. However, multimedia continues to be treated as “black boxes” of data in most systems available today. We have further developed our interactive conducting systems in this past year by building a “hybrid” system which combines the best of the original *Personal Orchestra* and *You’re the Conductor* (Personal Orchestra 2). We have also been working on an improving various aspects of the conducting system, discussed below.

One of the challenges of designing an interactive conducting system is how to properly map the user’s conducting gestures with a baton to the music beat. We studied this mapping in more detail through a series of user studies comparing the temporal characteristics of conducting gestures amongst conductors and non-conductors. Our aim was twofold: to determine a method of systematically distinguishing conductors from non-conductors, and to better understand the various mental models of conducting. Our results confirmed that conductors, unsurprisingly, place their beats ahead of the music beat, and with little variance. Non-conductors, however, also place their beats slightly ahead of the beat on average, but vary them significantly more. By analyzing only beat placement, however, we were able to uncover a variety of differing conceptual models
of conducting. Some users, for example, unconsciously conduct to the rhythm of the music rather than the beat. Others synchronize their beats to the upwards turning point of a simple up-down gesture, rather than the downwards turning point.

![Graph](image)

*Left: Comparison between a conductor’s and a non-conductor’s conducting.*

*Right: Our multiresolution peak picking algorithm.*

Current multimedia frameworks do not easily support such time based interaction such as where a digital audio/video recording must be synchronized both to each other and to an external clock. This can be described as a conceptual model conflict between engineers of a multimedia framework, who treat time as evenly spaced intervals much like a clock (“clock time”) and developers using these frameworks to build applications, who treat time more as dynamically-sized intervals that expand and contract over time in response to user input. We developed the *Semantic Time Framework*, a new multimedia framework to address this conceptual model issue.

The above research has been integrated into the third Personal Orchestra system, *Maestro!* and is being installed in the Betty Brinn Children’s Museum in Milwaukee, USA. The exhibit will open to the public on March 11, 2006.

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**The Regensburg Experience**

*Rafael Ballagas, Eric Lee, Daniel Spelmezan, David Holman, Jan Borchers*

The Regensburg Experience (REX) is a project with the goal of providing visitors with an enriching experience. The role of the Media Computing Group in this project is to design and develop a series of interactive exhibits that enable visitors to actively and interactively partake in the city’s rich culture and history. Each system is distinct with its own set of research questions and goals; these exhibits include:

**REXplorer:** With REXplorer, we want to offer an alternative to people who find standard tourist offerings a little boring. REXplorer immerses tourists in the Immerwährrender Magietag (The everlasting day of magic) to create a world of magic and
spirits that they explore to learn about different periods, and people of Regensburg’s past. It is a game that is played in the city streets, extending the Regensburg Experience outside of the museum. The basic premise of the game is that certain landmarked buildings have locked magical spirits, secrets, and treasures inside of them, all of which can be unleashed and interacted with by the way of the proper magical spell gesture. Game players can rent a “magic wand”, a gesture sensing and location tracking smartphone running custom software and data necessary for the game. REXplorer is unique blend of fantasy and reality, fiction and historical fact that gives tourist an entertaining perspective on the cities historical treasures.

REXplorer is a very exciting project for us as a research team because it breaks new ground in how people can use the mobile phone, a device that they carry with them everyday, to interact the environment around them. The project is also exciting because it makes contributions in the emerging field of serious games by applying a game approach to the serious topics of tourism and education. In addition, the project explores novel uses of mobile social software allowing tourists to interact with each other as well as with their friends and family at home through a specially designed travel journal weblog that reflects the events happening in the game.

**Minnesang:** This exhibit tries to convey the curiousness of Old German by providing a customized translation service that can convert the spoken language of the visitor using voice conversion. The objective of voice conversion is to convert a speaker’s voice to exhibit desired characteristics, while preserving the original content (meaning), e.g., the speech of one speaker is perceived as if it was spoken by another speaker. The research goals of this is to understand how personalization can improve the educational experience by making the exhibit more engaging.

**Time Window:** Visitors to Regensburg will have the opportunity to glimpse into Regensburg’s past. The system is inspired by the historical viewpoints found in many European cities. These viewpoints typically have a static artist rendering of the city at a certain point in history. Our vision is to have a time window that shows the progression of Regensburg’s history through audio clips, video clips, photos, and artist renderings. Users can move through periods of Regensburg’s past through novel input devices and metaphors. The primary research goals are creating novel visualization metaphors and mappings to help guide users through the large amounts of information.

**Medieval Band:** Museum visitors directly interact with mock instruments on the floor to collaboratively create music that is acoustically adjusted by a computer for harmonization. This exhibit is designed to teach visitors about medieval music and common instruments of the time. Users experience the sense of being in a medieval band by playing along with other museum visitors. The exhibit consists of three mock instruments that people can walk up and start to “play”. The research questions consist of how to assist collaborative content creation such that all of the individual players notes are slightly transformed to “sound good” while still maintaining the feeling of control for each musician. This assistance must not only happen on the harmonic
(pitch) scale, but also on the temporal scale.

**Organic Interfaces: Fly: An Organic Presentation Tool**
*David Holman, Predrag Stojadinovic, Thorsten Karrer, Jan Borchers*

While Computer Science has looked at biologically inspired algorithms, this idea has not been carried over to the user interface. At the Media Computing Group, we are examining interfaces that respect, and are inspired by, laws found in physics, biology, and human cognition. For example, the movement of a school of fish, a highly complex structure, appears calm, continuous, and fluid; it is organic. We label this research area Organic Interfaces.

The Fly presentation tool is an early example of an interface that adheres to Organic interface principles. Current presentation software, like PowerPoint, structure slides in a linear sequence. The Fly design introduces a spatial organization that is based on Mind Maps. Using colour associations, spatial relations, and fluid movement, it shows how presentation software can structure a meaningful overview of the underlying content using naturally occurring design principles.

**Audiospace: A Universal Audio Service for Interactive Rooms**
*Christoph Wilhelm, Eugen Yu, Jan Borchers*

Audiospace is a middleware for real-time transport of audio over high-speed LANs. It is designed as an integral part of the Aachen Media Space, which made high reliability, multiple audio channels, low latency, ease of use and good integration into the host environment key requirements.
The Aachen Media Space contains several Apple PowerMac G5 workstations running MacOS X, and an 8 speaker surround sound audio system. Audiospace enables each of these computers to play back audio streams over this central speaker system.

Both the server application and the kernel driver for the client have been implemented under Mac OS X, and allow a reliable transport of multichannel streams in CD quality over the MediaSpace’s GBit Ethernet or 802.11g wireless networking. The server uses several of CoreAudio’s AudioUnits: The HALOutput unit provides access to the audio hardware, the MatrixMixer unit is responsible for mixing several streams, and each incoming stream gets its own Converter unit, allowing clients to choose their audio format independently. In addition, the Varispeed AudioUnit is being used for clock skew compensation.

The software is available for download from our web site.

HCI Design Patterns: Capturing User Interface Design Guidelines for Interactive Multimedia Systems and Environments

Jan Borchers

HCI Design Patterns are a format to capture golden rules, design guidelines, and design rationale when building interactive systems. Building on our past work in this area, we have established a collaborative web site for the growing international community of researchers working on this topic (http://www.hcipatterns.org/) which we host as heads of the IFIP task group on this topic.
In 2003, we worked with international partners both at the CHI 2003 Patterns Workshop and online, to create a structural specification for HCI Design Patterns. The result, PLML (the Pattern Language Markup Language, pronounced pell-mell), is expressed as a Document Type Definition (DTD) in XML, and can be found on our web site.

Several pattern languages, including our own HCI Design Patterns for Interactive Exhibits, have been converted by their authors into PLML and been made available online for general use.

Together with partners in the RUFAE network, we are currently working on a new pattern language for interactive environments such as the Aachen Media Space. It will capture the lessons we learned by designing this and other similar spaces (at Stanford and elsewhere), and should be of help to others planning to create similar environments.

**Other Activities**

The Media Computing Group at RWTH Aachen University was established in October 2003.

Our infrastructure that is currently being installed consists of 3 XServe G5 servers with a 1TB XServe RAID, around 15 Dual-2GHz G5 desktop machines with 23” Cinema Displays and iSight cameras for the student Laboratory, and several G4 PowerBooks with similar periphery for our staff. The Media Space (in its final setup) will contain eight 40” mobile interactive LCD screens, a large rear projection screen, an eight-channel networked surround audio setup with four discrete amplifiers and dedicated Firewire audio interface, high-fidelity videoconferencing and a variety of non-standard input and output technologies (infrared batons, various sensors, Bluetooth devices,
etc.) We create this environment to facilitate experimentation with time-based multi-
media for our students and staff.

In 2005, examples of our work were on permanent display at the HOUSE OF MUSIC
VIENNA, the Children’s Museum in Boston, and were also exhibited at the Tag der
Informatik at RWTH Aachen on December 2th.

We worked as reviewers for CHI 2005, UIST 2005, and host the hci-patterns.org home
page as heads of the IFIP task group on this topic. We also worked as co-chairs for the
Interactivity Venue at CHI 2006.

Talks and Publications

Talks

Tico Ballagas: iStuff Mobile: Rapidly prototyping novel interactions for mobile phones
and ubicomp environments, Usability Research Colloquium, Deutsche Telekom Labs
at TU Berlin, Berlin, Germany, January 2006.

Tico Ballagas: iStuff: Rapidly Prototyping Physical User Interfaces, Laboratory of

Tico Ballagas: Interacting with Large Public Displays using Phonecams , Advanced
Topics in HCI Course, Ludwig Maximillian University, Munich, Germany, May 2005.

Tico Ballagas: Interacting with Large Public Displays using Phonecams , iRoom
Lunch Series, Stanford University, Palo Alto, CA, January 2005.

Tico Ballagas: Interacting with Large Public Displays using Phonecams, Ubiquitous
Computing Research Group Lunch Series, Georgia Institute of Technology, Atlanta,

Eric Lee: Improving orchestral conducting systems in public spaces: examining the
temporal characteristics and conceptual models of conducting gestures, CHI 2005,
Portland, Oregon, USA, April 2005.

Eric Lee: Designing Time-Based Interactions With Multimedia, ACM Multimedia

Publications

Rafael Ballagas, Steffen Walz, and Jan Borchers: REXplorer: A Pervasive Spell-
Casting Game for Tourists as Social Software, Workshop on Mobile Social Software
(MoSoSo) CHI 2006, Montréal, Canada.

ric Lee, Henning Kiel, Saskia Dedenbach, Ingo Gruell, Thorsten Karrer, Marius Wolf,
and Jan Borchers: iSymphony: An Adaptive Interactive Orchestral Conducting Sys-
tem for Conducting Digital Audio and Video Streams, Extended Abstracts of CHI
2006, Montréal, Canada.


Software for Embedded Systems

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Overview

Informatik 11 is representing the field of embedded software at RWTH Aachen University. The chair was established in November 2003. Our research is focused on design methodology and software technology for software-intensive embedded systems. Based on the experiences with the current practice in industry, our aim is to develop methods and technologies for embedded software which help software engineers to meet today's increasing quality demands. Our approaches are built on a model-based engineering paradigm. Analyzable models shall be employed early and continuously during the development process and not only for functional but also for quality requirements. The methodological issues of interest include aspects as diverse as, for example, safety and reliability of software-controlled systems, quality evaluation of architectures, process organization by agile methods, and the application of formal methods to safety-critical systems.

With respect to teaching, we further elaborated our lectures for the specialization area Embedded Software. The curriculum is currently divided into the lectures Introduction to Embedded Systems, Embedded Software Engineering, Dynamic Systems for Software Engineers, and Formal Methods for Embedded Systems. In all lectures we try to create a sensitivity to real-world requirements in the embedded systems industries and enable computer science students to communicate properly with control engineers. The same spirit of cross-disciplinarity is driving the preparation of a new Masters program in Control Engineering Science scheduled to begin in the winter term 2007. It will be offered by four faculties – computer science, mechanical engineering, materials engineering, and electrical and computer engineering – and be open to graduates from all of these disciplines.

In 2005 our chair moved for the second time since its founding – this time to the final premises on the third floor of the so-called old building. Having the group together on one floor with short distances between the office rooms, the laboratory, and the seminar room is a distinct improvement. We are looking forward to fill the new rooms with further researchers in new and exciting projects.

Research Projects

Automotive Software Engineering

Daniel Klünder, Stefan Kowalewski

The dramatically increasing amount and importance of software in automotive electronic systems poses new challenges to the engineering of such systems. Today's cars host nearly 1 GByte of code distributed over up to 70 electronic control units inter-
connected with up to five different buses. We believe that the key to meeting the challenges posed by this rising system complexity can be found in a sound design and analysis of the system’s architecture. Therefore we are interested in design and analysis methods for system and software architecture which support the achievement of predefined quality goals and, in particular, meet current requirements like composability and exchangeability of software components from different sources and over the complete vehicle network.

One way to analyze software architectures is the examination of scenarios that focus on a product’s requirements. In requirements engineering we distinguish between functional and non-functional (also qualitative) requirements of a product. Qualities are desired features which exceed correct functionality, e.g. reliability, changeability or testability. Whether a product achieves its quality requirements is strongly affected by its software and system architecture. A careful requirements analysis therefore enables the designer to choose an architecture for the system by balancing opposing requirements. One way to achieve the detected quality goals is to construct the system from architectural patterns.

<table>
<thead>
<tr>
<th>Software architecting methods:</th>
<th>Multidisciplinary systems architecting methods:</th>
<th>Methods also addressing process and organization:</th>
<th>Generic methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• SAAM (SEI)</td>
<td>• SE practices (INCOSE)</td>
<td>• Systems Engineering (Martin)</td>
<td>• TRIZ (Altshuller)</td>
</tr>
<tr>
<td>• ATAM</td>
<td>• 1471 (IEEE)</td>
<td>• Systems Architecting (Maier, Rechtin)</td>
<td>• GST (Hitchins, Heylighen)</td>
</tr>
<tr>
<td>• 4+1 (Kruchten)</td>
<td>• ZIFA (Zachman)</td>
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<td>• 4 views (Soni)</td>
<td>• 9126 (ISO)</td>
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<tr>
<td>• VAP (Bredemeyer)</td>
<td>• VAP (Bredemeyer)</td>
<td></td>
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</tbody>
</table>

Figure 22: Classification of architecting Methods according to Muller.

Figure 22 shows a classification of architecting methods according to Muller. The more general a method is the more it is placed to the right of the table. For analyzing existing systems’ architectures we are studying the application of specialized software architecting methods as well as more general methods in the automotive domain. We hope to find a systematic way of applying architectural patterns that assists in reaching a product’s business goals.

Hybrid Control

Ralf Mitsching, Stefan Kowalewski
The increasing complexity of the automotive control systems calls for more powerful design approaches. One promising way is the application of hybrid systems methods in the control software development. They combine discrete and continuous models to describe a system’s dynamic behavior. Nowadays, they are typically derived from simulation models with a rudimentary use of methodical results from hybrid systems research.

The objective of the EU-founded „Network of Excellence“ HYCON (http://www.ist-hycon.org) is to develop and apply the hybrid systems approach to the design of embedded control systems. More than 25 European universities and industrial partners joined in HYCON. The focus of Informatik 11 is the design of motor control-unit software using Hybrid Models and the knowledge transfer in the domain of Hybrid Systems.

Automotive Control: Variability in Hybrid Models for Automotive Software  One main issue in industry is to handle the high number of variants of motor control-unit software and the simultaneous moving to model-based development with automatic code generation. Our approach is to introduce variability management in the development of Hybrid Models to enable developers of automotive systems to systematically re-use Hybrid Models.

Knowledge Management: Virtual library The literature on Hybrid System is spread over different engineering fields such as control engineering, mathematical systems theory and computer science. The partners of HYCON create a common reference archive. Our task is to add assistance in retrieving knowledge efficiently from the reference archive with advanced services.

ZAMOMO
Jacob Palczynski, Andreas Polzer, Stefan Kowalewski

ZAMOMO is a BMBF-funded project dealing with the “integration of model–based software engineering with model–based controller design”. The project goal is to bring together the different views, methodologies, models, tools and processes of the two disciplines of control engineering and computer science. The project is focused on a the exemplary application of automotive engine control systems. The consortium is built by the Institut für Regelungstechnik of RWTH Aachen University, Fraunhofer Institute for Applied Information Technology (FIT), St. Augustin, VEMAC GmbH & CO KG, Aachen, AVL Deutschland GmbH, Mainz-Kastel, and Informatik 11).
Traditional methods for achieving safety properties mostly originate from hardware-dominated systems. Software-intensive embedded systems require new approaches, as they are for example suggested by the emerging standard IEC 61508. We are interested in developing constructive and analytical methods for ensuring safety which have a sound formal basis but which are also efficiently applicable in different domains, like automotive or railway systems.

One of our interests in this field is the influence of hardware decisions on the safety and reliability of the according software. We see a chance to improve safety and reliability of a system by finding the optimal hardware-software combination. On the one hand this could be an appropriate microcontroller (MCU) with the according software or a programmable logic circuit (PLD) like an FPGA or a CPLD designed in a suitable hardware description language.

In this context, we conducted empirical studies, which took place in graduate lab exercises (Hauptstudiumspraktikum) in summer term 2005 and winter term 05/06, in order to get the necessary basic data to work with. In these experiments two hardware structures were compared. Early results show differences in the failure behavior (systematic failures). Further analysis is done at the moment in order to determine if these differences in failure behavior lead to an significant improvement of failure independence.

On the other hand, the optimal hardware-software combination could be a partition of the systems functionality on a suitable microcontroller/microprocessor with the corresponding software and an appropriate programmable logic circuit. One of the major problems when dealing with software safety is complexity. However, the safety critical functions are in some cases of a simpler nature. Thus, the idea is to implement the safety critical part in a very simple way on the programmable logic circuit and leave the complex higher level functionality for the microcontroller. The advantage of this approach is that the basic safety critical functions on the programmable logic circuit are independent of the CPU, they can be implemented in redundant hardware modules and they are easier to verify (eg timing analysis of programmable circuits is usually easier than the one of software running on a CPU). We plan an experiment dealing with this aspects in summer 2006.

In order to provide our results for other designers of safety critical systems we plan to allocate them in a pattern catalogue with the according building codes.
The growing complexity of current automotive electronics and the lack of standards in this field lead to problems concerning non-functional properties of the software involved like discussed in the section *Automotive Software Engineering*. New approaches like drive-by-wire require adapted architectures and methods to deal with the according safety and reliability requirements.

In order to support our theoretical research we see a need for an experimental platform. This platform should be realistic on the one hand, but easy to handle in an academic setting on the other hand. For this reason we chose a platform based on a commercial out of shelf model cars in scale 1:5.

These cars usually are equipped with hydraulic brakes and combustion engines. The latter lead to several problems, since test drives are possible outside only and safety regulations have to be considered. Consequently, we replaced the original engines with electrical ones, powered by batteries. The original remote control had to be replaced in order to transmit data readable for computational units. For realization of automotive functions several sensors are needed. All four wheels are equipped with optical speed sensors for speed measurement. In order to perform environment recognition ultrasonic and infrared sensors have been used.

Two of these cars are available at our institute. This allows easier comparisons between different approaches, challenges between several development teams and realization of
functionalities needing at least two cars, like adaptive cruise control. One of the cars has been adapted like described above and some computation units (microcontroller) have been integrated (see figure 23). The second car is still under development.

So far these cars have been used mostly in diploma and master thesis concerning safety and reliability properties (e.g. applying IEC61508, drive by wire). Other diploma theses are planned, e.g., on applying design patterns on safety critical embedded systems and automatic parking concerning safety requirements.

Model Checking Source Code for Embedded Systems

Bastian Schlich, Stefan Kowalewski

Embedded systems are frequently used in safety-critical environments. Full testing of such applications is often not possible because it is too time consuming or too expensive. The problem is that errors in those systems may lead to severe events. Therefore, industries have become interested in model checking software for those systems. Since many different tools are used in the development of software for embedded systems, the most promising use of model checking is the application to the C code that is created in almost every embedded software project.

We surveyed 14 existing C code model checkers and found out that none of them is able to model check C source code for embedded systems. The main reasons for this inability are the following:

- too restricted a set of analyzable C constructs
- inability to deal with hardware particularities
- partly inappropriate specification techniques

As a consequence, we developed a model checker called [mc]square. [mc]square stands for: Model Checking MicroController. It is capable of model checking source code for the ATMEL ATmega microcontroller family. We do explicit CTL model checking.

Our approach is depicted in Figure 24. It works as follows. First, the C code is compiled with the GNU C Compiler (GCC) to an elf or od file. Then this file is read by [mc]square. Now an external simulator called Avrora is used to build the state space step by step. After that each state is annotated with the atomic prepositions that are satisfied in this state. In the next step the model checking is accomplished. Finally the counter-example is shown in the C source code file.

We finished the implementation of all steps except for the last one. We are currently working on the presentation of the counter-examples in the C source code file. The advantages of our approach are as follows:
• Assembly language constructs are easier to handle because they have a fixed semantics in contrast to the C language.

• Compiler behavior is considered.

• Embedded assembly language constructs can be analyzed.

• Hardware features are considered.

• Externally available simulator is used.

With [mc]square, we checked some small programs that could not be checked by the existing general purpose C code model checkers. We checked the light switch program that we used in a case study. This program results in a state space that consists of 1,159 states. We verified different formulae and for each of these formulae [mc]square needed about 300 ms to check it. This time includes the time needed for the generation of the complete state space.

To show that the different modules of [mc]square are exchangeable, we implemented two different state space builders. The first state space builder creates the concrete state space and is able to deal with up to 640,000 states per gigabyte RAM. The second one creates an under-approximation and is able to deal with up to 3,800,000 states per gigabyte RAM. It can be used for debugging purpose that means for finding errors and not for proving their absence. This kind of usage of model checking is also advocated by Ball, Kupferman, and Yorsh.
An experiment on refactoring for embedded systems was carried out during fall 2005. It consisted of twelve main study period students who were randomly assigned to either a refactoring or a documentation (placebo) treatment. The participants were paid for participation which strongly increased control and validity of the experiment. First results show a significant difference in the memory consumption of the refactoring group. The main reason is assumed to be a better micro structure of the code as the text-area of the memory was much smaller in the refactoring group. This positive characteristic of refactoring was bought with a significantly higher development time of the refactoring group as this group needed about 27 hours for the programming compared to 20 hours for the documentation group. A further analysis of this experiment is currently done for the abstract syntax tree and its evolution over time. This is expected to yield differences concerning architectural properties of both groups.

Concerning the planning time experiment executed in 2004, the main differences observed are to be replicated during an upcoming lab course in 2006. This is targeted mainly on the type of work over the course of development, which was divided into function based, architecture based, failure based, or general change based programming. In addition, a quantification of the planning step is one of the major goals of the experiment, as this variable must be controlled to assess the difference of an agile, shorter planning versus a classical longer planning approach.

Other Activities

Stefan Kowalewski:

Editing:

- Member of the Editorial Board (Herausgeberbeirat) of at-Automatisierungstechnik, Oldenbourg-Verlag, Munich
- Associate Editor of the IEEE Transactions on Control Systems Technology

Program committees:


• 2nd IFAC Conf. on the *Analysis and Design of Hybrid Systems (ADHS)*, Alghero, Italy, June 2006.

• Int. Workshop on *Discrete Event Systems (WODES)*, Ann Arbor, USA, July 2006.


• IEEE Int. *Conference on Control Applications (CCA)*, Munich, October 2006.

Falk Salewski:

Program committees:

• International Workshop on Reconfigurable Computing Education (RC-education) March 1, 2006 Karlsruhe, Germany

## Talks and Publications

### Papers

Falk Salewski and Stefan Kowalewski: *Zuverlässigkeitsmechanismen für Eingebettete Systeme*, Kurzfassung des Vortrags vom Workshop Zuverlässigkeit in eingebetteten Systemen. In Softwaretechnik-Trends, GI, Band 25, Heft 4, ISSN 0720-8928 (in German)


**Talks**

Stefan Kowalewski: *Eingebettete Software im Auto – Herausforderung an der Schnittstelle zwischen Informatik und Regelungstechnik*, Informatik-Kolloquium, Universität Augsburg, 24.11.2005

Stefan Kowalewski: *Entwurf eingebetteter Software: Herausforderungen und methodische Ansätze*, Technische Universität Braunschweig, 14.11.2005


Stefan Kowalewski: *Architecture and control issues in embedded software and systems engineering*, Ford ESST Meeting, Ford-Forschungszentrum Aachen, 23.-24.08.2005

Stefan Kowalewski: *Entwurf eingebetteter Softwate: Herausforderungen und neue methodische Ansätze*, REGINA Management-Treffen, DSA GmbH, Aachen, 11.05.2005

Scientific Computing

Staff

• Faculty:
  Univ.-Prof. Christian H. Bischof, Ph.D.

• Secretary:
  Renate Didolff

• Lecturer:
  PD Dr.-Ing. H. Martin Bücker

• Research Assistants:

  Dipl.-Math. Oliver Fortmeier (since 09/2005 funded by DFG within SFB 540)
  Dipl.-Ing. Monika Petera (funded by DFG within GK Hierarchy and Symmetry in Mathematical Models)
  Dipl.-Inform. Arno Rasch (funded by DFG within SFB 401)
  Dipl.-Ing. Emil Slusanschi (until 06/2005 funded by DFG within SFB 540)
  Dipl.-Inform. Andre Vehreschild
  Dipl.-Inform. Andreas Wolf (funded by GEOPHYSICA Beratungsgesellschaft mbH)
Overview

A recurring theme of the research activities at the Institute for Scientific Computing is the interplay of methods from computer science with mathematics and engineering or natural sciences. Problems occurring in practice are often too complex to be solved with techniques from a single discipline. The enormous requirements with respect to data handling and computational power can be accommodated only with an interdisciplinary approach. Here, the central roles of computer science are to keep the complexity at a manageable level by making use of problem-inherent structure, and to provide appropriate software tools that allow users from technical or scientific disciplines to easily benefit from algorithms derived this way.

Our research addresses various topics of high-performance computing, including computational differentiation, parallel computing, and efficient numerical methods. Computational differentiation comprises the ensemble of techniques that, given an arbitrarily complex program computing some function $f$ (a large simulation code, say), yields another program that computes the derivative $f'$ along with $f$. These techniques rely on Automatic Differentiation (AD), which in turn is based on the fact that any program is built up from elementary operations, such as addition or multiplication, for which the derivatives are known. Starting with these “elementary” derivatives, the chain rule of differentiation is applied over and over again to obtain the derivative of the whole program. The associativity of the chain rule allows the elementary derivatives to be combined in many different ways, all leading to the same final result, but at widely differing costs. Finding the program that computes $f'$ at minimum cost is conjectured to be an NP-hard problem.

One particular area of research at our institute is the development or refinement of heuristics for reducing the cost of derivative computations with AD. In addition to optimized application of the chain rule, mathematical knowledge can be used to make the evaluation of the derivatives more efficient in terms of memory and operations. We also strive to transfer the AD theory into tools that enable practitioners to differentiate large programs involving complex control structures. Examples for such tools include the ADIFOR and ADIC systems, co-developed by Prof. Bischof, that are able to augment Fortran 77 and C programs, respectively, with derivative code.

Cooperation with other institutes throughout the university is enhanced by the fact that Prof. Bischof is also the head of the Computing and Communication Center (CCC) of the RWTH which offers cutting-edge computational power and advanced visualization techniques (such as Virtual Reality) to RWTH researchers.

Members of the Institute for Scientific Computing teach several courses related to High-Performance Computing (HPC), which is offered as Vertiefungsfach in the Computer Science curriculum.

- *Einführung in High-Performance Computing* (Introduction to High-Performance Computing)
is the basis for more specialized courses, such as

- *Parallele Algorithmen zur Vorkonditionierung linearer Systeme* (Parallel Pre-conditioning Techniques for Linear Systems),
- *Parallele Algorithmen und Software für iterative Methoden* (Parallel Algorithms and Software for Iterative Methods),
- *Semantische Transformationen* (Semantical Transformations),
- Computational Differentiation,
- Automatic Differentiation in MATLAB,
- *Virtuelle Realität* (Virtual Reality) offered in cooperation with the Computing and Communication Center.

In addition, seminars and practical courses are offered, giving a deeper understanding of HPC-related issues. More information on our teaching activities is available at [http://www.sc.rwth-aachen.de](http://www.sc.rwth-aachen.de).

### Research Projects

**Computational Differentiation in Numerical Flow Analysis**

*A. Rasch, C. Bischof, M. Bücker*

This subproject of the Collaborative Research Centre (SFB) 401, “Modulation of flow and fluid–structure interaction at airplane wings”, is aimed at developing efficient techniques for computing partial derivatives for Navier–Stokes Computational Fluid Dynamics (CFD) solvers. Such partial derivatives are needed, for instance, in sensitivity analysis and in design optimization. Due to strong non-linearities of the solution, as well as very high memory and runtime requirements of the simulation software, the traditional approach of approximating the derivatives with divided differences is not appropriate in these applications, in particular in three dimensions.

Therefore we rely on Automatic Differentiation (AD) tools for obtaining the derivatives along with the simulation results. Using the ADIFOR tool, we augment the TFS CFD solver, developed at the Aerodynamics Institute (AIA) of the RWTH, with code for computing partial derivatives, in particular the derivatives of the computed velocity or pressure fields with respect to fluid and geometrical parameters. The availability of such accurate derivative information is crucial if the TFS code is used within some
optimization framework, e.g., for the estimation of turbulence parameters and wing shape optimization.

Furthermore, Automatic Differentiation is employed to obtain the analytic flux Jacobian for an implicit Newton-Krylov method which is used in the recent flow solver QUADFLOW currently under development within SFB 401. In contrast to numerical approximation of the Jacobian, the use of AD-generated code for the Jacobian calculation generally leads to increased performance and robustness of the overall computational method. Since in principle, only Jacobian-vector-products are needed by the iterative method implemented in QUADFLOW, we plan to avoid the explicit assembly of the whole Jacobian and generate code for computing Jacobian-vector products, yielding significant savings in memory consumption. This will also allow the transition from the currently used first-order-discretization in space to a second-order discretization scheme with improved convergence behavior.

An Environment for Parameter Identification and Sensitivity Analysis

E. Slusanschi, C. Bischof, M. Bücker

This project is part of the Collaborative Research Centre (SFB) 540, “Model-based experimental analysis of kinetic phenomena in fluid multi-phase reactive systems”. Several projects in the SFB 540 aim at developing a better understanding of complicated processes through the use of already existing simulation packages or newly developed software in the context of an inverse problem formulation. In order to support this process, we are developing an environment for parameter identification, which allows the coupling of simulation codes with algorithms for the solution of inverse problems with little effort. Tools for the automatic differentiation of programs are an important ingredient, as they allow the exact and efficient computation of derivatives of existing programs and thus increase both the robustness and speed of solvers for inverse problems. Another contribution is the automatic generation of marshalling code which effects the interfacing of the world of simulation with that of numerical solvers for inverse problems. In particular, we plan to develop such an environment around the models for dripping processes on films that are employing the commercial FLUENT CFD solver, and the SEPRAN solver, developed at Delft University of Technology, that is used in the modelling of boundary processes. The development of numerical methods that are specifically tailored to these problems is infeasible due to the complexity of the codes employed.
ADiMat—Automatic Differentiation of MATLAB Programs
A. Vehreschild, C. Bischof, M. Bucker, A. Rasch

The MATLAB problem solving environment is widely used in the natural and engineering sciences. Its popularity is mainly due to its wealth of high-level data types and powerful mathematical operators, as well as to its flexibility and ease-of-use. The goal of this project is the design and implementation of an automatic differentiation tool for MATLAB. The ADiMat tool allows augmenting MATLAB programs with additional statements such that derivatives are computed along with the original function. ADiMat implements a hybrid approach combining source transformation and operator overloading techniques in order to achieve high performance while allowing for MATLAB’s dynamic type system.

Reliable Parameter Estimation for Reactive Flows in Hot Aquifers
A. Wolf, C. Bischof, M. Bucker

This project deals with the numerical simulation of reactive transport in porous media using the simulation package SHEMAT (Simulator for HEat and MAss Transport). SHEMAT is an easy-to-use, general-purpose reactive transport simulation code for a wide variety of thermal and hydrogeological problems in two or three dimensions. The goal of this project is to develop a parallelization of SHEMAT based on the OpenMP standard for shared memory computers as well as to establish a methodology to reliably estimate model parameters using automatic differentiation. This project is funded by GEOPHYSICA Beratungsgesellschaft mbH and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Second Order Derivatives in Process Engineering
M. Petera, C. Bischof, M. Bucker

Dynamic optimization is becoming increasingly important in process engineering. Quasi-Newton methods approximating second order derivatives are currently in frequent use and it is not clear whether or not exact second order derivatives would increase the rate of convergence in actual industrial engineering problems. The goal of this project is to develop an automatic differentiation system specifically designed to evaluate second order derivatives for modeling languages that are typical in process
Parallel Simulation of Reactive Multiphase Fluid Flow Models

O. Fortmeier, C. Bischof, M. Bücker

This project which is a joint work with the Chair for Numerical Mathematics is part of the Collaborative Research Centre (SFB) 540, “Model-based experimental analysis of kinetic phenomena in fluid multi-phase reactive systems”. The main topic of this project is the development of a parallel solver (DROPS) for the incompressible Navier-Stokes equations that can be used for the numerical simulation of certain two-phase fluid flow models which are considered in this SFB. The focus of our work is on the development of a hybrid parallelization strategy combining the advantages of OpenMP and MPI. Research topics include parallel grid refinement, load balancing, and parallel iterative algorithms to solve sparse systems of linear equations.

Other Activities

Our institute takes care to maintain and extend its national and international cooperations in the field of High-Performance Computing, in particular through visits of researchers from other institutions:

- Paul Willems, Applied Computer Science, University Wuppertal, (February 1, 2005)
- Günter Gottstein and Volker Mohles, Institute of Physical Metallurgy and Metal Physics, RWTH Aachen, (April 6, 2005),
- Felix Wolf, University of Tennesse, Knoxville, USA, (June 9, 2005),
- Oliver Fortmeier, Institute for Geometry and Practical Mathematics, RWTH Aachen, (July 8, 2005),
- Wolfgang Wiechert, Department of Simulation, University of Siegen, (July 22, 2005),
- Ulrich Schollwöck and Ian McCulloch, Institute for Theoretical Physics C, RWTH Aachen, (August 8, 2005),
- Holger Dachsel, Zentralinstitut für Angewandte Mathematik, Forschungszentrum Jülich, (August 29, 2005),
Christian Bischof is speaker of the Working Group “Parallelism” within the *Forum Informatik* and organizes — jointly with Th. Lippert (Forschungszentrum Jülich GmbH), E. Speckenmeyer (University of Cologne) and U. Trottenberg (Fraunhofer Institute for Algorithms and Scientific Computing) — the *Kolloquium über Parallelverarbeitung in technisch-naturwissenschaftlichen Anwendungen*, a series of symposia concerned with parallel processing in engineering and scientific applications. This series, initiated in 1993 under participation of K. Indermark and F. Hoßfeld, has since then established itself as a forum for discussion and information exchange among the Northrhine-Westphalian institutions concerned with parallel processing.

Martin Bütter co-organized the following workshops:

- Second European Workshop on Automatic Differentiation held at Swindon, UK, November 17–18, 2005.
- Seventh Workshop on High Performance Scientific and Engineering Computing with Applications, held in conjunction with the 34th International Conference on Parallel Processing 2005 (ICPP–2005), Oslo, Norway, June 14–17, 2005.
- First European Workshop on Automatic Differentiation held at Nice, France, April 14–15, 2005.

In addition, Martin Bütter served on the program committee for:

- Workshop on Language-Based Parallel Programming Models (WLPP) held in conjunction with the 6th International Conference on Parallel Processing and Applied Mathematics (PPAM’2005), Poznan, Poland, September 13–16, 2005.
- Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC–05) held in conjunction with the 19th International Parallel and Distributed Processing Symposium (IPDPS–2005), Denver, USA, April 4–8, 2005.

Martin Bütter and Uwe Naumann are also co-editors of the following book:

Talks and Publications

Talks


H. M. Bücker: *Tutorium zum automatischen Differenzieren*, Internes Seminar des SFB 540, RWTH Aachen, Germany, 4. Oktober 2005

H. M. Bücker: *Aufbau und Funktionsweise eines Rechners*, Vorkurs Informatik der Fachgruppe Informatik für Studienanfänger, Aachen, Germany, 4. Oktober 2005


C. H. Bischof: *Recent Developments in Automatic Differentiation*, Department of Computer Science, UC Davis, USA, July 27, 2005

O. Fortmeier: *Stabile Finite Elemente Diskretisierungen für Konvektions-Diffusionsprobleme*, Lehrstuhl für Hochleistungsrechnen, RWTH Aachen, Germany, 8. Juli 2005


M. Petera: *Automatic Differentiation in CapeML and an Application to a Distillation Column Problem*, Graduiertenkolleg “Hierarchie und Symmetrie in mathematischen Modellen”, RWTH Aachen, Germany, June 03, 2005


M. Petera: *ADiCape in a large scale industrial problem*, 1st European Workshop on Automatic Differentiation, Nice, France, 15. April 2005

H. M. Bucker: *Automatische Berechnung von Ableitungen für MATLAB-Programme*, Universität Siegen, Siegen, Germany, 7. April 2005


H. M. Bucker: *Was nutzen algorithmische Ableitungen in geophysikalischen Computersimulationen?*, Fakultät für Geowissenschaften, Ludwig-Maximilians-Universität, München, Germany, 25. Januar 2005

**Publications**


LuFG Software and Tools for Computational Engineering

Staff

- Faculty:
  Uwe Naumann
- Secretary:
  Renate Didolff
- Research Assistant:
  Ebadollah Varnik
- Technical Staff:
  Dmitrij Gendler
- Student Researchers:
  Lilya Sadikova, Yuxiao Hu, Michael Maier
Overview

Our research activities aim to provide algorithms and software tools to support the use of modern methods from applied mathematics and computer science in computational science and engineering. More specifically, we are interested in the source transformation of numerical simulation programs with the objective to modify the semantics based on well-defined mathematical rules. The automatic generation of tangent-linear and adjoint codes represents an important example for such a transformation. Ongoing projects are dedicated to the corresponding analytic and compiler issues as well as to the investigation of related graph-theoretical and combinatorial problems.

Research Projects

Adjoint Compiler Technology and Standards (ACTS)

Naumann

The ACTS project is a collaborative research and development effort in automatic differentiation (AD) focusing on its application and next-generation tool development. The project also involves oceanographers and chemical engineers at MIT and computer scientists at Argonne National Laboratory/University of Chicago and Rice University. Its main outcome is a platform for the development and implementation of programming language independent AD algorithms. The software is known as OpenAD. Its main application within the ACTS project is the generation of an adjoint for the MIT General Circulation Model (http://mitgcm.org). Refer to http://www.mcs.anl.gov/OpenAD for further information.

Compilation of Adjoint Codes and Application for Optimization (CACAO)

Naumann

The CACAO project aims to advance open tools for the automatic differentiation (AD) of numerical programs and their application for large-scale non-smooth optimization in geoscience and fluid dynamics. This project is a collaboration with the Institute for Scientific Computing at RWTH Aachen University, the Institute of Oceanography at Hamburg University, the Max-Planck-Institute for Meteorology in Hamburg,
the Department of Mathematics at Humboldt University Berlin, and the Institute for Scientific Computing at Technical University Dresden. A collection of proposals (Normalverfahren) has been submitted to the DFG.

CACAO combines the development of numerical simulation codes in oceanography, meteorology, and aeronautics with the automatic generation of the corresponding adjoint codes through AD by compiler-based source transformation. Special emphasis is put on the use of AD for large-scale non-smooth optimization in the context of sensitivity studies, data assimilation, and inverse design and for uncertainty quantification. The combining element of all individual contributions to this effort is the need for derivative information with respect to a very large number of model parameters for potentially only piecewise differentiable functions. Neither classical numerical differentiation by finite difference quotients nor standard tangent-linear models provide adequate support for the optimization algorithms to be newly developed. The ability to generate robust adjoint codes automatically based on the original numerical model is crucial for gaining further insight into the real-world behavior of the underlying physical systems.

### Combinatorial Problems in AD

*Hu, Naumann, Varnik*

The ability to generate efficient derivative code for numerical programs requires the solution of various graph-theoretical and combinatorial problems. We have been focusing on the efficient accumulation of derivative information by elimination techniques on the linearized (dual) computational graph. Furthermore, we are interested in the efficient reversal of numerical programs in the context of automatic generation of efficient adjoint codes.

### AD-enabled Compiler Technology

*Naumann*

With \texttt{sin} or \texttt{exp} being intrinsics in virtually all high-level programming languages could \texttt{jacobian} or \texttt{hessian} not be intrinsics as well? The integration of features that are of interest to numerical simulation into widely used compilers is an important goal of our work. We have been collaborating with the Numerical Algorithms Group (NAG) in Oxford, the University of Hertfordshire, Hatfield, UK, and Humboldt University Berlin in a project that aims to put automatic differentiation capabilities into NAG’s Fortran 95 compiler. Refer to
http://www.nag.co.uk/nagware/research/ad_overview.asp

for further information on the CompAD project.

**Automatic Differentiation of Assembler Code (ADAC)**

*Gendler, Naumann*

We are working on the automatic generation of tangent-linear and adjoint models for assembler code resulting from the application of the GNU Compiler Collection (gcc) to numerical programs written in a variety of high-level programming languages. Refer to

http://www.stce.rwth-aachen.de/ADAC/

for further information.

**Program Analysis**

*Sadikova, Naumann*

The quality of the result of any source transformation depends heavily on the amount of knowledge about the program that can be gathered at compile time. We are investigating certain domain-specific data-flow analyses in the context of AD.
Other Activities

Prof. Naumann is a co-organizer of the Third International Workshop on Automatic Differentiation and its Applications to be held in Reading, UK, in May 2006.

Talks and Publications

Talks

Naumann: Min-Ops Derivative Computation is NP-complete, 2nd European Workshop on Automatic Differentiation, Shrivenham, Swindon, UK, November 2005

Naumann: Adjoint Compiler Technology, AGU Fall Meeting, San Francisco, USA, December 2005

Publications


M. Maier and U. Naumann: Intraprocedural adjoint code generated by the differentiation-enabled NAGWare Fortran compiler, To appear in proceedings of ECT 2006, Civil-Comp Press


U. Naumann: Syntax-Directed Derivative Code (Part II: Adjoint Code), AIB 2005-17
Dissertations
In this thesis we consider games over graphs as a means to investigate the inner structure of process logics, in particular of the $\mu$-calculus $L_\mu$. First, we show that Parikh’s Game Logic, a two-variable sublogic of the $\mu$-calculus, is expressive enough to capture a very powerful class of games, namely parity games. From this we can conclude that this apparently simple logic has a strict alternation hierarchy and reaches arbitrarily high levels of the $L_\mu$ alternation hierarchy. Secondly, we investigate a class of path-forming games with a long tradition in mathematics and applications to planning, and establish several results on their determinacy and logical definability. Finally, we devise a game that captures relevant issues of descriptive and computational complexity of the $\mu$-calculus. At the one hand, we show that this game naturally leads to instances of the model-checking problem for $L_\mu$ that can be solved in polynomial time. On the other hand, it allows us to prove a lower bound for the number of variables needed to describe transition systems in $L_\mu$. Thus we can demonstrate that the expressive power of the $\mu$-calculus strictly increases with the number of variables used in formulae. Already a particular case of this result, that three variables can express more than two, allows us to separate the expressive power of Parikh’s Game Logic and the $\mu$-calculus, a question that was open since 1983.

Evaluator: Prof. Dr. E. Grädel
External Evaluator: Dr. Igor Walukiewicz
Date of oral exam: May 12, 2005
A message-passing automaton is an abstract model for the implementation of a distributed system whose components communicate via message exchange and thereby define a collection of communication scenarios called message sequence charts. In this thesis, we study several variants of message-passing automata in a unifying framework. We classify their expressiveness in terms of state-space properties, synchronization behavior, and acceptance mode and also compare them to algebraic characterizations of sets of message sequence charts, among them the classes of recognizable and rational languages.

We then focus on finite-state devices with global acceptance condition that communicate via a priori unbounded channels. We show them to be exactly as expressive as the existential fragment of monadic second-order logic over message sequence charts and to be strictly weaker than full monadic second-order logic. It turns out that message-passing automata cannot be complemented and that they cannot be determinized in general. Those results rely on a new proof technique, which allows to apply graph acceptors as introduced by Thomas to the framework of message sequence charts.

**Evaluator:** Prof. Dr. K. Indermark  
**External Evaluator:** Prof. Dr. W. Thomas  
**Date of oral exam:** March 7, 2005
A common problem in the context of geometry processing is the large variety of possible surface representations used in practice. While traditional NURBS surfaces are the standard geometry representation employed by most CAD systems, triangle meshes have developed into an efficient and flexible alternative, and are therefore proposed as the main surface representation.

I will present methods for representing technical datasets by triangle meshes, such that these are of sufficient quality to be used in numerical simulations. This requires a concise approximation of the surface geometry as well as carefully optimized surface tessellations avoiding numerically critical degenerate triangles.

The second part of the talk deals with high quality shape editing based on concepts of surface optimization. Multiresolution modeling techniques will be shown to allow for both fine-scale and large-scale deformations while preserving all important surface features in an intuitive and natural manner. Robust and efficient techniques for solving the involved optimization problems are discussed.

Evaluator: Prof. Dr. L. Kobbelt
External Evaluator: Prof. Dr. P. Schröder
Date of oral exam: July 11, 2005
**Models and Algorithms for Ground Staff Scheduling on Airports**

**Jörg Herbers**

The planning of airport ground staff gives rise to a number of challenging optimisation problems. Ground handling workloads are naturally represented as work tasks, e.g. for baggage unloading or passenger check-in. These workloads must be covered by appropriate employees. Staff scheduling is usually carried out in several stages: In demand planning, workloads are aggregated and analysed, in shift planning, appropriate shift duties are generated, and rostering consists in generating lines of duty for the workers. These phases are strongly interrelated, and different optimisation problems have to be solved at each stage. Workforce scheduling models have traditionally built upon aggregate labour requirements given in discrete time periods. However, the literature does not describe any models or algorithms for the generation of appropriate workload representations. Additionally, it will not always be sufficient to cover coarse-grained abstractions of workloads. If information on flights as well as passenger and load figures are sufficiently exact, we will rather be interested in directly covering individual work tasks. Furthermore, shift scheduling and rostering approaches have regularly taken special assumptions or investigated simplified problems, limiting their practical applicability. In this work, we tackle optimisation problems at different planning stages. We show how in the presence of movable tasks, we can obtain a suitable demand curve representation of workloads, using a levelling procedure which combines aspects from vehicle routing and resource levelling. Furthermore, we devise two algorithms for task-level shift planning which relates to vehicle routing and shift scheduling models. The first method is an improvement procedure, building upon the results of a construction phase and dealing with a complex shift planning setting. The second algorithm focuses on a subclass of task-level shift planning and is able to solve many problems to proven optimality. Finally, we design an algorithm for complex cyclic rostering on the basis of aggregate workloads. The approach builds upon a novel model for representing flexible breaks and solves the shift scheduling and rostering stage simultaneously. Models and algorithms proposed in this thesis are more integrated and tackle more complex settings than previous approaches. We employ modern constraint programming and integer programming solution techniques, including column generation and branch-and-price. For the novel optimisation problems treated in this work, we provide complexity results. All algorithms are evaluated on complex large-scale test cases from the practice of airlines, airports and ground handling companies.

**Evaluator:** Prof. Dr. J. Hromkovic  
**External Evaluator:** Prof. Dr. H.-J. Zimmermann, Prof., Prof. Dr. P. Rossmanith  
**Date of oral exam:** March 14, 2005
The globally increasing use of data communication services, together with the development of innovative value added services, have considerably contributed to a dynamic convergence of different communication systems. However, provision of services across heterogeneous networks is still a highly complex task. Examples here include hand-over and billing mechanisms across wireless local area networks of different providers. Such services have long been available in traditional telecommunication networks.

This thesis focuses on the realisation of complex services in heterogeneous network structures. A state-of-the-art review is followed by a discussion and analysis of object oriented approaches. However, increasing users mobility and the option of object migration lead to highly complex scenarios with a huge variety of parameters. Therefore, the thesis introduces a simulation environment which allows a comparably simple and user-friendly evaluation of such scenarios.

Evaluator: Prof. Dr. O. Spaniol
External Evaluator: Prof. Dr. Claudia Linnhoff-Popien
Date of oral exam: 2 February 2005
Integrierte Low-Cost eHome-Systeme - Prozesse und Infrastrukturen
Michael Kirchhof

Up to now, eHome systems have been developed only in small numbers and have been custom-made. This costly situation can be changed. The goal is to provide an effective and efficient realization of integrated low-cost eHome systems. These systems are integrated by being web-enabled, connected to a service provider, and able to handle the heterogeneity within the eHome. They have to be low-cost to be successful in the market.

The development stages of eHome systems are separated into generations. First, the structure and the associated processes of the current state are analyzed. It is shown, how these systems impose burdens on the users by adding complexity to daily life instead of reducing it. The vision of an innovative forward-looking eHome system is introduced as third generation of eHome systems. The proposed optimized solution is based on product families and automated configuration and deployment techniques.

To support the development of eHome services, an eHome-specific software architecture is introduced. This architecture handles dynamic aspects of such systems and provides the developer with functionality-oriented components and abstracts from technology and device details. Furthermore, a set of basic infrastructure components to handle recurring and central tasks is introduced to ease the development of services. Thus, the maintainability of long-running eHome systems is increased.

The use of imperative programming languages for implementing functionality constitutes a breach. This complicates the development of services, as the provided language elements do not reflect the needs of developers. To solve this problem, a declarative specification using rules is introduced. With this new paradigm for services, development and maintainability are facilitated. The declarative paradigm allows for a flexible automatic evaluation of atomic correlations. It is shown how this paradigm can be seamlessly integrated into the component-based world. The large number of services in the ubiquitous eHome systems will cause conflicts on shared devices and resources. This will degrade an eHome system and will lead to irritation of the user. This issue is addressed by a conflict detection and conflict resolution.

Finally, the distribution phase of eHome systems is discussed. The goal is to optimize the costly distribution and customizing of eHome systems for individual users. To raise the efficiency and effectiveness, a competence-oriented procedure is developed. In addition, this procedure improves flexibility. Finally, the appropriateness of a workflow management system to handle the concurrent process instances is discussed.

**Evaluator:** Prof. Dr.-Ing. Manfred Nagl  
**External Evaluator:** Prof. Dr. Harald C. Gall  
**Day of oral exam:** October 18, 2005
In this dissertation, the authoring tool `aTool` is described. It is an extension to MS-Word and allows the author to create the *formal structure* of his text while he is writing and formatting it. The structure is modeled as an XML document. `aTool` supports the author in creating that structure by semi-automatically deriving it from the text’s typography. The former internal structure has thus been made external.

The formalized text structure reduces publication time for articles, allows better archiving and supports text understanding. `aTool` is unique in its editing capabilities: Today’s XML tools are either specialized editors, which are too complex for the casual writer, or pure batch-converters, that still need manual corrections on their output documents.

`aTool` is based on requirements developed in cooperation with the publisher Springer-Verlag. Its primary area of application is, therefore, scientific articles. Springer-Verlag wants its authors to stick to a predefined text structure. With `aTool` these structure requirements are formalized in an extended DTD, making `aTool` parameterizable. The author uses `aTool` to create his text. He can still use *instance-based formatting* to mark up and structure his text. `aTool` continuously and incrementally parses the formatted text and creates an *integrated, typed XML structure*.

To do this, `aTool` abstracts from the concrete formatting and then unites equally formatted characters to tokens. The *parsing* step then creates a tree structure solely from the token sequence. The more complex *mapping* derives types for the elements on this tree, based on the formatting as well as on the formalized structure requirements. As the author works with formatting, the mapping emphasizes typography over structure. As parsing and mapping must be ambiguous for natural texts, `aTool` works semi-automatically and postpones decisions until the author solved problematic cases.

If the derived structure violates the given requirements, `aTool` calculates constructive error messages. It determines all minimal editing command sequences that correct the erroneous structure and presents them to the author giving him concrete directions.

Although `aTool` has been designed with the publication scenario in mind, it can be used wherever structure documents are required and the authors are accustomed to writing formatted texts with MS-Word.

This thesis, therefore, also tests `aTool`’s applicability in the area of variant support. In cooperation with T-Systems GEI GmbH, a software manual has been used as an example. For each variant of the software a modified manual is to be created. `aTool` is used to support the creation of these manuals’ document family. The XML structure of the document variants helps to determine common and variant specific parts. These parts are separated and collected again in a single document source covering all variants. From that source, specific variants are automatically created. As the same configuration is used to define the software variant as the manual variant, both products are always consistent. We expect changes in the
manuals as well as in the software. Therefore, the topic of maintenance is well addressed in the thesis. Again the XML structure helps in the process.

The structure recognition of \textit{aTool} finds its limits when it comes to complex semantical text structures. Those structures are not integrated in the natural text and emphasized using typography and formatting. Such a structure, modeling topics, and their semantical relations must be modeled as a graph. The co-dissertation [Gat04] developed CHASID which uses a top-down approach to create the text model in accordance with a sophisticated document scheme.

As a third application area, the thesis describes \textit{aTool} as media creator in an integrated application of \textit{aTool} and CHASID. Here, the user friendly, and unintrusive \textit{aTool} is used as a front-end for the semantically rich CHASID. The derived syntactical structure of \textit{aTool} becomes an intermediate step in the creation of the semantical structure of CHASID easing the process for the author. Specific XML elements are then mapped to semantical concepts in CHASID via application specific parameterization.

\textbf{Evaluator:} Prof. Dr.-Ing. Manfred Nagl  
\textbf{External Evaluator:} Prof. Dr. Ulrik Schroeder  
\textbf{Day of oral exam:} April 6, 2005
Adaptive User Interfaces are an important success factor for the development of information and communication systems and, in particular, for those subsystems where interaction with end-users is critical, like therapeutical and training systems. Current adaptive interfaces are based upon user and device profiles.

The presented work adds a new powerful tool for the development of such adaptive systems by analysing the arousal states of the user with non-invasive biofeedback sensors. This provides reliable means to recognise the arousal states of the user that complements research attempts in this area that interpret arousal states by other external signals of the human body, like gestures, speech intonation, blood pressure, skin-conductivity etc.

On this basis, an architecture to build generic emotional computer systems is constructed, which can be used as a template to create such systems in different application areas. The developed system proposes a combination of sensors and a set of effective algorithms to infer the arousal state of the user. This information is used to modify the behaviour and the interfaces of the application. In particular, a therapeutical system was developed where Interface Agents which themselves can communicate through mimic, speech and affective expressions with the user modify their behaviour according to the arousal status of the user. This approach can be extended to develop narrative training and therapeutical systems, which could adapt their functionality and user interface to the motivation level of the user, and focus her attention on the fulfilment of the current task.

The aforementioned recognition process elicits the users arousal states at a level sophisticated enough for the target systems. It is beyond the scope of this work to imitate affective or recognition abilities of human beings. The process describes several input devices to measure the arousal state of a user and shows a concept for its interpretation. The architecture consists of the following components:

- Input devices, e.g., optical sensors, acoustical sensors or biofeedback sensors.
- Assessment methodologies and stochastic methods.
- Simulation of emotions in Interface Agents.
- Integration in applications, and especially as a multimodal Human-Computer Interface.

As a proof-of-concept, the author developed and thoroughly evaluated a therapeutical system TAPA, Training by Animated Pedagogical Agents targeted to learning disabled children. These children have frequently deficits in their meta-memory strategies, i.e., the users knowledge about their own memory abilities, like categorising objects. TAPA is based upon the concepts described above and uses the skin conductivity sensor as the input device to measure the users arousal states. The system trains end-users to improve their meta-memory abilities, and the evaluations performed with groups of children with a variety of learning disabilities
have shown very promising results, as children who used the system greatly improved their skills in this area in comparison to different control groups.

The development of TAPA, and in general of any emotional computer system, requires a multidisciplinary approach where different disciplines and technologies collaborate together, especially computer science and psychology. Among the technologies utilised in this work, we can highlight: interface design and story-telling, user modelling, e-learning and biofeedback sensors.

Evaluator: Prof. Dr. Thomas Berlage
External Evaluator: Prof. Dr. Matthias Jarke
Date of oral exam: June 24, 2005
This thesis presents an eLearning framework that allows to interactively work and experiment with mathematics; applications using this framework therefore open an intuitive perspective on mathematics and its practical use. The thesis is mainly organised in four chapters, each of which documents a step in the development process of the framework. The first chapter discusses the technical and practical foundations of web based learning and analyses existing solutions in the field of mathematics. The second chapter then takes a look at didactical concepts that are helpful for designing the framework and presents a didactical design process. The third chapter in turn describes the implementation of a component framework which meets the requirements stated in the first two chapters, and the last chapter describes the application and evaluation of the framework in a wide range of learning scenarios.

Taking a look at the constraints of web based learning reveals the sharp distinction between micro (client-based) and macro (server-based) level applications that leads to the specific structure of existing technical solutions in this field of eLearning software. Additionally, it can be seen that the content of an eLearning site is strongly determined by the underlying role model. This is illustrated by the analysis of two exemplary eLearning sites, which vary not only in terms of interactivity but also by the stakeholders (student, author, tutor, etc.) they address. It is shown that an increase of interactivity and reusability may be achieved on the one hand by extending the role model and on the other hand by adding further levels of development on the micro-level.

After discussing the differences of learning models and their relation to the concept of interactivity, we use Bruner’s Theory of Representations to design a suitable content model in mathematical eLearning. This content model is complemented on the methodic level by the taxonomy of Bloom. Combined with the discussion of some aspects of learner orientation, this leads to a comprehensive didactic design process for mathematical eLearning media.

Based on the technical and didactical requirements, the resulting implementation is described, consisting primarily of two frameworks: The MathletFactory, a framework for mathematical applets, and the TestletFactory a framework for interactive tests. While both of these offer a high amount of flexibility and reusability to students and authors, the MathletFactory additionally has a specific interface, allowing application programmers to rapidly develop new mathlets by simply adding mathematical entities to an applet and by specifying their displayed representation and update behaviour.

A focus of this work is put on the evaluation of the framework in several courses and training activities, leading to further didactical insights and to substantial technical improvements of the framework. For example, in response to discovered misconceptions, further user information like the domain of mathematical expressions are added. Also, the teacher’s and author’s perspective on the framework is illuminated, leading to a higher degree
of flexibility and reusability of the framework and eventually even to its transferability to extra-mathematical contexts. The outlook finally provides a view on possible integration paths leading towards a mathematical eLearning/-Teaching/-Research (eLTR) infrastructure as well as to an improved integration into the university’s local eLearning network.

**Evaluator:** Prof. Dr. Schroeder  
**External Evaluator:** Prof. Dr. V. Enß  
**Date of oral exam:** February 28, 2005
Mobile agents are largely autonomous programmes which may traverse networks independently. The mobility may be deployed, for example, to move programme execution across a network to a more powerful machine, or to avoid creation of a performance bottleneck in a network. To effectively achieve such a performance improvement precise knowledge about a networks resource utilisation is crucial. This holds particularly for heterogeneous systems such as the Internet, where no quality of service can be guaranteed. Many agent-based Internet applications have been discussed in the literature. However, so far approaches towards resource management and a performance-oriented service selection have hardly been discussed.

The thesis introduces an approach towards such a performance-oriented service selection for mobile agents. It is based upon a dedicated performance server that collects and analyses information on resource utilisation. Agents may use these information for service selection. The evaluation of this approach is done using benchmarks and analytical models.

**Evaluator:** Prof. Dr. O. Spaniol  
**External Evaluator:** Prof. Dr. Claudia Linnhoff-Popien  
**Date of oral exam:** 2 February 2005
Investigations on Linear Transformations for Speaker Adaptation and Normalization

Michael Pitz

In current state-of-the-art speech recognition systems linear transformations are widely used to care for a potential mismatch of the training and testing data and thus enhance the recognition performance. A large number of approaches has been proposed in literature, though the connections between them have been disregarded so far. By developing a unified mathematical framework, close relationships between the particular approaches are identified and analyzed in detail.

Mel frequency Cepstral coefficients (MFCC) are commonly used features for automatic speech recognition systems. The traditional way of computing MFCCs suffers from a twofold smoothing, which complicates both the MFCC computation and the system optimization. An improved approach is developed that does not use any filter bank and thus avoids the twofold smoothing. This integrated approach allows a very compact implementation and needs less parameters to be optimized.

Starting from this new computation scheme for MFCCs, it is proven analytically that vocal tract normalization (VTN) equals a linear transformation in the Cepstral space for arbitrary invertible warping functions. The transformation matrix for VTN is explicitly calculated exemplary for three commonly used warping functions. Based on some general characteristics of typical VTN warping functions, a common structure of the transformation matrix is derived that is almost independent of the specific functional form of the warping function. By expressing VTN as a linear transformation it is possible, for the first time, to take the Jacobian determinant of the transformation into account for any warping function. The effect of considering the Jacobian determinant on the warping factor estimation is studied in detail.

The second part of this thesis deals with a special linear transformation for speaker adaptation, the Maximum Likelihood Linear Regression (MLLR) approach. Based on the close interrelationship between MLLR and VTN proven in the first part, the general structure of the VTN matrix is adopted to restrict the MLLR matrix to a band structure, which significantly improves the MLLR adaptation for the case of limited available adaptation data.

Finally, several enhancements to MLLR speaker adaptation are discussed. One deals with refined definitions of regression classes, which is of special importance for fast adaptation when only limited adaptation data are available. Another enhancement makes use of confidence measures to care for recognition errors that decrease the adaptation performance in the first pass of a two-pass adaptation process.

Evaluator: Prof. Dr.-Ing. Hermann Ney
External Evaluator: Prof. Dr. Christian Wellekens
Date of oral exam: March 14, 2005
In the classical framework of graph algorithms, program logics, and corresponding model checking games, one considers changes of system states and movements of agents within a system, but the underlying graph or structure is assumed to be static. This limitation motivates a more general approach where dynamic changes of structures are relevant.

In this thesis, we take up a proposal of van Benthem from 2002 and consider games and modal logics over dynamically changing structures, where we focus on the deletion of edges of a graph, resp., transitions of a Kripke structure. We investigate two-player games where one player tries to reach a designated vertex of a graph while the opponent sabotages this by deleting edges. It is shown that adding the ‘saboteur’ makes these games algorithmically much harder to solve. Further, we analyze corresponding modal logics which are augmented with cross-model modalities referring to submodels from which a transition has been removed. On the one hand, it turns out that these ‘sabotage modalities’ already strengthen standard modal logic in such a way that many nice algorithmic and model-theoretic properties get lost. On the other hand, the model checking problem remains decidable.

The main limitation of modal logic is the lack of a mechanism for unbounded iteration or recursion. To overcome this, we augment the ‘sabotage modal logics’ of the first part of the thesis with constructors for forming least and greatest monadic fixed-points. The resulting logic extends the well-known $\mu$-calculus and is capable of expressing iterative properties like reachability or recurrence as well as basic changes of the underlying Kripke structure, namely, the deletion of transitions. Finally, we introduce extended parity games where in addition, both players are able to delete edges of the arena and to store, resp., restore the current appearance of the arena by use of a fixed number of registers. We show that these games serve as model checking games for the aforementioned ‘sabotage $\mu$-calculus’.

Evaluator: Prof. Dr. W. Thomas
External Evaluator: Prof. Dr. J. van Benthem (University of Amsterdam & Stanford University)
Date of oral exam: December 08, 2005
Recently, the focus in statistical machine translation changed from single-word-based to phrase-based approaches. These methods allow to take more local context into account and they can improve local reordering, leading to significantly better translation quality. In this thesis, we present training and decoding techniques that allow for a generalization of the phrase alignment to a hierarchical alignment using cascaded probabilistic transducers.

First, we present a novel phrase alignment method, based on extensions of existing word alignment algorithms. The major advantage of the new method is, that it uses neither the maximum approximation nor heuristically combined alignments.

For training a hierarchical phrase alignment, we present an extension to the so-called HMM alignment in a word graph. By using a cascade of finite state transducers on a bilingual corpus, we perform bilingual partial parsing. The graph alignment method then finds the best assignment between both parse-structures and allows for an estimation of the probabilities of the probabilistic transducers.

Then, we describe a two-phase decoding algorithm. First, we apply the transducers to generate translations for single words and phrases of a sentence. The result is a graph structure. In the second phase, we perform a single-best path or n-best paths search in this graph. The search algorithm is formulated in a way, that word reordering between source and target is possible. Recombination of partial hypotheses as well as a flexible pruning strategy ensure fast decoding.

We present experimental results on various corpora, restricted domains with limited vocabulary as well as more or less unrestricted domains with very large vocabulary.

**Evaluator:** Prof. Dr.-Ing. Hermann Ney  
**External Evaluator:** Prof. Dr. Alexander Waibel  
**Date of oral exam:** December 9, 2005
Indoor Geolocation Using Wireless Local Area Networks

Michael Wallbaum

Location information is essential for many application domains, such as seafaring, aviation, robotics, virtual reality, logistics and land surveying, just to name a few. However, no existing positioning system fulfils the needs of all domains. Particularly, positioning in indoor areas is still a topic of research, since conventional GPS does not provide coverage within buildings. Even if this were the case, its accuracy would not be sufficient to discriminate different rooms, not to mention floors. Cellular network positioning systems do provide indoor coverage but are even less accurate. Although specialised indoor positioning systems have been proposed, these are typically cost-intensive and restricted to single buildings or even rooms. A low-cost solution to the problem of locating users within buildings are location systems based on Wireless LAN, which are the topic of the thesis. In indoor areas the use of a Wireless LAN infrastructure as positioning system for location-aware applications offers some advantages compared to other solutions. Firstly, Wireless LANs and associated end-user devices have become wide-spread in the past few years. Thus, operators of location systems are relieved from the burden of installing costly dedicated systems. Secondly, location services based on Wireless LAN sensors offer accuracy sufficient to meet the requirements of many applications. Location estimates can be given with an accuracy ranging from few hundreds down to some meters, depending on whether simple proximity detection or more complex schemes are used. This can easily compete with the accuracy currently offered by mobile communication networks. Finally, in contrast to GPS, Wireless LAN positioning systems unconditionally work indoors as well as outdoors. This facilitates the deployment of a wide range of location-aware services using a single infrastructure.

The thesis describes a Wireless LAN positioning system, which is embedded in a logically centralised location service. The presented system has a number of properties that render it particularly suitable for large-scale deployment and its integration with wide-area cellular communication networks. In this context issues related to planning, deployment and maintenance are of utmost importance. Wireless LAN positioning relies on received signal strength measurements, and existing systems require time-consuming calibration measurements in the entire area of coverage. Moreover, this training phase must be repeated whenever the environment changes, e.g. when new access points are installed. This is unacceptable to mobile operators with Wireless LANs in hundreds of hotels, airports and public places. The presented system uses radio propagation models to eliminate the need for extensive work in the field. Furthermore, an analytical model is introduced that provides support in the planning phase by predicting the location accuracy in a given environment. Indoor location systems are typically expected to achieve at least room-level accuracy for most position estimates. This meets the requirements of virtually all frequently mentioned indoor applications. Hence, an algorithm is proposed with a resolution in the order of a few meters. A problem in this respect is that reference data obtained from radio propagation models is generally less accurate than data from calibration measurements. Despite this obstacle, the proposed positioning scheme provides a performance similar to existing systems. In
addition, the location estimates do not lag, since the scheme holds state information. This is a significant advantage when tracking moving objects. Finally, the scheme also allows to estimate the location error dynamically at run-time. Good error estimates permit users to judge the quality of location information, and consequently serve to increase the system’s credibility.

Evaluator: Prof. Dr. O. Spaniol
External Evaluator: Prof. Dr. Martin Mauve
Date of oral exam: December 20, 2005
The extension of formal verification methods to infinite models requires classes of graphs which are finitely representable and for which the model checking problem is decidable. We consider three approaches to define classes of finitely representable graphs: internal representations as configuration graphs of higher-order pushdown systems, transformational representations by application of operations which preserve the decidability of the model checking problem, and by composition from components using synchronized products.

In the first part of the thesis we show that the hierarchy of higher-order pushdown graphs coincides with the Cauca hierarchy of graphs. We thus obtain transformational representations of higher-order pushdown graphs and can conclude that they enjoy a decidable monadic second-order theory.

In the second part of the thesis we investigate synchronized products of finitely representable infinite graphs and show that the decidability of an extension of first-order logic with reachability predicates is preserved under the formation of finitely synchronized products. This result is complemented by undecidability results for extensions of the admissible product operations as well as the expressive power of the logic under consideration.

Evaluator: Prof. Dr. W. Thomas
External Evaluator: Dr. habil. D. Cauca
Date of oral exam: June 30, 2005
• Faculty:
  Prof. Dr.-Ing. Hermann Ney
• Research Assistants:
  Dipl.-Inform. Willi Geffers
• Technical Staff:
  Marion Brandt-Röhrig, M.A.
  Stefanie Scholten
  Frank Tammer
  Karl-Heinz Thevis
• Student Workers:
  Moaffak Assassa
  Uta Christoph
  Jens Forster
  Enisa Mušović
  Faruk Sari
  Ilhan Ucar
Overview

Since 1985 the System Administration Group (RBI\textsuperscript{1}) operates several computer labs and provides technical support for the Department of Computer Science at RWTH Aachen. The principal task of the RBI is to install, maintain, and evolve the local network and several central services, including file servers, a database server, mail server, and web server. Students, faculty, and staff have free unlimited access to the computer labs operated by the RBI.

The computer labs are used in computer science courses and for student and faculty research projects. Especially for novice users, a user helpdesk is offered during business hours. The labs are provided with PCs running the Debian GNU/Linux operating system. The computers are equipped with various hardware extensions and software to support the students in doing their exercises and projects. All computers are part of the local area network and provide unrestricted access to the campus backbone and the internet.

News

- The user administration for the computer labs has been reorganized. Now administration and helpdesk are both located in room 4u16a and there are no longer explicit opening hours for the user administration. Two LDAP servers are now used to maintain user specific data.

- In the computer labs, 4 workstations have been replaced. The new computers are equipped with 3.2 GHz Intel Pentium IV CPU, 2 GB memory, 200 GB hard disk, and gigabit ethernet. Furthermore, a laser printer has been replaced. The printing service is now provided by two HP LaserJet 4100 and 4300 printers.

- The file server disk capacity for students has been extended. The Sun Enterprise 250 server now provides 14 additional disks with 146 GB per disk and the total disk capacity of all file servers increased to 3 terabyte.

- 18 additional compute nodes have been purchased to extend the high-performance computing cluster. The nodes are based on IBM eServer 326 with 2 AMD Opteron CPUs, 8-16 GB RAM, and several gigabit ethernet ports. 4 nodes provide AMD's Dual-Core technology. Altogether the cluster offers a total of 49 compute nodes and 98 CPUs. The N1 Grid Engine software is used to schedule jobs on the cluster.

\textsuperscript{1}Rechnerbetrieb Informatik
Equipment

Computer Laboratories

Altogether the RBI operates seven labs in the basement of the E1 and E2 building. The labs are provided with various hardware platforms running the Debian GNU/Linux operating system.

<table>
<thead>
<tr>
<th>Room</th>
<th>Computers</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>4U13</td>
<td>6</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>4U15</td>
<td>20</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>4U16</td>
<td>16</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>4U18</td>
<td>16</td>
<td>Intel P-III PC</td>
</tr>
<tr>
<td>6U07</td>
<td>8</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>6U09</td>
<td>8</td>
<td>AMD Opteron PC</td>
</tr>
</tbody>
</table>

Also available are two high-quality postscript laser printers as well as color ink printers. The outputs can be obtained from the user helpdesk located next to the labs in building E1.

Two computer labs and the staff offices are located in the basement of building E2. The labs are particularly intended for practical courses and student research projects.

Most GNU tools and many other free- and shareware tools are installed. For documentation purposes the typesetting system \TeX/L\TeX and desktop publisher OpenOffice are available. Programming languages are particularly important and C, C++, Fortran, Pascal, and JAVA including extension libraries, source code management systems like CVS and subversion as well as source level debuggers are available. Coding is done with popular editors like vi and XEmacs. Especially for students in the first stage of the study course interpreters and compilers for Clisp, Scheme, and Prolog are installed.

In addition the computers in the labs are configured for cluster grid computing. The N1 Grid Engine software is used to schedule jobs on the cluster.

Server Equipment

- Currently the RBI operates 3 file servers, a Sun Fire 280R, a Sun Enterprise 250, and a Sun Enterprise 3000, with a total hard disk capacity of almost 3 terabyte.
• Install servers for Linux speed up and simplify the installation of the computers in the labs. The operating system is automatically installed from network including all customizations.

• A dedicated mailserver provides email service for the students.

• Furthermore the RBI provides the primary webserver of the department.

• A database server running the Oracle database management system contains the database of the computer science library and handles all inquiries.

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**Local Area Network**

Since 1986 the Department of Computer Science runs a computer network according to the IEEE 802.3 standard. Twisted pair cables according to 10BaseT and 100BaseT are widely-used. Previously installed thin and thick wire cables are hardly used today.

The bandwidth increased significantly due to inexpensive switching technology and an increase of the transfer rate from 10 to 100 Mbit/s. Above all an uncoupling of the network traffic and thus a further increase of the network throughput could be obtained by switching technology. Simple Ethernet HUBs with a transfer rate of 10 Mbit/s were replaced by FastEthernet switches using transfer rates of 100 Mbit/s and load balancing.

A CISCO Catalyst 6500 router is used as the primary router for the whole department and provides redundant access to the campus backbone. For services that require high network bandwidth, e.g. fileservers and database servers, we use gigabit ethernet either over twisted pair or over optical fiber. New chairs realize their local network completely based on optical fiber.

A wireless LAN has been installed in all public areas of the department and most chairs and research areas. Currently the wireless LAN is based on the IEEE 802.11 b/g standard and operates at a maximum speed of 54 Mbit/s.

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**Multimedia**

Two multimedia rooms are available for video conferencing and live recording of presentations. Each of the rooms has two video beamers and two video cameras, video and audio mixers, several video recorders, and computers for video processing.

Additional beamers and digital cameras can be borrowed for courses and presentations.
Services

User Helpdesk and Opening Hours

The user helpdesk is located in room 4U16a in the basement of building E1. You may contact it directly, by email rbi-beratung@informatik.rwth-aachen.de, or by phone 0241/80-21038.

Usually the computer labs are open as follows:

<table>
<thead>
<tr>
<th>Period</th>
<th>Mon</th>
<th>Tue - Thu</th>
<th>Fri</th>
</tr>
</thead>
<tbody>
<tr>
<td>during terms</td>
<td>9 a.m. - 7 p.m.</td>
<td>9 a.m. - 9 p.m.</td>
<td>9 a.m. - 6 p.m.</td>
</tr>
<tr>
<td>between terms</td>
<td>9 a.m. - 7 p.m.</td>
<td>9 a.m. - 5 p.m.</td>
<td></td>
</tr>
</tbody>
</table>

For detailed information and current changes please note the announcements on the billboards or check http://www.informatik.rwth-aachen.de/rbi.html for a listing of all RBI labs’ hours of operation, including exceptions due to holidays and breaks.

Computer Science Library

The RBI maintains the entire hard- and software of the computer science library. This includes the workstations and PCs of the library staff and library users as well as the database server. The database contains the entire stock of books and journals of the library. The RBI develops and supports dedicated software for cataloging and querying the database.
Staff

- Head:
  Dipl.-Bibl. Renate Eschenbach-Thomas

- Assistants:
  Nadine Behnke
  Ingo Hengstebeck
  Florian Hillebrand
  Michael Rose
  Ralitza Vantcheva
  Martina Witt
  Birgit Zagolla

The library is open to everyone. Students use it as a reference library, but they may take books home overnight. Professors and scientific assistants may borrow books and use them in their offices.

Opening hours: Mo-Fr: 9 a.m. - 8 p.m.

**Address:** Bibliothek der FG Informatik, RWTH Aachen, Ahornstr. 55, D-52056 Aachen, Germany
http://www-bib.informatik.rwth-aachen.de

**Phone:** +49/241/ 80-21025
**Fax:** +49/241/ 80-22366
**E-Mail:** biblio@informatik.rwth-aachen.de
1 What you can find in our library:

- More than 34000 monographs and conference proceedings recorded in an online public access catalogue (OPAC)
- “Handapparate”: Required readings for the courses, compiled by professors for their students, accessible on special shelves
- All diploma theses of our department recorded in a separate database
- Complete stock of the Springer “Lecture Notes in Computer Science” up to Volume 3000 as well as “Informatik-Fachberichte / Informatik Aktuell” up to last year; from then on only selected titles
- More than 300 journals
- Always up to date: Magazines like C’t, iX, PC Professionell, Linux-Magazin, Die ZEIT, Wirtschaftswoche, . . .
- Technical reports from our 59 exchange partners from domestic and foreign universities
- Service for department staff: Books and articles not available on site are procured from the central university library or from international library supplies
- Website containing plenty of information on our stock as well as interesting computer science links
- Four workstations and 60 comfortable work places; separate student group work spaces
- MoPS-zone for laptop users
- Scanner and copier
- Guided tours through the library for new members of our department providing information on our services
- Friendly and qualified consulting and assistance for our visitors
- Up-to-date press reviews on computer science, student life and the RWTH Aachen
2 News

The Open-Air Reading Room ("Lesegarten")

After years of planning, following an initiative and idea of the librarian, Renate Eschenbach-Thomas, and her long efforts in realizing the project, the open-air reading room of the library was finally completed in October 2005. This is an open space of about 150 square meters accessible from the main room of the library, surrounded by some plants and a gangway which connects two buildings of the Computer Science Center. When the weather permits, about fifty seats at seven round tables invite the users of the library to do their studies in the open air. Of course, there are also umbrellas for shelter from the sun on hot days. During the warm October (and even November) 2005, many students, assistants, and professors enjoyed this new library space which seems to be unique in the whole university.

The open-air reading room is also unique in another sense: In view of unsurmountable difficulties to realize this project from money of the university or the state, the open-air reading room was financed completely by sponsor money from all groups of the computer
science department; they contributed resources of their free funds (earned in industrial projects), altogether around 15000 Euro. This is a remarkable sign of solidarity for which the many users of the library thank their professors in the computer science department very much.

In the year 2006, more work is to be done to complete the “green belt” around the reading space, and in spring 2006 the official opening party will be held. In the next annual report, news about this event will be presented, as well as some pictures.

**Literature Search Training**

Our service in training the competence of students in literature search (especially the efficient use of online databases for computer science) was extended considerably on the levels of proseminars and seminars. In most proseminars and many seminars, this training (with exercises prepared individually for each participant and her/his topic) is now compulsory, and the evaluations by the participants show that this teaching unit is highly ranked and popular.
Botzen, Matthias
Bremer, Barbara
Deifuß, Georg
Forster, Jens
Friedrich, David
Giebel, Robert
Habets, Corinna
Hillebrand, Florian
Hink, Gregor
Kesselheim, Thomas
Kube, Ralph
Kuramoto, Nobuyoshi
Lehnen, Patrick
Loch, Eva
Martini, Andrea
Mungard, Nan
Nelles, Anna
Peter, Katharina
Runte, Sven
Scholtes, Sebastian
Schmiedt, Jacob
Schwark, Christoph
Simon, Peter
Spiller, Robert
Wüst, Sebastian
Overview

Fachschaft Mathematik, Physik, Informatik  Tel. (02 41) 80-45 06
Kármánstraße 7, 3rd level (mail at: FS I/1, Templergraben 55, 52056 Aachen)
e-mail: fs@fsmpi.rwth-aachen.de
WWW: http://fsmpi.rwth-aachen.de/

Opening hours during lecture period:  Mo–Fr  12–14 h
during lecture free period:  Tu & Th  12–14 h
Meetings of the Fachschaft:  Mo 19 h in the rooms of the Fachschaft
Plenary meetings:  at the beginning of each semester

The Fachschaft (group of student representatives) is a part of the student body and represents the interests of all students who study mathematics, physics, or computer science at the RWTH Aachen.

At the beginning of each semester a plenary meeting is held where every student of mathematics, physics, and computer science at the RWTH Aachen is invited. Here, the election of the collective takes place, and the major topics concerning the upcoming semester and the work of the Fachschaft in general are addressed. The collective is a group of students who take responsibility towards the accomplishment of the aspired goals and tasks. In addition to the collective other students work for/in the group of student representatives. Working at this group is complimentary.

We have weekly meetings where current concerns are discussed and work is coordinated. Any student of mathematics, physics, or computer science at the RWTH Aachen is welcome, allowed to speak, and invited to participate. Decisions are made in consensus.

Service

The Fachschaft has regular opening hours and offers support to students by students concerning the course of study but also on issues not directly related to the university. We have a collection of old exercises and protocols of exams which can be viewed and copied in our rooms. We have implemented a digital collection of old exercises and protocols which is used for all newly incoming exercises and protocols. Furthermore there are books, magazines and newspapers.

Dealing with the Situation of the Students

To work against the anonymity of the university and help beginners to orient we work together with the ErstsemesterInnen Projekt der Fachschaften (autonomous fresh(wo)men project) and support the ErstsemesterInnen-AG. For further information, see next section.

The Fachschaft delegates students into several academic boards in accordance with the elections.

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Introduction of new Students

To introduce the new students to their new environment there are events organized by students. The ErstsemesterInnen-AG, a work group of the Fachschaft, arranges tutoring groups. These groups consist of several beginners and two tutors (students in a higher semester) as a first step for the new students to get to know each other.

Further, there is a weekend organized in a youth hostel. Every semester the ErstemesterInnen-AG publishes a magazin (ES-Info) containing information and guidance to people planning to study mathematics, physics or computer science at the RWTH.

The goals of these activities are:

- Build social contact after the loss of the old environment.
- Help to cope with the transfer from school to university (learning in individual responsibility) and to form groups (studying in a group, teamwork).
- Support in managing their studies.
- Basic approaches to reflect one’s own study situation.
- Information/Discussion on opportunities to exert influence in the university (academic self-management).
- Inspire studying in a solidary environment.

Working groups

The Fachschaft supports the foundation and work of student working groups. Hence the facilities of the Fachschaft is used by a few working groups.

ErstsemesterInnen-AG: Supports the beginners. See above.

Geier: The Geier (engl. vulture) is a leaflet (twosided DIN A4) with newsworthy information and references to events. The Geier is published every two weeks.

Publications

Was’n los, magazine of the Fachschaft, once or twice a semester.

ES-Info, information for beginners, once a semester.

Flyers, information about current things

Joint Projects and Organizations
The Bonn-Aachen International Center for Information Technology (B-IT) is a pioneering activity of the German Federal government and the state of North-Rhine-Westphalia in their effort to establish excellence clusters across universities and research institutes in Germany. B-IT is a joint institute of RWTH Aachen University and Bonn University in cooperation with the Fraunhofer Institute Center Birlinghoven Castle and the FH Bonn-Rhein-Sieg in Sankt Augustin. B-IT aims at the internationalization and acceleration of study programmes in Applied Informatics.

Supported by the B-IT Foundation and supplementary NRW state and federal funds, B-IT offers highly selective English-language master programmes in Media Informatics, Life Science Informatics, and Autonomous Systems. Moreover, B-IT offers summer
and winter schools for qualified undergraduate students from Bonn and RWTH Aachen University. The B-IT programmes are distinguished by a deep integration of teaching and research through close cooperation with the participating Fraunhofer institutes of Applied Information Technology (FIT), Autonomous Intelligent Systems (AIS), Media Communication (IMK), and Scientific Computing and Algorithms (SCAI).

From RWTH Aachen University, Prof. Dr. Matthias Jarke serves as Founding Director (together with Prof. Dr. A.B. Cremers, Bonn, and Prof. Dr. K. Witt, FH Bonn-Rhein-Sieg), whereas Prof. Dr. Otto Spaniol is Study Coordinator of the Media Informatics programme and Dr. Jürgen Rapp serves as study advisor. Main highlights of the year 2005 include:

• The accreditation process for the B-IT University Master Programmes was successfully completed officially in March 2005.

• The cooperation programmes signed in 2004 concerning pre-selection of top students from the Chinese provinces of Jiangsu and Sichuan were successfully brought into practical operation, as was the Erasmus-Mundus programme awarded to the Media Informatics programme together with the Computer Science departments of the Universities of Trento (Italy) and Edinburgh (UK), as one of only two successful applications in the computer science field. This 2.5 million EUR programme, called the European Master of Informatics (EuMI), will enable us for the next five years to support top extra-European students with quite generous stipends.

• While eight of the nine endowed B-IT professorships are now filled, the number of students has reached full capacity in Media Informatics and is approaching it in the other programmes. Students stem from 34 countries throughout the world, including an increasing number of German bachelor graduates.

A major effort was dedicated to the preparation of a BITGRAD proposal within the Graduate School section of the German Excellence Initiative, aimed at augmenting B-IT with a doctoral programme. As countrywide the only computer science graduate school proposal, BITGRAD passed the first round of reviews and was asked to prepare a full proposal which will be decided in the fall of 2006.
The mission of the Fraunhofer FIT Institute for Applied Information Technology in Birlinghoven Castle and Aachen is to support human-centered computing in the context of organizational processes. Researchers in FIT study lifecycle-wide methods for the design and evolution of adaptive, user-oriented information and cooperation systems in the interplay of human work practice with organizational processes.

In June 2005, a five-year technical and business audit for FIT was held with a very positive evaluation of the institute’s development since the merger of GMD into Fraunhofer in 2001, and excellent prospects for the future. Third-party funding of FIT grew by 7% to 4.6 million EUR in 2005, fostered by major cooperation projects with leading companies such as SAP, Telekom, and Microsoft, as well as with several small and medium enterprises.

With a research staff of about 80, plus about 60 student researchers, FIT pursues its mission in three major research areas which are complemented by special business fields and competence centers (see http://www.fit.fraunhofer.de for details):

- **FIT.CSCW** (leader: Prof. Dr. Wolfgang Prinz) investigates the field of Cooperation Systems. In 2005 two EU projects were successfully finished. The DRM project developed project management tools for the Microsoft SharePoint col-
laboration platform. The MOSAIC project investigated a roadmap for future collaboration environments and published the results in a book. COMIST a strategic support action of the EU developed a community portal for the AMI@Work communities of the EU. Within the recently started pervasive games project iPerG, a first version of the Epidemic Menace game was successfully demonstrated and played by two teams at the Fraunhofer Campus in Sankt Augustin.

The CONNECT project demonstrated the augmentation of museum exhibits successfully at several European science museums. A new version of BSCW, the web-based groupware platform of FIT.CSCW has been released and the 10th anniversary of BSCW has been celebrated at a users group meeting. For a large Swiss organisation a tool for the migration of the LinkWorks groupware system to MS-SharePoint has been developed. In a study for the United Nations the feasibility of a Government out of the Box solution for the rapid installation of eGovernment solutions in failed states has been analysed; one of the field studies was linked to the research on cultural heritage recovery in Afghanistan done at Informatik V.

- **FIT.LIFE** (leader: Prof. Dr. Thomas Berlage) investigates the field of Life Science Informatics, addressing navigational support for micro-surgery, systems environments for large-scale bioinformatics research, and assistive devices for users with special needs. The group investigates navigational software support in a newly established FUSION project on minimally-invasive liver therapy (http://www.somit-fusion.de). The group also developed a first prototype of a user-trainable analysis software for cell-based high throughput experiments that is being evaluated by multiple industrial users. Jointly with RWTH’s Informatik V and FIR institutes, an IBM Shared University Grant awarded in late 2004 provides the technical infrastructure. The FIT.BIKA competence center on barrier-free internet access (leader: Dr. Carlos Velasco) achieved a world-wide distribution agreement of their web content checking technology and continued to broaden the approach through their involvement in multiple European projects and activities.

- **FIT.ICON** (leader: Prof. Dr. Reinhard Oppermann) develops context-adaptive and mobile systems for eLearning and mobile work. Jointly with Informatik V, they are main partners in the ProLearn European Network of Excellence in Professional Technology-Enhanced Learning; other large eLearning projects include the AILB project which develops novel tools to enhance the basic professional competencies for hearing-impaired young workers; the latter is a joint project with the DESIRE research team at RWTH Aachen University led by Prof. Dr. Ludwig Jäger. Contextualization in mobile work settings is also the main topic of the MICA project that was recently started to make the SAP software environment more flexibly usable, and of a project with the new Telekom Labs in Berlin that addresses end-user development of advanced phone functionalities.
The FIT working group in Aachen is led by Dr. Andreas Becks and addresses information management aspects in business and engineering processes. Two major projects have been completed with remarkable success in 2005. The SEWASIE EU project has built a semantic web infrastructure for electronic business in cooperation with Informatik V, an Aachen-based software house, and a number of partners in Italy. In a final project review in Aachen, not only the project as a whole but in particular FIT and Informatik V received very high scores for their scientific and practical results.

Another effort, in cooperation with the Japanese Ricoh Corporation, has been concluded successfully with a project presentation in Tokyo. In close cooperation with the chemical engineering projects at Informatik V this project has addressed the media change between paper-based and electronic information media in business processes. This work has been embedded in the Business Process and Decision Support business field at Fraunhofer FIT which is coordinated by Prof. Dr. Thomas Rose.

As a new major activity, FIT and Informatik V have started the pre-launch phase of the “Zentrum für Softwarekonzepte - ZfS”, an initiative of Microsoft Germany in cooperation with several academic research institutions in Germany. In ZfS, researchers from FIT and Informatik V will work together in transferring research and development knowledge related to .NET technologies to small and medium enterprises.

Through these research activities, and through the teaching cooperation in the context of the Bonn-Aachen International Center for Information Technology (B-IT) and the BITGRAD Graduate School Proposal within the German Excellence Initiative, Fraunhofer FIT has further deepened its ties to RWTH Aachen University in 2005.

EU project CONNECT allows highschool teachers to configure their own dynamic augmentation of museum exhibits.
Graduiertenkolleg „Software für Kommunikationssysteme“ (Software for Communication Systems)

The „Graduiertenkolleg“ initiative is funded by the German Research Association (DFG). Its major intention is to substantially reduce the average time necessary to complete a PhD thesis. This time is generally considered as overly high and should, ideally, be reduced to three years while keeping the scientific quality at the highest possible level.

The proposal entitled 'Software for Communication Systems' was eventually accepted. Compared to its predecessor it covers more focused research questions, which concentrate on computer science and information technology. While this narrowing of focus is regrettable we have to recognise that this move satisfies the major intentions behind the concept of the „Graduiertenkolleg“.

- a. the initiative will be ongoing without further support from DFG (i.e. that there is a automatic dissemination and continuation aspect)
- b. there is always room for new proposals and new subjects in the programme.

1 Research Programme

The ideas of our „Graduiertenkolleg“ SSoftware for mobile Communication Systemsäre as follows (for a full version of the proposal (in German language) please see http://www-i4.informatik.rwth-aachen.de/Kolleg/):

New ways of exchanging data through different types of networks are continuously evolving. This includes particularly mobile communication, which has by now become more or less ubiquitous, thanks to an ever increasing level of user acceptance. This, in turn, is largely due to improved standards and a vastly expanded variety of services. Future application developments will more and more be based on user requirements rather than just feasibility. Here, the most important domains include electronic commerce, transport telematics, new forms of working, and other innovative concepts such as e-learning, e-government, and e-home. For these new applications to be acceptable, new underlying technologies and services are a sine-qua-non. Moreover, the increasing mobility of users will lead to an equally increasing role wireless networks will play in communication infrastructures. Yet, users expect application functionalities to be independent from the underlying communication network. Considerable additional research will be needed to actually meet this requirement. Within the framework of the Graduate School research will focus on three areas: 'Applications’, 'Middleware and New Services’ and 'Network Infrastructure’. New applications
will be specified, implemented, and tested. Middleware architectures and associated new services will on the one hand be designed to meet user and application requirements. On the other hand, they will be capable of adapting to different underlying communication architectures and infrastructures. Work will focus on those applications and services which lend themselves to access via wireless networks. Mechanisms to improve efficiency and reliability will be designed and evaluated.

The activities of the Graduate Schools will thus also contribute to making the European Commission’s vision of ‘e-Europe 2005: An Information society for all’ a reality. In addition, co-operation is sought with partners from industry. Major companies, including Ericsson, Philips, T-Mobile, and Nokia are co-operating with members of the ‘Graduiertenkolleg’ on a non-profit basis. Likewise, there is close co-operation with the Collaborative Research Centres ‘IMPROVE’.

2 Members of the „Graduiertenkolleg“

We are more than happy that all positions have been taken by highly qualified students. The current (April 2006) grant holders include:

- Dipl.-Inform. Ibrahim Armac, Chair Informatik III, Prof. Dr. Nagl
- Dipl.-Inform. Gernot Fabeck, Chair Theoretische Informationstechnik, Prof. Dr. Mathar
- Dipl.-Inform. Ingo Fliegen, Chair Informatik IV, Prof. Dr. Spaniol
- M.Sc. Lucia Draque Penso Rautenbach, Chair Informatik IV Lab, Prof. Dr. Freiling
- Dipl.-Inform. Sebastian Max, Chair Comnets, Prof. Dr. Walke
- Dipl.-Inform. Christof Mosler, Chair Informatik III, Prof. Dr. Nagl
- M.Sc. Satish Narayana Srirama, Chair Informatik V, Prof. Dr. Jarke
- M.Sc. Janne Riihijaervi, Chair Mobilfunknetze, Prof. Dr. Mähönen
- Dipl.-Inform. Stefan Schiffer, Chair Informatik IV Lab, Prof. Dr. Lakemeyer
- Dipl.-Inform. Arne Schmitz, Chair Informatik VIII, Prof. Dr. Kobbelt
- Dipl.-Inform. Dominik Schmitz, Chair Informatik V, Prof. Dr. Jarke
- Dipl.-Inform. Martin Wenig, Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Inform. Alexander Zimmermann, Chair Informatik IV, Prof. Dr. Spaniol
Seven students left the ‘Graduiertenkolleg’ during the reporting period. By now, they have successfully completed their theses, or are near completion.

- Dipl.-Phys. Vahza Amiranashvili, Chair Informatik IV Lab, Prof. Dr. Lakemeyer
- Dipl.-Inform. Zinaida Benenson, Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Ing. Lars Berlemann, Chair Comnets, Prof. Dr. Walke
- Dipl.-Inform. Ulrich Norbisrath, Chair Informatik III, Prof. Dr. Nagl
- Dipl.-Inform. Nico Wallmeier, Chair Informatik VII, Prof. Dr. Thomas
- M. Sc. Jianhua Wu, Chair Informatik VIII, Prof. Dr. Kobbelt
- Andras Zolnay MSc, Chair Informatik VI, Prof. Dr. Ney

This represents an extremely international group. The respective home countries include China, Germany, Georgia, Finland, India, Brasilia, and Tunisia.
The Collaborative Research Center (CRC) 476 IMPROVE (Computer Support for Cross-Company Development Processes in Chemical Engineering) is a long-term research project, funded by the Deutsche Forschungsgemeinschaft (DFG) since August 1997. The project is reviewed every 3 years. It is carried out by several groups of RWTH Aachen University. The partners come from different domains in engineering and computer science. Speaker is Prof. Dr.-Ing. M. Nagl, Computer Science 3 (Software Engineering), Speaker Substitute Prof. Dr.-Ing. W. Marquardt, Chemical Engineering.

**Aim**

The aim of CRC IMPROVE is computer support for development processes across different departments/companies in chemical engineering. We regard development processes in their early phases (conceptual design and basic engineering). The long term goal is the formulation of a formalized and integrated process and product model for development processes in chemical engineering.

On this basis, we develop new tools within an integrated development environment which interact synergetically. The environment uses existing tools to avoid the reimplementation of their functionality. The environment is based on a software architecture which is related to the process and product model and which allows the a-posteriori integration of existing tools.

The developed concepts are validated using a reference scenario, namely the development of a polyamide-6 plant.
Status

After the successful peer review in 2003, the last two years were determined by ongoing research work. On the other side the next peer review in 2006 was started to be prepared. Peers recommended in 2003 to start transfer projects in the next phase, beginning 2006. Therefore, application-dependent tasks have been strengthened.

Especially, a proposal book has to be prepared describing successful past work and our plans for 3 years future work. Furthermore, we plan to deliver the preliminary version of a volume of the series Lecture Notes in Computer Science, to be sent out to peers in the spring. This volume is to describe the scientific results of IMPROVE from 1997 to 2006.

In order to intensify the contacts between CRC IMPROVE and industry, a two days symposium was organized by LPT and TU Berlin in 2004. Another event will be organized in 2006.

On the other side, there are fundamental research questions for which the CRC wants to get at least a partial solution. They mostly belong to the long-term key problem, namely to develop a formal handlayered process/product model for chemical engineering.

Project data at a glance

*Partners of RWTH Aachen:*
Chemical Engineering (LPT) http://www.lpt.rwth-aachen.de
Labor Research (IAW) http://www.iaw.rwth-aachen.de
Software Engineering (Inf. 3) http://www-i3.informatik.rwth-aachen.de
Information Systems (Inf. 5) http://www-i5.informatik.rwth-aachen.de
Distributed Systems (Inf. 4) http://www-i4.informatik.rwth-aachen.de

*Adjunct project also financed by DFG:*
Plastics Engineering Lab (IKV) http://www.ikv-aachen.de
Virtual Reality Center (RKZ) http://www.rz.rwth-aachen.de

Project running since 1997

*External funding*
German Research Foundation (Deutsche Forschungsgemeinschaft)

*Contact*

*Prof. Dr. M. Nagl (Department of Computer Science III; Speaker)*
Tel.: +49-241-80-21300, Fax: +49-241-8888-218
e-mail: nagl@i3.informatik.rwth-aachen.de

http://www-i3.informatik.rwth-aachen.de/sfb476
Overview

"Lehrstuhl für Informatik VI"

TC-STAR is an EU funded integrated project and brings together partners from twelve different European research sites from both academia and industry. Its focus lies on advanced research in all core technologies for speech-to-speech translation: speech recognition, speech translation, and speech synthesis.

<table>
<thead>
<tr>
<th>TC-STAR</th>
<th>Participating companies:</th>
<th>Participants from academia:</th>
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<tbody>
<tr>
<td><a href="http://www.tc-star.org">www.tc-star.org</a></td>
<td>ELDA</td>
<td>ITC-irst (Trento)</td>
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<td>FP6 integrated project</td>
<td>IBM</td>
<td>LIMSI-CNRS (Paris)</td>
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<td>starting April 2004</td>
<td>Nokia</td>
<td>RWTH Aachen University</td>
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<td>granted for 3 years</td>
<td>Siemens</td>
<td>SPEX (Nijmegen)</td>
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<td>funding 11 million Euro</td>
<td>Sony</td>
<td>UKA Universität Karlsruhe</td>
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<td>total 18 million Euro</td>
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<td>UPC (Barcelona)</td>
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Project Objectives

The objectives of the project are extremely ambitious: to make a breakthrough in speech-to-speech translation research to significantly reduce the gap between human and machine performance. The focus lies on the development of novel algorithms and methods, integrating relevant human knowledge which is available at translation time into a data-driven framework.

Examples of such new approaches are the integration of linguistic knowledge in the statistical approach of spoken language translation, the statistical modelling of pronunciation of unconstrained conversational speech in automatic speech recognition, and new acoustic and prosodic models for generating expressive speech in synthesis.

TC-STAR has been granted for three years with a total funding sum of 11 million Euro. It targets a selection of unconstrained conversational speech domains - i.e. broadcast news and parliamentary debates - and a few languages relevant for Europe’s society and economy: native and non native European English, European Spanish and Chinese.

This work is supported by the collection of language resources. While competition is fostered by the setup of an infrastructure for competitive evaluation, the project supports cooperation by a technological infrastructure (common language resources, workshops, formats, APIs) and strives for the effective dissemination of scientific results within the consortium and the research community.
Let us now focus on the contribution of Lehrstuhl für Informatik VI to several of the work packages of the TC-STAR project.

The Statistical Approach to Speech-to-Speech Translation

The statistical approach to pattern recognition, highly developed especially in the field of speech recognition, has been successfully applied to the more general field of automatic processing of human language, including the translation of spoken and written language and the understanding of natural language and spoken dialogue systems.

The general framework for our research activities is based on statistical decision theory and problem specific modelling – acoustic–linguistic modelling for speech recognition and linguistic modelling for translation. The probabilistic framework and statistical decision theory have some characteristic advantages:

- The approach is able to model weak dependencies and vague knowledge at all levels of the system.
- Due to the statistical formulation of both the speech recognition and the translation problem, the combined problem of recognizing and translating speech can be described in a single, consistent mathematical framework.
- The free parameters of the models can be automatically learned from training data (or examples), and there exist powerful algorithms for this purpose.
- Using the Bayes decision rule, the final decision is made by taking all available context into account.

Automatic Speech Recognition

A speech recognition system can typically only recognize words that are part of its so-called recognition vocabulary. While this can be very large, new out-of-vocabulary words occur frequently – just think of proper names. We work on open vocabulary methods that target to overcome this restriction. Other improvements cover lightly supervised transcription where the system is trained using speech of which the text is not exactly known and new optimization criteria for automatic speech recognition systems. Within the speech recognition part of TC-STAR, we cover the languages English and Spanish.

Spoken Language Translation

Lehrstuhl für Informatik VI is work package leader of the spoken language translation work package. In our own department, we develop translation systems for Chinese-English (business news domain) and for both Spanish-English and English-Spanish (EPPS domain). In EPPS, an interesting aspect is the translation of spoken language (which differs from written language in several aspects) in a large domain – this is a novel task for the research community. Three different types of input to the translation component are considered:
Our research focuses on innovative translation methods, the use of human-supplied knowledge, and on the integration of machine translation and speech recognition.

As an integral part of the research work, system performance is measured in objective benchmarks on various publicly available language resources. In the strive for an improved system performance, a typical research task is to invent new statistical models which do more exactly represent the real world while being robust to estimate and efficient to compute.

The Creation of Language Resources

Lehrstuhl für Informatik VI makes a major effort in building the European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation. The EPPS corpus consists of acoustic data, corresponding transcriptions, and parallel texts/translations of plenary sessions of the European Parliament in the languages English and Spanish. We collect the acoustic recordings and transcribe recordings in English, either original parliamentary speeches (many of them by non-native speakers) or speech from simultaneous translation into English. Spanish transcriptions are produced by UPC. We also take care of the parallel text corpora - this technical term describes texts which consist of pairs, one sentence (sometimes more) in the source language and its translation in the target language. Although the exact correspondences between words or sub-phrases are not provided, it is possible for the machine translation systems to derive that information from the data in a statistical model estimation process called training.

The typical amount of data used in contemporary state-of-the-art systems and also generated in this project is in the range of a hundred hours of acoustic recordings and of about one hundred million running words of text in the parallel texts.
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REGINA e.V. - Kompetenznetz IT/Informatik Aachen-

Scientific activities in the field specified by the terms information, information technology and computer science extend far beyond the faculties known under the name of “computer science” or “information technology”. Nowadays, many faculties such as the humanities, social sciences, psychology, linguistics, economics, to name but a few, have now turned their attention to the possibilities of this technology and its application. Therefore, a major task of the Forum Information Technology is to provide a (virtual) meeting place for different disciplines and to form a melting pot from which new forms of co-operation can emerge resulting in the breakdown of traditional structures between the technical disciplines. As the nature of this complex subject and the initiated developments can no longer be mapped on the
traditional structure of the technical disciplines, the university needs a suitable “interface” thus allowing dialogue between all parties concerned: The Forum Information Technology provides and is responsible for offering this “interface”.

Project Activities
In projects covering a wide thematic spectrum researchers follow approaches to technical and organisational problems which arise with the ‘information society’. One of the objectives is to encounter the continuous information requirements of companies and institutions including their adaptation, handling, updating and processing. The Forum Information Technology with its projects participates substantially in the implementation of a regional network infrastructure, and is working on the development of information and communication services. Following are the current activities:

- The SFB 427 **“Media and Cultural Communication”** approaches the analysis of the “media revolution” from a cultural studies perspective. With the cultural-sciences research-programme “Media and Cultural Communication” (founded in 1999) one of the largest human-sciences research projects in Germany of the last decade has entered its third phase (2005-2008) in 2005. The programme is unique due several aspects: Foremost it represents a new type of a collaborative-research-programme which integrates advanced teaching. Secondly the programme-concept operates between the universities of Aachen, Bonn and Cologne. The programme is distinguished by a cultural-sciences paradigm, the transdisciplinary orientation, its intensified internationalisation, the promotion of young scientists and by a co-ordinated study program. contact: Prof. Matthias Jarke, Chair of Computer Science V, jarke@cs.rwth-aachen.de further information at: http://www.graeculus.de/

- The SFB 476 **IMPROVE (Information Technology Support for Collaborative and Distributed Design Processes in Chemical Engineering)** provides support for collaborative process engineering processes through innovative concepts from informatics. It is a long-term research project funded by the Deutsche Forschungsgemeinschaft (DFG) since August 1997. The project is reviewed every 3 years. It is carried out by several institutes and departments of RWTH Aachen University. The partners come from various domains, including chemical engineering, plastic engineering, software engineering, information systems, and communication systems. contact: Prof. Manfred Nagl (Speaker), Department of Computer Science III, nagl@i3.informatik.rwth-aachen.de further information at: http://www-i3.informatik.rwth-aachen.de/sfb476

- The SFB 540 **“model-supported experimental analysis of kinetic phenomena in multiphase fluid reaction system”**. The goal of the Collaborative Research Centre is the development of a new methodology for the systematic modeling of kinetic phenomena in fluid multi-phase reactive systems on different scales of size and detail. To reach this goal, activities such as process measurement, modeling, numerical simulation and
solution of inverse problems, which have so far been conducted separately, are coordi-
nated and combined in one work process. This leads to an improved physical under-
standing and a sufficiently accurate predictive mathematical model. The work process
should be designed to be applicable in an industrial context for routine measurement
and modeling of kinetic phenomena for a given fluid multi-phase multi-component
system. The only way to guarantee a successful methodology development is to carry it
out in interaction with difficult modeling problems. This ensures mutual gain for both
method-oriented and problem-oriented research approaches. The method-oriented
projects focus on the efficient simulation of fluid multi-phase reactive systems and on
the solution of the inverse problem. contact: Prof. Wolfgang Marquardt (Speaker),
Department of Process Systems Engineering, secretary@lpt.rwth-aachen.de further
information: http://www.sfb540.rwth-aachen.de/

• The “DFG Graduate College”, “Software for mobile Communication Systems” en-
ables interdisciplinary research through grants to PhD students. New ways of ex-
changing data through different types of networks are continuously evolving. This
includes particularly mobile communication, which has by now become more or less
ubiquitous, thanks to an ever increasing level of user acceptance. This, in turn, is
largely due to improved standards and a vastly expanded variety of services. Future
application developments will more and more be based on user requirements rather
than just feasibility. Here, the most important domains include electronic commerce,
transport telematics, new forms of working, and other innovative concepts such as e-
learning, e-government, and e-home. For these new applications to be acceptable, new
underlying technologies and services are a sine-qua-non. Moreover, the increasing
mobility of users will lead to an equally increasing role mobile wireless networks will
play in communication infrastructures. Yet, users expect application functionalities to
be independent from the underlying communication network. Considerable additional
research is needed to meet this requirement. Within that framework of the Graduate
College research is focussed on three areas: ‘Applications’, ‘Middleware and New
Services’ and ‘Network Infrastructure’. contact: Prof. Otto Spaniol, Department
of Computer Science IV, spaniol@informatik.rwth-aachen.de further information at:
http://www-i4.informatik.rwth-aachen.de/Kolleg/

• The Virtual Reality Center Aachen (VRCA) coordinates and promotes the VR research
and teaching activities at RWTH Aachen University. Right now, 39 institutes and 10
companies are organized within VRCA, and more than 30 research activities are being
carried out in an interdisciplinary cooperation between RWTH institutes, primarily in
mechanical engineering and medicine. The VRCA-workshop took place in september
2005 and had approximately 100 visitors. contact: Dr. Torsten Kuhlen, Center for
Computing and Communication, kuhlen@rz.rwth-aachen.de Further information at:
http://www.rwth-aachen.de/vrca

Additionally following projects should be mentioned:
• The Working Group “Parallelism”, contact: Prof. Christian Bischof, Center of Computing and Communication, bischof@sc.rwth-aachen.de, further information at: http://www.fz-juelich.de/zam/pkoll/index.html

• The “Bonn-Aachen International Center for Information Technology (B-IT)”, contact: Prof. Matthias Jarke, Department of Computer Science V, jarke@cs.rwth-aachen.de, further information at: http://www.b-it-center.de

• The Working Group “eLearning”, contact: Prof. Ulrik Schroeder, Computer-supported Learning; Nicole Siepmann, Forum Information Technology, further information at: http://lufgi9.informatik.rwth-aachen.de/elAG/

• The “HeRBiE: binaural hearing for mobile robots”, contact: Prof. Dr. Gerhard Laki-meyer, Knowledge-Based Systems & Cognitive Robotics Group, lakemeyer@informatik.rwth-aachen.de, Prof. Dr. Hermann Wagner, Institut for Biology II, wagner@bio2.rwth-aachen.de, Further information at: http://www.bio2.rwth-aachen.de/research/ITDrobo
e.htm

• The “Center for Computational Engineering Science (CCES)”, contact: Prof. Marek Behr Ph.D., Computational Analysis of Technical Systems, behr@cats.rwth-aachen.de, Further information at: http://www.cces.rwth-aachen.de

• The “WebKnowledge Map - WeKnow”, contact: Prof. Dr. Klaus Henning, ZLW/IMA, henning@zlw-ima.rwth-aachen.de, Further information at: http://www.zlw-ima.rwth-aachen.de
Competence Network REGINA

Under the banner “Cooperation is strength”, REGINA has been engaged successfully for now fifteen years in promoting the regional ICT-sector. REGINA is a combination of more than 100 Aachen-based companies, educational establishments and research institutes. Although competitors in some areas, the mainly small to medium-size enterprises which make up the network have formed an alliance to bring mutual benefit to all its members. Many of the general tasks they face are dealt with through collaboration within REGINA, in order to prevent unnecessary repetition or duplication of work. In the ICT environment, REGINA members make a considerable contribution to securing Aachen’s position as a high-tech region. Most of them are innovative small to medium-size enterprises.

Their business activities fall into the following categories:

- Communication
- Hardware
- Domain specific software
- Technical applications/automation
- Control & Optimization
- Infrastructure, Internet, e-commerce
- Media / Media Production
- Technology transfer
- Research and training

REGINA companies include world market leaders in specialized sectors, such as AIXTRON (semiconductor technology), DSA (quality assurance for the automobile industry), Parsytec (surface inspection systems) and CSB (application domain-specific software for the food industry).
Activities in 2005

REGINA’s Events

The events organized by the REGINA IT network are not private meetings, as they address real technical, economic, and strategic issues affecting the business of the network’s members. When members meet at the management get-togethers, information events, specialist conventions, and in working groups organized by REGINA, each of the members can expect to benefit from the experience of the others. This was traded on a wide variety of topics in the last year (examples):


Round-table Discussion: Innovative Technologies - How do we compete with other nations?
Looking for partners?
Great interest was shown by IT companies in the region when REGINA organized the company presentation event INFOrmatica. This event contained a wide variety of topics relevant to the information and communication technology sector, giving both young and established companies the opportunity to present themselves and those activities for which they seek to cooperate with partners. In 2005, the INFOrmatica included a Dutch section, introduced by a presentation of REGITEL, the Limburg ICT-Network, and completed by three Dutch ICT-companies.

Meeting and keeping high-quality talents
Research institutions such as RWTH Aachen University, Aachen University of Applied Sciences, and the Research Center Julich, as well as the major development laboratories of industrial companies provide the Aachen region with a density of research and development which is almost unique in Europe. The IT sector is one of the most promising focal fields.

REGINA is engaged in developing strong links between research and industry. The aim is to educate highly qualified young talents as future employees in regional IT companies, so that expertise is rooted in the Aachen region in the long term. This effort is supported by REGINA’s own Internet-based job-placement exchange, which not only advertises jobs for graduates but also training, work-experience opportunities, and postgraduate internships. Finally, grants for graduate students have been donated by REGINA companies.

Why has network membership tripled?
Because the concept of networking know-how and ideas really does work. This is readily confirmed by REGINA’s membership figures, which have climbed from 30 at its foundation in 1991 to more than 100 active participants today. The Aachen region is home to around 400 IT companies, which makes it a veritable power of this sector in Germany. With almost one in four of these companies as its members, REGINA has a clear and concise vision of its work in the years ahead: To preserve and extend Aachen’s position as Germany’s Silicon Valley, while actively welcoming new participants and ideas that allow the network to grow even more.
Technical Reports in Computer Science at the RWTH

This is a list of recent technical reports. To obtain copies of technical reports please consult http://aib.informatik.rwth-aachen.de/ or send your request to: Informatik-Bibliothek, RWTH Aachen, Ahornstr. 55, 52056 Aachen, Email: biblio@informatik.rwth-aachen.de

95-11 * M. Staudt / K. von Thadden: Subsumption Checking in Knowledge Bases
95-12 * G.V. Zemanek / H.W. Nissen / H. Hubert / M. Jarke: Requirements Analysis from Multiple Perspectives: Experiences with Conceptual Modeling Technology
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96-15 * H. Schimpe / M. Staudt: VAREX: An Environment for Validating and Refining Rule Bases

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97-02 J. Faassen: Using full parallel Boltzmann Machines for Optimization

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97-04 M. Mohnen / S. Tobies: Implementing Context Patterns in the Glasgow Haskell Compiler

97-05 * S. Gruner: Schemakorrespondenzaxiome unterstützen die paargrammatische Spezifikation inkrementeller Integrationswerkzeuge

97-06 M. Nicola / M. Jarke: Design and Evaluation of Wireless Health Care Information Systems in Developing Countries

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2005-12 Neeraj Mittal / Felix C. Freiling / S. Venkatesan / Lucia Draque Penso: Efficient Reductions for Wait-Free Termination Detection in Faulty Distributed Systems

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2005-17 Uwe Naumann: Syntax-Directed Derivative Code (Part II: Intraprocedural Adjoint Code)


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