Annual Report 2003

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

This report contains a summary of all activities in the Computer Science Department at RWTH Aachen University in 2003, either in research, teaching, administration, or social life. Most of the news are good news, for which it is a pleasure to report about. There are, however, other ones, which make the job of ensuring good research and teaching even harder. They will demand even more engagement of the staff in the future to avoid further problems.

Chapter 1 of this report introduces new professors we have welcome in 2003 and sketches social events of this year. Chapter 2 gives details about our courses we offer in Computer Science within the Diploma or Master’s Program. Furthermore, we also provide courses in Computer Science for various other curricula in the university, either on basic or advanced level. The biggest part of this report (chapter 3) describes the research of groups of the department. A separate chapter (4) lists all dissertations finished in 2003. Furthermore, there is a chapter (5) giving details of central services of the department which lay the basis for our research or teaching activities. Finally, there is a chapter (6) on joint projects carried out by different groups which establish or strengthen relations to other disciplines within RWTH or even to outside organizations.

We now list a number of topics/highlights which had specific influence on the department in 2003:

- Prof. Jan Borchers, Computer Science Chair X “Media Informatics”, Prof. Felix Gaertner, Group “Dependable Distributed Systems”, Prof. Stefan Kowalewski, Chair XI “Embedded Systems”, and Prof. Peter Rossmanith, Group “Theoretical Computer Science” are new at RWTH Aachen. We heartly welcome these persons and express our expectations for a fruitful cooperation and further development of the department. Furthermore, we also welcome Prof. Wolfgang Prinz being appointed in cooperation with Fraunhofer Institut of Applied Information Technology at St. Augustin near Bonn.

- Prof. Hromkovic has left our department. He took an offer from Swiss Federal Institute of Technology (ETH) at Zurich and is now the leader of a group at ETH.

- The number of freshmen decreased slightly. Nevertheless, the department is still overloaded in terms of capacity calculations (about 210%).

- The Collaborative Research Center 476 “Information Technology Support for Collaborative and Distributed Design Processes in Chemical Engineering” (Speaker Prof. Nagl, see specific section), was peer reviewed in spring 2003. The review was finished successfully such that financial support by German Reserach Foundation (DFG) is guaranteed for another 3 years until mid 2006. This allows to continue a fruitful cooperation with engineering groups at RWTH.
• The Graduate College 643 “Software for Communication Systems” (Speaker Prof. Spaniol, see specific section) got further financial support for the time beginning of 2004 to mid 2005 after a successful review from outside peers. Within the CG, again, different disciplines from RWTH have a dense cooperation.

• The build-up of the Bonn-Aachen International Center for Information Technology (B-IT) continued successfully with a selection of the first full class of students in the Media Informatics Master Program. Two endowed chairs (Computer Science X and XI) are funded by resources coming from B-IT.

• Dr. Mareike Schoop (Computer Science V) was selected as the only female researcher to be awarded one of the first Young Investigator Groups within the highly competitive Action Plan Informatics of the German Science Foundation (DFG).

• Dr. Schoop and Dr. Noll (Computer Science II) were granted their habilitation in 2003.

• After serving four years as Vice President and Treasurer of the German Informatics Society GI, Prof. Jarke was elected as GI President for the period 2004-2005 in December 2003. With almost 25,000 members, GI is the largest computer society in the German-speaking countries.

• Prof. Thomas completed his four-year term as Chief DFG Reviewer for Computer Science. Prof. Jarke was re-elected as Senior DFG Reviewer for the field of Software Engineering.

• Within RWTH Aachen University an eLearning Working Group was founded in 2003. Prof. Schroeder was active in this group for our department. The group developed strategy for further development of eLearning at RWTH, organized the 1st eLearning Day, and initiated further activities.

• The study plan of “Informatik Diplom” and the teaching activities of the department were evaluated by a commission. Prof. Ehrich from Technical University of Braunschweig served as external member in this group. The evaluation was positive, a list of ToDos was derived for further improvement. Prof. Schroeder organized this evaluation.

• The study plan of “Secondary School Teachers in Computer Science” was adapted in 2003 (Prof. Schroeder). The same holds true for Master’s Program in Software Systems Engineering (Prof. Lakemeyer).

• Prof. Oberschelp, Emeritus at our department, contributed to the exhibition “Ex Oriente” in the City Hall and Cathedral of Aachen, from June 30 to September 28. Especially, he served as expert for the topics Mathematics, Algorithmics, and Astronomy in the Carolingian and Arabic-Islamic Middle Ages.
The members of the Department were active in organizing scientific workshops or conferences, which are described in the sections of the organizing institutions. Here is a list of these events:

- Prof. Bischof, Dr. Buecker, and Dr. Hovland (Argonne National Laboratory) organized the 2nd “Workshop on Automatic Differentiation and Applications”, held in conjunction with the “Intl. Conference on Computational Science and its Applications”, May 19, 2003, Montreal, Canada.

- In June 2003, the first “International Symposium on Geometry Processing” was held in our department (Prof. Kobbelt). The event turned out to be very successful with participants from all internationally recognized research groups (e.g. Stanford, Harvard, Caltech, ETH) and speakers including Fields-Medalist Shing-Tung Yau and other highly regarded scientists. Attendants from all major CAD companies attested that this research area is of high relevance to the manufacturing industry (such as e.g. automotive or rapid prototyping).

- The International Workshop “Applications of Graph Transformation with Industrial Relevance” (AGTIVE ’03) was organized by Prof. Pfaltz and Prof. Nagl from Sept. 27 - Oct. 1, 2003 at University of Virginia, Charlottesville, USA.

- Prof. Spaniol organized a joint workshop of 5 Graduate Colleges (Aachen, Berlin, 2 from Darmstadt, and Saarbrcken) from June 16 - 18, 2003, at Castle Dagstuhl, the Conference Location of German Computer Science Community. The aim of this workshop was to detect mutual relations between research work done by PhD Students in these Graduate Colleges.

On behalf of the department I would like to thank Mrs. Hanf and Prof. Kobbelt for the engagement they showed in editing this report. It should be mentioned that they have taken over this duty several times in the last years.

Aachen, April 2004

Manfred Nagl
Speaker of the Computer Science Department
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Faculty Life
Tag der Informatik — Day of Computer Science
2003

The Tag der Informatik (Day of Computer Science) at the RWTH Aachen is the traditional colloquium where the chairs of the computer science department present their research and teaching activities. The event was accompanied by poster, software and hardware exhibitions of industrial and research partners. This year’s day of computer science took place on December 5th, and was organized by the Computer Graphics Group.

The welcome address was given by the Dean Prof. Dr. Aloys Krieg and by the spokesman of the computer science department, Prof. Dr. Manfred Nagl. In the following the new members of the department gave introductory talks to present their respective fields, namely Prof. Dr. J. Borchers (Lehrstuhl X, Medieninformatik), Prof. Dr.-Ing. F. Gärtnert (Lehrgebiet IV, Verlässliche Verteilte Systeme), Prof. Dr. S. Kowalewski (Lehrstuhl XI, Software für eingebettete Systeme) and Prof. Dr. P. Rossmanith (Lehrgebiet I, Theoretische Informatik).

After a short break, selected research projects were presented by members of the CS department, emphasizing the diverse aspects of theory, practice, and applications of computer science: Model-checking ad infinitum (Dipl.-Inform. Stefan Währle, Lehrstuhl VII), AProVE: Automatisierte Terminierungsverfahren in der Praxis (Dipl.-Inform. René Thiemann, Lehrgebiet II), Ein graphbasiertes Managementsystem für übergreifende Entwicklungsprozesse (Dr. Bernhard Westfechtel, Lehrstuhl III), Neue Strategien für modernes Lernen - WLAN, URMEL und MoPS verändern den Campus (Dipl.-Inform. Frank Imhoff, Lehrstuhl IV), Datenmanagement: Relational Indexing (Dipl.-Inform. Jost Enderle, Lehrstuhl IX), Eine Simulationsumgebung für Agentennetzwerke (Dipl.-Inform. Dominik Schmitz, Lehrstuhl V), Interaktive Exploration instationärer Strömungen in virtuellen Umgebungen (Dipl.-Inform. Marc Schirski, Lehrstuhl für Hochleistungsrechnen), Geometrisches Modellieren auf polygonalen Netzen (Dipl.-Math. Mario Botsch, Lehrstuhl VIII).

The talks were completed by the highly informative as well as entertaining presentation of the invited speaker Prof. Dr. Markus Gross (ETH Zürich). In Interaktive Computergraphik: Forschung, Anwendung und Perspektiven he did not only give an state-of-the-art report about computer graphics but also showed demos of ongoing research in his own group.

After the scientific part of the day, this year’s industry sponsored student grant from AMB Generali was awarded following the last years’ tradition. Then, the final rounds of the programming contest Pengoban were presented. Over 15 teams participated and made it a great success. The prices were sponsored by Sun microsystems and the first price was awarded to Christian Terboven and Andre Hegerath (Team SandraX).

The evening programme was closed with the graduation celebration for the graduates and their families. The laudatio was given by Prof. em. Dr. W. Oberschelp and the diplomas along with a small present were handed to the recent graduates by Prof. Dr. L. Kobbelt.

After the official part of the day was over, the graduates and their families, the students, the visitors from academia and industry and most of the staff of the computer science department
came together to enjoy the traditional evening banquet. The Ritzefeld Big Band provided the appropriate musical background so the last of the roughly 300 guests did not leave until the early morning.

More impressions can be found online: http://www-i8.informatik.rwth-aachen.de/tdi03/
Sommerfest der Informatik – Computer Science Summer Party 2003

Each year, in the mid of the summer term, the Computer Science Department organizes a summer party for the ceremonial presentation of diploma certificates to the graduates of the first half of the year. The location of this event is Gut Melaten, an old estate owned by RWTH Aachen. The summer party 2003 took place on Friday, July 6th, 2003.

The summer party started with the official part, including an introductory talk and the ceremonial presentation of the diploma certificates, moderated by Prof. Dr. M. Nagl. About 50 students have received their diplomas at this summer party. Additionally, industry-sponsored grants were awarded.

The ceremonial part was followed by a cabaret of the group Buschtrommel. Together with this event, the informal part of the summer party was started with a buffet and several kinds of drinks. 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 financing of the event was possible by the support of some sponsors, namely Ericsson, Vodafone, AMB Generali, 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.
1 New Professors

In 2003, four new colleagues joint our department: Jan Borchers, Felix Grtner, Stefan Kowalewski, and Peter Rossmanith. Two of them replaced former faculty members Bodewijn Haverkort and Franz Baader who moved to full professor positions at other universities and the other two took on newly created positions that are partially funded via the Bonn-Aachen International Center for Information Technology. This increases the total number of our faculty (full and associate professors) to 19 and further extends the broad spectrum of research topics covered by our department ranging from theoretical to practical and applied computer sciences.

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

1.1 Jan Borchers

Jan Borchers recently joined RWTH Aachen University to establish the computer science chair “Informatik X”, the Media Computing Group. Here he answers our most burning questions.

Never heard of you before—since when are you at RWTH?

Since October 2003.

And where do you come from?

Tricky… I was born in Bremen, and experienced my first culture clash when I was assigned to Karlsruhe for my computer science studies. I also spent a semester abroad, at Imperial College in London. Something I definitely recommend doing as a student! For my PhD, I went to Linz in Austria for a year, then moved to Ulm, working remotely. Towards the end of my PhD, I switched with my advisor, Max Mühlhäuser, to Darmstadt University of Technology. After that, I had a great time working as acting assistant professor at Stanford University in California for two years. Then I was briefly at ETH Zurich as assistant professor, before joining RWTH. Confused?

Somewhat… but what we really want to know is what kind of research you’re doing. Something like age-see-eye, right?

Exactly! HCI stands for Human-Computer Interaction. I want to create new and more intuitive ways to use computers.

Oh, so you want to improve the Windows User Interface?

To be honest, I find traditional, desktop-oriented graphical user interfaces fairly boring (not that there aren’t ample opportunities to improve Windows). I’m much more fascinated by the question how we can make all these new interactive technologies really usable, and therefore useful, and how new user interfaces can give people a chance to experience new ways of interacting with technology and each other.
Sounds great, but a little general—how about an example?

Sure. Let’s say you’ve always dreamt of being a conductor. Maybe you’ve even conducted to a CD at home. But of course the orchestra never actually followed your conducting there. We designed a system to let you conduct a real audio and video recording of the Vienna Philharmonic, using an infrared baton. You can even control their tempo, without audio pitch changes (and if you conduct too badly they yell at you). This was a world premiere, and that’s what I mean by opening up new types of user experiences with digital media.

Sounds fun. Where can we try it?

In the House of Music Vienna, it’s a permanent public exhibit there. A similar project of ours is in the Children’s Museum in Boston. Or check our home page, we occasionally demo our systems at special events.

Have you done more exhibits like this?

Yep. We built systems to find pieces by humming, to improvise with computer support, or to take virtual city tours of Vienna for example. See www.actibits.com. They are a great testbed for our research, and raise really fascinating questions such as, can we create a media processing framework that can deal with a constantly changing time base? They are also a good way to make our research visible to a larger audience, and very rewarding for students and myself to work on. Much better than just writing a thesis that nobody reads except you and (hopefully) your advisor...

Cool, but are there other research topics apart from interactive exhibits?

Yes, two in particular. One is interactive rooms. We’re setting up the “Aachen Media Space” in which you’ll be able to work on static and time-based media collaboratively, using big interactive mobile displays, networked audio, and other cool devices instead of the old single monitor, mouse and keyboard. At Stanford, I noticed students in a similar room wasting a lot of research time soldering, running cables, and writing serial device drivers, so we created the iStuff toolkit and PatchPanel middleware to help with that.

The other is HCI Design Patterns, an idea to capture design guidelines that got kind of messed up in software engineering. I went back to the original literature from the 60’s—it’s from urban architecture, and it turns out HCI is a much better candidate for applying the pattern idea than software engineering! The result was my dissertation, a book, and since then an active new research area. Check out www.hcipatterns.org.

How about teaching?

I’ve been teaching my own HCI lectures since 1998. At RWTH, we offer Designing Interactive Systems I+II to learn the basics of HCI, cognitive psychology, interface design and UI technology, both for desktop and multimedia environments. Additional lectures, labs, and seminars cover interactive spaces, post-desktop user interfaces, patterns, and other topics we find exciting. We also teach classes in Bonn for the B-IT Master in Media Informatics Programme. Our classes are a little weird, students will find it hard to sleep through them. Ask those who took them to find out. Two of my PhD students are from the US and Canada, and most of our teaching is in English.
Interactivity, multimedia, ubicomp, patterns, media spaces... sounds exciting. How can students join in?

There’s always space for top students to do diploma theses, or maybe join us as Hiwis. We work mostly with Mac OS X. If you’re interested, just email us. We’re at http://media.informatik.rwth-aachen.de.

And what do you do when you don’t work?

I play jazz piano, and I like to go climbing, golfing, or dancing. I frequently play table tennis, frisbee, badminton, or pool depending on my activity level, or pursue other random outdoorsy dilettantism.

Thanks for your time!

The pleasure is all mine. :)

The interview was conducted, for lack of an interviewer, by Jan Borchers himself. But otherwise he is really quite normal.

1.2 Felix Gärtner

Felix Gärtner joined RWTH Aachen in October 2003 to lead the laboratory of Dependable Distributed Systems (Lehr- und Forschungsgebiet Informatik, Verteilte Systeme). Before coming to Aachen, Felix was a postdoc researcher in the research group of Rachid Guerraoui at the École Polytechnique Fédérale de Lausanne in Switzerland where he had an office with a great view on to Lake Geneva (see Figure 1).

His research interests are centered around designing, building and maintaining 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 faults as well as intentional, malicious attacks. Consequently, the research projects cover aspects of classical safety engineering (high-reliability and fault-tolerant systems) as well as IT security. The perspective on to both aspects of dependability opens a wide field for applied industrial research (e.g., network forensics, honeypot technologies) as well as more theoretical projects for students and PhD candidates (e.g., fault-tolerant and secure distributed algorithms).

Felix studied computer science at Darmstadt University of Technology, Philipps-Universität Marburg, and the University of Dublin, Trinity College. He holds a Diploma degree (Dipl.-Inform., 1998) and a PhD degree (Dr.-Ing., 2001) in computer science both from Darmstadt University of Technology. His PhD dissertation entitled “Formale Grundlagen der Fehler-toleranz in verteilten Systemen” won the 2001 Dissertation Award (Dissertationspreis) of the German Computer Science Society (Gesellschaft für Informatik). After one year as an assistant Professor at Darmstadt, we was awarded an Emmy Noether scholarship by the Deutsche Forschungsgemeinschaft to perform research on fault-tolerant and secure systems in Lausanne.
1.3 Stefan Kowalewski

When I joined the Computer Science faculty at RWTH Aachen University in November 2003 I felt like moving forward and backward at the same time. Geographically I moved back to the places and the region where I grew up and which I left more than twenty years ago (after finishing my social service in an old peoples home on Heinrichsallee which now no longer exists). In terms of scientific disciplines, however, I made a big leap forward into a community which I did not belong to originally but which fascinated and attracted me since many years.

By education I am an engineer. I studied Electrical Engineering in Karlsruhe and specialised in control theory. Already in my Diploma thesis at the Fraunhofer Institute for Information and Data Processing in 1990, I became interested in Computer Science topics, at that time formal models for discrete controllers. This interest continued when I moved to the Chemical Engineering Department at the University of Dortmund where I received my PhD in 1995 and stayed as a senior researcher for another five years. The work of the latter years finally lead to my habilitation in control and safety engineering which I obtained in 2003. In Dortmund I was working on formal modelling and verification of control software. Due to the interdisciplinary character of this research, there was a need (and the opportunity) to collaborate with many computer scientists worldwide. These were great experiences which strengthened my fascination by problems on the boundary between engineering and computer science.

I remained on that boundary while I was with the Corporate Research and Advanced Engi-
neering of the Robert Bosch GmbH in Frankfurt/Main from May 2000 to November 2003. I was responsible for a group that provided basic support for new software technologies and engineering methodologies to be transferred into the business units. Our main topics were software architecture evaluation, software product lines, and dependability analysis. During this time I got in touch with the great challenges created by the radical shift from mechanical or electronic to software-intensive systems in the automotive industry. And I learned how important (and still difficult) it is for engineers and computer scientists to communicate and collaborate efficiently, if we want to succeed.

Since November 2003 I am trying to contribute to these challenges from an academic position. I understand my role in the faculty as a bridge builder between the computer science community and the potential appliers of computer science methods in the engineering disciplines. For this task, I believe, the RWTH is a place with plenty of opportunities. At the time of writing these lines, our group is still in the process of building up the infrastructure and taking first steps in teaching and research. The current status is sketched in the description of Informatik XI in the main part of this report.

1.4 Peter Rossmanith

In April 2003, I came to Aachen to join the Computer Science Department as head of the Research and Teaching Group Theoretical Computer Science. It did not take long for me to feel at home because most of the infrastructure I needed was already there, including rooms and computers. Our small group was established quite fast. Stefan Richter accompanied me from Munich and soon we were joined by our secretary Valentina Elsner and my second assistant Daniel Mölle who studied in Dortmund.

Our plans for teaching include the usual undergraduate courses in theoretical computer science and more specialised graduate lectures in the design and analysis of algorithms, but also other topics like learning theory, lower bounds, complexity theory, computational biology and topics coming directly from our research.

In research we focus on exact solutions of hard problems. It is not well understood why many heuristic algorithms are very fast in practice, but there is no known algorithm with a proven performance guarantee that comes close to their running time. An established approach is to investigate the parameterized complexity. For example, many problems in circuit design are computationally hard in general, but only for an unrestricted number of layers. In practice there are only a small number of layers and if this is the parameter $k$, then algorithms can be designed whose running time is polynomial in the input size and exponential in $k$. We also try other approaches to identify real world instances and to explain why they can be solved efficiently.

I was born in Czechoslovakia, but spent most of my life in Munich, where I also studied computer science at the TU Munich. While I liked Munich a lot, Aachen is beautiful, too. I miss the mountains and lakes of Bavaria, but I am excited about the location of Aachen.
within Europe; especially the proximity of Belgium and the Netherlands is great. The sea is also quite close.

I thank my new colleagues for the cordial welcome and for the general very nice atmosphere in the department.
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: 2424 (total number in fall term 2003)
Female rate: approx. 14 %

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

*Technische Redaktion (Magister/Magistra Artium) - program*

at the RWTH Aachen University

Short description

*Technische Redaktion* 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*. *Technische Redaktion* 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 *Technische Redaktion* have chosen *Principles of Computer Science* as their second main subject.

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**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 *Technische Redaktion* 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 in 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 acquaintance 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.

**Further information**

For more detailed and current information on the teachers’ curriculum, visit the webpage http://lehramt.informatik.rwth-aachen.de

The contact persons within the Department of Computer Science are

Prof. Dr. U. Schroeder, Lehrgebiet Informatik IX, RWTH Aachen,
E-Mail: schroeder@informatik.rwth-aachen.de,

Dr. V. Penner, Lehrstuhl Informatik VII, RWTH Aachen,
E-Mail: penner@informatik.rwth-aachen.de.
Schnupperstudium - Study Day for Girls

The Schnupperstudium is organised once a year to provide an opportunity for female pupils to get to know programmes of study with a low ratio of female students such as computer science.

In 2003, three computer science workshops were offered by four female computer scientists from RWTH Aachen. The aim was to introduce the study programme both from the point of view of current students and by exemplifying certain study elements with the Game of Life. The latter part allowed the pupils to experiment with the game and to get to know intuitively some theoretical constructs. Two current computer science students then introduced organisational aspects of the computer science programme at RWTH Aachen and discussed their personal experiences.

Finally, the Markt der Möglichkeiten gave an overview of different programmes of study and offered information about central institutions such as Fachschaften, Studienberatung, and Berufsberatung.

PARTICIPANTS

Researchers
- Aida Jertila (Lehrstuhl für Informatik V)
- Antje Nowack (LuFG Mathematische Grundlagen der Informatik)
- Dr. Mareike Schoop (Lehrstuhl für Informatik V)
- Nicola Ueffing (Lehrstuhl für Informatik VI)

Student Tutors
- Uta Christoph
- Jessica Huster
## 1 Courses in Summer term (Sommersemester 03)

### 1.1 Undergraduate Courses 2nd semester

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>Spaniol</td>
<td>Rechnerstrukturen (Computer Organisation)</td>
</tr>
<tr>
<td>Seidl</td>
<td>Datenstrukturen und Algorithmen (Data structures and algorithms)</td>
</tr>
<tr>
<td>Esser</td>
<td>Differentialgleichungen und Numerik (Differential Equations and Numerics)</td>
</tr>
<tr>
<td>Triesch</td>
<td>Diskrete Strukturen (Discrete structures)</td>
</tr>
</tbody>
</table>

### 1.2 Undergraduate Courses 4th semester

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>Indermark</td>
<td>Automatentheorie und Formale Sprachen (Automata Theory and Formal Languages)</td>
</tr>
<tr>
<td>Mathar</td>
<td>Einführung in die Stochastik für Informatiker (Introduction to Stochastics for Computer Scientists)</td>
</tr>
<tr>
<td>Kobbelt, Bischoff</td>
<td>Ausgewählte Kapitel der Computergraphik (Selected Topics in Computer Science)</td>
</tr>
<tr>
<td>Giesl, Dlugozs, Thiemann</td>
<td>Proseminar IT-Sicherheitskonzepte und Sicherheit in Java (IT-Security Concepts and Security in Java)</td>
</tr>
<tr>
<td>Spaniol, Günes</td>
<td>Proseminar Kommunikationsprotokolle</td>
</tr>
<tr>
<td>Lakemeyer, Iwan</td>
<td>Proseminar Künstliche Intelligenz (Artificial Intelligence)</td>
</tr>
<tr>
<td>Westfechtel, Böhlen, Becker</td>
<td>Objektorientierte Softwareentwicklung in Eiffel (Object-Oriented Software Development in Eiffel)</td>
</tr>
<tr>
<td>Lichter, von der Maßen</td>
<td>Methoden und Techniken des Requirements Engineering (Methods and Techniques of the Requirements Engineering)</td>
</tr>
<tr>
<td>Schroeder</td>
<td>User Interface Design</td>
</tr>
<tr>
<td>Indermark, Stolz</td>
<td>Softwarepraktikum Funktionales Programmieren in Haskell (Practical Course Functional Programming in Haskell)</td>
</tr>
<tr>
<td>Bemmerl, Finocchiaro</td>
<td>Softwarepraktikum Parallelrechner (Software Lab Parallel Systems)</td>
</tr>
<tr>
<td>Bücke, Bischof</td>
<td>Softwarepraktikum Paralleles Programmieren mit Java (Software Lab Parallel Programming in Java)</td>
</tr>
</tbody>
</table>
Penner Softwarepraktikum Visualisierung von Algorithmen
Ney Softwarepraktikum Muster- und Bilderkennung (Software Lab Pattern and Image Recognition)
Spaniol, Krempels Praktikum Agententechnologie (Software Lab Agent Technology)
Unger Praktikum Entwurfsmethoden für Algorithmen (Design methods for algorithms)
Seidl Softwarepraktikum Datenstrukturen (Software Lab Data structures)

1.3 Graduate Courses
Walke Kommunikationsnetze und Verkehrstheorie II
Rokitansky Stochastische Simulation II
Krieg Kryptographie (Cryptography)
Hromkovič Approximative und Randomisierte Algorithmen (Approximation and Randomized Algorithms)
Hromkovič, Böckenhauer, Bongartz Algorithmische Grundlagen der Bioinformatik (Algorithmic Foundations of Bioinformatics)
Indermark Programmanalyse und Compileroptimierung (Program Analysis and Compiler Optimization)
Giesl Automatisierte Programmverifikation (Mechanized Program Verification)
Thomas Angewandte Automatentheorie (Applied Automata Theory)
Thomas Rekursionstheorie (Recursion Theory)
Grädel, Blumensath Mathematische Logik II (Mathematical Logic II)
Rossmanith Parametrisierte Algorithmen (Parameterized Algorithms)
Nagl, Haase, Marburger Die Softwaretechnik-Programmiersprache Ada 95 (The Software-engineering Programming Language Ada 95)
Westfechtel Management von Software-Entwicklungsprozessen (Management of Software Development Processes)
Lichter Software-Qualitätssicherung (Software Quality Assurance)
Spaniol, Thißen  
Verteilte Systeme (Distributed Systems)

Kesdogan, Spaniol  
Web Protocols and Practice

Jarke, Klamma, Spaniol  
Implementation of Databases

Lakemeyer  
The Logic of Knowledge Bases

Prinz  
CSCW & Groupware: Konzepte und Systeme zur computergestützen Zusammenarbeit (CSCW & groupware: concepts and systems for computer supported cooperative work)

Gross  
Human-Computer Interaction and Requirements

Ney, Schlüter  
Digitale Signalverarbeitung für Sprache und Bilder (Digital Processing of Speech and Image Signals)

Ney  
Advanced Topics in Statistical Learning

Ney  
Statistical Methods in Natural Language Processing

Kobbelt  
Computergraphik I (Computer Graphics I)

Kobbelt  
Computer Vision und bildbasiertes Rendering (Computer Vision and Image Based Rendering)

Schroeder  
E-Learning (E-Learning)

Bischof  
Semantische Transformationen (Semantical Transformations)

Bücker, Bischof  
Parallele Algorithmen und Software für iterative Methoden (Parallel Algorithms and Software for Iterative Methods)

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

Hromkovič, Unger  
Seminar Algorithmische Kryptographie

Indermark, Stolz  
Seminar Compilerbau (Compiler Construction)

Giesl  
Seminar Verifikation von Programmen: Terminierung und Model-Checking (Seminar Program Verification: Termination and Model-Checking)

Giesl  
Seminar Verifikation von Programmen: Partielle Korrektheit und Beweisen mit Induktion (Seminar Program Verification: Partial Correctness and Inductive Theorem Proving)

Thomas, Löding, Wöhrle  
Seminar über Automathentheorie
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<th>Seminar/Praktikum</th>
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<tbody>
<tr>
<td>Rossmanith</td>
<td>Seminar Algorithmen für die Textverarbeitung</td>
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<tr>
<td>Rossmanith</td>
<td>Seminar Datenkomprimierung</td>
</tr>
<tr>
<td>Nagl, Kirchhof, Kraft</td>
<td>Seminar Vom konzeptuellen Gebäude-Entwurf zum integrierten eHome</td>
</tr>
<tr>
<td>Spaniol, Günes, Pils</td>
<td>Seminar Datenkommunikation und Verteilte Systeme</td>
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<tr>
<td>Gross</td>
<td>Seminar Web Engineering</td>
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<tr>
<td>Ney</td>
<td>Seminar Spracherkennung und Sprachverarbeitung (Seminar Speech Recognition and Language Processing)</td>
</tr>
<tr>
<td>Kobbelt, Bischoff</td>
<td>Proseminar Ausgewählte Kapitel der Computergraphik (Seminar Selected Topics in Computer Graphics)</td>
</tr>
<tr>
<td>Seidl</td>
<td>Seminar Algorithmen für das Data Mining (Seminar Algorithms for Data Mining)</td>
</tr>
<tr>
<td>Berlage</td>
<td>Explorative Visualisierung biomedizinischer Daten (Visual exploration of biomedical data)</td>
</tr>
<tr>
<td>Bischof, Bücke</td>
<td>Seminar Java in Computational Science (Seminar Java in Computational Science)</td>
</tr>
<tr>
<td>Indermark, Weber</td>
<td>Compilerbau (Compiler Construction)</td>
</tr>
<tr>
<td>Nagl, Norbisrath</td>
<td>Softwaretechnik-Projektparaktikum Ubiquitous Computing</td>
</tr>
<tr>
<td>Spaniol, Imhoff, Seipold</td>
<td>Virtuelles Informatik-Praktikum</td>
</tr>
<tr>
<td>Spaniol, Krempels</td>
<td>Praktikum Agententechnologie (Agent Technology)</td>
</tr>
<tr>
<td>Martini, Thißen</td>
<td>Mobile Ad-Hoc Networks</td>
</tr>
<tr>
<td>Jarke</td>
<td>User-oriented system design and personalized information services for nomadic information and e-learning systems</td>
</tr>
<tr>
<td>Lakemeyer, Iwan</td>
<td>Roboterpraktikum Mobile Robotik (Mobile Robot Lab)</td>
</tr>
<tr>
<td>Kobbelt, Sovakar</td>
<td>Hauptpraktikum Spezialeffekte (Special Effects)</td>
</tr>
<tr>
<td>Schroeder</td>
<td>eLearning Praktikum Eigenständiges Lernen und Lernkontrolle (Self-Directed Learning and Assessment)</td>
</tr>
<tr>
<td>Wisskirchen, Berlage</td>
<td>Praktikum Analyse biomedizinischer Bilder (Biomedical Image Analysis)</td>
</tr>
<tr>
<td>Name</td>
<td>Arbeitsgebiet</td>
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<tr>
<td>-----------------------</td>
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</tr>
<tr>
<td>Kraiss, Gönner, Hansjürgens</td>
<td>Praktikum Virtuelle Realität (Laboratory on Virtual Reality)</td>
</tr>
<tr>
<td>Imdermark, Giesl, Bollig, Noll, Stolz, Weber</td>
<td>Arbeitsgemeinschaft Modellierung Verteilter Systeme (Working Group Modelling Concurrent Systems)</td>
</tr>
<tr>
<td>Imdermark, Giesl</td>
<td>Arbeitsgemeinschaft Programanalyse (Working Group Program Analysis)</td>
</tr>
<tr>
<td>Giesl, Dlugosz, Thiemann</td>
<td>Arbeitsgemeinschaft Programverifikation</td>
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<tr>
<td>Grädel, Thomas</td>
<td>Arbeitsgemeinschaft Logik und Automaten</td>
</tr>
<tr>
<td>Nagl, Westfechtel</td>
<td>Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge</td>
</tr>
<tr>
<td>Lichter</td>
<td>Arbeitsgemeinschaft Produktlinienentwicklung</td>
</tr>
<tr>
<td>Wallbaum, Pils, Günes, Spaniol</td>
<td>Arbeitsgemeinschaft Mobilkommunikation (Study Group Mobile Communications)</td>
</tr>
<tr>
<td>Seipold, Spaniol</td>
<td>Arbeitsgemeinschaft Multimediakommunikation (Study Group Multimedia Communication)</td>
</tr>
<tr>
<td>Kesdogan, Wienzek, Spaniol</td>
<td>Arbeitsgemeinschaft Sicherheit in der Kommunikationstechnik (Study Group Security in Communication Systems)</td>
</tr>
<tr>
<td>Imhoff, Thißen, Diepolder, Spaniol</td>
<td>Arbeitsgemeinschaft Verteilte Systeme (Study Group Distributed Systems)</td>
</tr>
<tr>
<td>Kesdogan, Spaniol</td>
<td>Arbeitsgemeinschaft: Privacy Enhancing Techniques</td>
</tr>
<tr>
<td>Schoop, Jarke</td>
<td>Arbeitsgemeinschaft Kooperative Informationssysteme</td>
</tr>
<tr>
<td>Klamma, Jarke</td>
<td>Arbeitsgemeinschaft Deduktive Objektbanken (Working group deductive objects bases)</td>
</tr>
<tr>
<td>Lakemeyer, Iwan</td>
<td>Arbeitsgemeinschaft Kognitive Robotik (Working Group Cognitive Robotics)</td>
</tr>
<tr>
<td>Ney</td>
<td>Arbeitsgemeinschaft Bilderkennung (Working Group Image Recognition)</td>
</tr>
<tr>
<td>Ney</td>
<td>Arbeitsgemeinschaft Spracherkennung (Working Group Speech Recognition)</td>
</tr>
<tr>
<td>Ney</td>
<td>Arbeitsgemeinschaft Sprachübersetzung (Working Group Machine Translation)</td>
</tr>
</tbody>
</table>
Schroeder  
\textit{Arbeitsgemeinschaft eLearning (Working Group eLearning)}

Spaniol  
\textit{Graduiertenkolleg Software für Kommunikationssysteme}  
\textit{(Graduate School Software for Communication Systems)}
2 Courses in Winter term (Wintersemester 03/04)

2.1 Undergraduate Courses 1st semester

Giesl  
Programmierung (Programming Concepts)[Prog]

Esser  
Analysis fr Informatiker (Analysis for Computer Scientists)[MathIn]

Pahlings  
Lineare Algebra (Linear Algebra)[VLA]

2.2 Undergraduate Courses 3rd semester

Spaniol  
Systemprogrammierung (System Programming)

Rossmanith  
Berechenbarkeit und Komplexiti (Computability and Complexity)

Grädel  
Mathematische Logik (Mathematical Logic)

Schumacher  
Elektronische Grundlagen für Informatiker

Indermark, Weber  
Proseminar Websprachen

Ney, Schlüter  
Proseminar Datenkompression (Seminar Data Compression)

Seidl  
Proseminar Methoden und Werkzeuge

Penner, Löding, Wallmeier  
Proseminar Effiziente Datenstrukturen für große Mengen

Jarke, Ragia  
Proseminar Geografische Informationssysteme (Geographic Information Systems)

Nagl, Kirchhof, Fuß, Westfechtel  
Softwarepraktikum Web-Technologien

Kobbelt, Sovakar  
Basispraktikum Computergraphik (Basic practical Course Computergraphics)

Bemmerl, Finocchiaro  
Softwarepraktikum Parallelrechner (Software Lab Parallel Systems)

Spaniol, Krempels  
Agententechnologie (Agent Technology)

Spaniol, Wienzek  
Netzwerkprogrammierung (Network Programming)

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2.3 Graduate Courses

Hromkovič, Unger, Seibert  
*Effiziente Algorithmen (Algorithms Design)*

Hromkovič, Unger, Seibert  
*Theoretische Informationstechnik*

Indermark  
*Logikprogrammierung (Logic Programming)*

Noll  
*Formal Models of Concurrency*

Thomas  
*Automata on infinite objects*

Grädel  
*Theorien - Spiele - Algorithmen (Theories - Games - Algorithms)*

Thomas  
*Model-Checking*

Nagl, Kraft, Ranger  
*Einführung in die Softwaretechnik (Introduction to Software Engineering)*

Westfechtel  
*Spezifikation von Softwaresystemen (Specification of Software Systems)*

Lichter, von der Maßen, Weiler  
*Software-Produktlinienentwicklung (Software Productline Construction)*

Lichter  
*Objektorientierte Software-Konstruktion (Object-Oriented Software Construction)*

Spaniol, Thißen  
*Datenkommunikation (Data Communication)*

Kesdogan, Spaniol  
*Privacy Enhancing Techniques*

Jarke, Nissen  
*Introduction to Database Systems*

Jarke, Klamma, Gans  
*Unternehmensgründung und neue Medien (Entrepreneurship and new Media)*

Lakemeyer  
*Introduction to Artificial Intelligence*

Reiser  
*E-Commerce and Client/Server Systems: Capacity Planning and Performance Analysis*

Reiser  
*Introduction to Visual Processing and Computer Vision*
<table>
<thead>
<tr>
<th>Name</th>
<th>Course</th>
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</thead>
<tbody>
<tr>
<td>Berlage</td>
<td>Einführung in die Bioinformatik (Introduction to Bioinformatics)</td>
</tr>
<tr>
<td>Ney</td>
<td>Mustererkennung und Neuronale Netze (Pattern Recognition and neural Networks)</td>
</tr>
<tr>
<td>Kobbelt, Lehmann, Ney, Repges, Seidl, Spitzer</td>
<td>Ringvorlesung Medizinische Bildverarbeitung (Lecture Medical Image Processing)</td>
</tr>
<tr>
<td>Kobbelt</td>
<td>Computergraphik II (Computer Graphics II)</td>
</tr>
<tr>
<td>Kobbelt</td>
<td>Geometrische Modellierung I (Geometric Modeling I)</td>
</tr>
<tr>
<td>Seidl</td>
<td>Data Mining Algorithmen (Data Mining Algorithms)</td>
</tr>
<tr>
<td>Bücker</td>
<td>Einführung in High-Performance Computing (Introduction to High-Performance Computing)</td>
</tr>
<tr>
<td>Kuhlen</td>
<td>Virtuelle Realität (Virtual Reality)</td>
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<tr>
<td>Kraiss</td>
<td>Mensch-Maschine Systeme I (Human Machine Systems I)</td>
</tr>
<tr>
<td>Broll</td>
<td>Virtual and augmented Reality</td>
</tr>
<tr>
<td>Gärtner</td>
<td>Von Apollo bis Space Shuttle: Fallstudien verlässlicher Systeme (From Apollo to Space Shuttle: Case Studies in Dependable Systems)</td>
</tr>
<tr>
<td>Borchers, Lee, Ballagas</td>
<td>Designing Interactive Systems</td>
</tr>
<tr>
<td>Kowalewski</td>
<td>Einführung in eingebettete Systeme (Introduction in embedded systems)</td>
</tr>
<tr>
<td>Rokitansky</td>
<td>Stochastische Simulation I</td>
</tr>
<tr>
<td>Walke</td>
<td>Grundgebiete der Informatik 3 (Basics of Computer Science 3)</td>
</tr>
<tr>
<td>Waldke</td>
<td>Kommunikationsnetze und Verkehrstheorie I (Communication Networks and Traffic Theory I)</td>
</tr>
<tr>
<td>Schumacher</td>
<td>Lokale Datennetze für industrielle Anwendungen (Local Area Networks for Industrial Applications)</td>
</tr>
<tr>
<td>Indermark, Noll</td>
<td>Seminar Analyse und Optimierung imperativer und funktionaler Programme</td>
</tr>
<tr>
<td>Giesl, Dlugosz, Thiemann</td>
<td>Seminar Terminierungsanalyse (Termination Analysis)</td>
</tr>
<tr>
<td>Thomas, Altenbernd, Rohde, Wöhre</td>
<td>Seminar über Theoretische Informatik: Automaten und semistrukturierte Daten (XML)</td>
</tr>
<tr>
<td>Name</td>
<td>Seminar</td>
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<tr>
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<tr>
<td>Grädel</td>
<td>Seminar Modelltheorie endlicher Strukturen (Seminar Model Theory of Finite Structures)</td>
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<tr>
<td>Lichter</td>
<td>Seminar Qualitätssicherung (Seminar Quality Assurance)</td>
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<tr>
<td>Günes, Pils, Spaniol</td>
<td>Seminar Datenkommunikation und Verteilte Systeme (Seminar Data Communication and Distributed Systems)</td>
</tr>
<tr>
<td>Jarke, Klamma</td>
<td>Implementierung von XML-Datenbanken (Implementation of XML Databases)</td>
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<tr>
<td>Prinz</td>
<td>Seminar Computer-Supported Cooperative Work</td>
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<tr>
<td>Ney</td>
<td>Seminar Data-Mining and Learning from Data</td>
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<tr>
<td>Seidl</td>
<td>Seminar Ähnlichkeitssuche in Datenbanken (Seminar Similarity Search in Databases)</td>
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<tr>
<td>Schroeder, Giani</td>
<td>Seminar Situiertes blended learning in der Hochschule (Situated blended learning)</td>
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<td>Schroeder, Giani, Weckauf</td>
<td>Seminar eLearning Technologien (eLearning Technologies)</td>
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<tr>
<td>Bischoff, Kobbelt</td>
<td>Seminar Parametrisierung und Texturierung (Seminar Parameterization and Texturing)</td>
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<tr>
<td>Kraiss, Dörfler</td>
<td>Seminar, Machine Vision</td>
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<tr>
<td>Kuhlen, Bischof</td>
<td>Seminar Aktuelle Themen der Virtuellen Realität</td>
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<td>Lichter</td>
<td>Lehrgebietsseminar</td>
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<tr>
<td>Kowalewski</td>
<td>Seminar Modellierungsmethoden für eingebettete Software (Modeling methods for embedded software)</td>
</tr>
<tr>
<td>Thomas, Löding</td>
<td>Praktikum Model Checking</td>
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<tr>
<td>Nagl, Böhlen, Norbisrath</td>
<td>Softwaretechnik-Projektpraktikum Werkzeugunterstützung zur eHome-Dienstespezifikation (Graduate Lab Course: Tool Support for Specifying eHome-Services)</td>
</tr>
<tr>
<td>Spaniol, Krempels</td>
<td>Praktikum Agententechnologie (Agent Technology)</td>
</tr>
<tr>
<td>Martini, Thißen</td>
<td>Local and Personal Area Networks</td>
</tr>
<tr>
<td>Jarke</td>
<td>User-oriented system design and personalized information services for nomadic information and e-learning systems</td>
</tr>
<tr>
<td>Name</td>
<td>Praktikum/Arbeitsgemeinschaft</td>
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<tr>
<td>Jarke, Klamma, Gans</td>
<td>Projektpraktikum Unternehmensgründung und neue Medien (Lab High-tech entrepreneurship and new media)</td>
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<tr>
<td>Lakemeyer, Iwan</td>
<td>Roboterpraktikum Mobile Robotik (Mobile Robot Lab)</td>
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<tr>
<td>Ney</td>
<td>Praktikum Sprach- und Bildverarbeitung (Laboratory Course Speech and Image Recognition)</td>
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<td>Seidl</td>
<td>Praktikum Data Mining Algorithmen (Algorithms for Data Mining)</td>
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<td>Kraiss, Bley</td>
<td>Praktikum Multimedia-Techniken (Laboratory on Multimedia Techniques)</td>
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<td>Bemmerl, Jabs</td>
<td>Betriebssystempraktikum Realzeitverarbeitung (Operating System Laboratory: Realtime Computing)</td>
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<tr>
<td>Vehreschild, Bischof</td>
<td>Parallele Numerische Algorithmen (Parallel Numerical Algorithms)</td>
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<tr>
<td>Indermark, Giesl, Bollig, Noll, Stolz, Weber</td>
<td>Arbeitsgemeinschaft Modellierung Verteilter Systeme (Working Group Modelling Concurrent Systems)</td>
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<tr>
<td>Indermark</td>
<td>Arbeitsgemeinschaft Programmanalyse (Working Group Program Analysis)</td>
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<td>Giesl, Dlugosz, Thiemann</td>
<td>Arbeitsgemeinschaft Programmverifikation</td>
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<td>Grädel, Thomas</td>
<td>Arbeitsgemeinschaft Logik und Automaten (Working Group on Logic in Computer Science)</td>
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<td>Nagl, Westfechtel</td>
<td>Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge</td>
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<td>Wallbaum, Pils, Günes, Spaniol</td>
<td>Arbeitsgemeinschaft Mobilkommunikation (Study Group Mobile Communication)</td>
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<td>Seipold, Spaniol</td>
<td>Arbeitsgemeinschaft Multimedialkommunikation (Study Group Multimedia Communication)</td>
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<td>Kesdogan, Wienzek, Spaniol, Gärtner</td>
<td>Arbeitsgemeinschaft Sicherheit in der Kommunikationstechnik (Study group Security in Communication Systems)</td>
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<td>Imhoff, Thißen, Diepolder, Spaniol, Gärtner</td>
<td>Arbeitsgemeinschaft Verteilte Systeme (Study group Distributed Systems)</td>
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<td>Kesdogan, Spaniol</td>
<td>Arbeitsgemeinschaft Privacy Enhancing Techniques</td>
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<td>Broll</td>
<td>Virtual and augmented Reality</td>
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<td>Jarke, Klamma</td>
<td>Arbeitsgemeinschaft Deduktive Objektbanken (Working group deductive object bases)</td>
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</table>
Lakemayer, Iwan  
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)

Schroeder, Giani, Weckauf  
Arbeitsgemeinschaft eLearning (eLearning colloquia)

Schroeder, Giani, Weckauf  
Arbeitsgemeinschaft Softwaretechnik für eLearning Systeme

Spitzer, Repges, Lehmann, Spreckelsen, Weßel  
Anleitung zu selbst. wissenschaf. Arbeiten (How to prepare your thesis)

Ney, Bisani, Schlüter  
Kurs Programmierung in der Forschung (Course Programming in Research)

Kobbelt  
Arbeitsgemeinschaft Geometrische Modellierung (Working Group Geometric Modeling)

Spaniol  
Graduiertenkolleg: Software für Kommunikationssysteme (Graduate school. Software for Communication Systems)

### 2.4 Other courses

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

Grädel  
Informatik-Kolloquium (Computer Science Colloquium)
3 Talks within the Computer Science Colloquium

January, 9  Prof. Dr. Wil van der Aalst, TU Eindhoven, Netherlands
Towards an Extendible, Interorganizational, Highly Expressive Workflow Language base on XML, Petri Nets, and Workflow Patterns

January, 16  Prof. Dr. Klaus-Jörn Lange
Symmetrie und Reversibilität bei Kellerautomaten

February, 13  Dr. Mareike Schoop
Neuere Ansätze in der Datenmodellierung

February, 24  Prof. Dr. Juhani Karhumäki, University of Turku
Computing Partial Information out of Intractable one: An Example

March, 6  Prof. Dr. Gerhard Fischer, University of Colorado
Human-Computer Interaction and New Medio: Research Challenges for the Future

March, 31  Dr. Ralf Klasing, CNRS/INRIA Sophia Antipolis
Communication in Interconnection Networks in the Disjoint-Paths Modes

May, 8  Prof. Dr. Gottfried Vossen
Theorie und Praxis der Datenbankmetaprogrammierung

May, 28  Prof. Dr. Hermann Maurer, Graz
Ein mögliches Szenario für den PC um 2010 und seine Bedeutung für unser Leben

June, 3  Dr.-Ing. Martin Bücker
Graphpartitionierung in Computational Engineering & Science

June, 5  Prof. S.V.R. Raghavan, IIT Madras
QoS Studien in Multimedia Communication

June, 16  Prof. Dr. Hector J. Levesque, University of Toronto
Joint ability of groups of agents

June, 25  Prof. Koichi Wada, Nagoya
Algorithms of acknowledged broadcasting and gossiping in ad hoc radio networks

June, 26  Dr. Maurice Pagnucco, University of New South Wales
Causal vs. minimal change approaches to reasoning about action

June, 27  Prof. Dr. Gregory Kersten, University of Ottawa
The Science and Engineering of E-Negotiations

July, 3  Prof. Javier Esparza
Model checking pushdown processes

July, 24  Dr. Thomas Noll
Programmoptimierung durch Konstantenanalyse
<table>
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<tr>
<th>Date</th>
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<tr>
<td>November, 6</td>
<td>Dr. Walter Unger</td>
<td>Die Komplexität von diskreten Optimierungsproblemen und deren Beweisstrukturen</td>
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<tr>
<td>November, 6</td>
<td>Dr. Sebastian Seibert</td>
<td>Transformationsalgorithmen und Komplexitätsschranken für Modelle der Automatentheorie</td>
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<tr>
<td>November, 6</td>
<td>Dr. Guido Proietti</td>
<td>Nearly Linear Time Updating of a Minimum Spanning Tree after Temporary Removal of every Node</td>
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<td>November, 19</td>
<td>Prof. Stefano Crespi Reghizzi, Politecnico di Milano</td>
<td>Formal language definition by associations instead of grammars</td>
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<tr>
<td>November, 24</td>
<td>Dr. Andrzej Pelc, University of Quebec</td>
<td>Broadcasting in radio networks</td>
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<tr>
<td>November, 27</td>
<td>Prof. Dr. Harry Buhrman, Center for Mathematics and Computer Science (CWI) &amp; University of Amsterdam</td>
<td>Quantum Fingerprinting</td>
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<tr>
<td>December, 5</td>
<td>Prof. Dr. Markus Gross, ETH Zürich</td>
<td>Interaktive Computergraphik</td>
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</table>
4 Diploma theses

Ahmeti, Luan  
*Mobilitätsunterstützung in EGPRS Netzen* (Walke, Spaniol)

Altenbernd, Jan-Henrik  
*Automaten über unendlichen zweidimensionalen Bildern* (Thomas, Hromkovic)

Arnolds, Andreas  
*Integration von visuell gestütztem Text Mining und Information Brokering für den durchgängigen Informationszugriff* (Jarke, Lakemeyer)

Assent, Ira  
*Complexity of Two-Way Las Vegas Automata and Related Models* (Hromkovic, Thomas)

Bauland, Michael  
*NTRU encryption system* (Kari, Hromkovic)

Bayerle, Edmund  
*Modell-Checking über unendlichen durch Tree-Rewriting erzeugten Transitionssystemen* (Thomas, Indermark)

Brandt, Sebastian  
*Eine prozeßintegrierte Umgebung für den verfahrenstechnischen Entwurf* (Jarke, Lakemeyer)

Braun, Stefan  
*Ein Inspektionswerkzeug für Java-Objekte* (Lichter, Nagl)

Büyük, Kiymet  
*Voice over EGPRS* (Haverkort, Jarke)

Caliskan, Murat  
*Konzeption und Realisierung von XML Web Services für mobile Anwendungen* (Concept and Realization of XML Web Services for Mobile Applications)(Walke, Jarke)

Calmes, Laurent  
*A binaural sound source localisation system for a mobile robot* (Lakemeyer, Wagner)

Capellmann, Andreas  
*SUCherverfahren zur automatischen Generierung von Polynomordnungen* (Giesl, Lakemeyer)

Celik, Sami  
*Adaptives Caching in Proxy-Servern* (Haverkort, Lakemeyer)

Chen, Xin  
*Performance Evaluation of Multi-Hop concept for IEEE 802.11.e (Leistungsbewertung von Multi-Hop-Konzept für IEEE 802.11e)* (Walke, Haverkort)

Chilinski, Alexander  
*Sicherheitsmanagement für SG-MIXe* (Spaniol, Nagl)

Deißner, Klaus Friedrich  
*Entwicklung und Bewertung eines dezentralen Systems zur passiven Lastbalancierung in heterogenen Verteilten Systemen* (Development and evaluation of decentralised passive load balancing system for heterogeneous distributed systems)(Spaniol,Nagl)
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
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<tbody>
<tr>
<td>Dröttboom, Sascha</td>
<td>Evaluation von Mechanismen zur Unterstützung von Dienstgarantien in Backbone-Netzen (Hoßfeld, Spaniol)</td>
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<tr>
<td>Effendi, Lucky</td>
<td>Formale Spezifikation und Entwicklung eines Simulationswerkzeuges zur Leistungsbewertung des Bluetooth-Protokollstapels (Walke, Haverkort)</td>
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<td>Einhoff, Gerrit</td>
<td>Quality of Service Routing for an IP Premium Service based on MPLS Traffic Engineering (Spaniol, Nagl)</td>
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<td>Elyas, Abdulla</td>
<td>Untersuchung statistischer Verfahren zur Kursprognose (Ney, Jarke)</td>
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<tr>
<td>Emir, Burak</td>
<td>Extending pattern matching with regular tree expressions for XML-processing in Scala (Odersky, Indermark)</td>
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<tr>
<td>Faust, Simon</td>
<td>Virtuelles Tischtennis - Entwicklung von und multimodale Interaktion mit einem kinematischen Modell für virtuelle Akteure (Bischof, Hoßfeld)</td>
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<td>Fischbach, Christian</td>
<td>Konzeption einer Web-basierten Werkzeugumgebung für das Projektmanagement (Lichter, Haverkort)</td>
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<td>Fritz, Christian</td>
<td>Integrating decision-theoretic planning and programming for robot control in highly dynamic domains (Integration von entscheidungstheoretischem Planen und Programmieren zur Robotersteuerung in hochdynamischen Umgebungen)(Lakemeyer, Jarke)</td>
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<td>Fuß, Christian</td>
<td>Entwurf und Realisierung eines a-posteriori Integrators zur reaktiven und inkrementellen Verzahnung von XML-Dokumenten mit repräsentationsorientiertem Text (Nagl, Spaniol)</td>
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<td>Giani, Eva-Maria</td>
<td>Konzeption und Implementierung eines interaktiven Lernsystems zur Grundvorlesung über Automatentheorie (Thomas, Haverkort)</td>
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<tr>
<td>Harman, Yasemin</td>
<td>Modellierung von Web-Servern mit stochastischen Petri-Netzen (Haverkort, Spaniol)</td>
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<tr>
<td>Hops, Daniel</td>
<td>Konzeption und Entwicklung einer Motivationskomponente für E-Learning Systeme (Schroeder, Spaniol)</td>
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</tbody>
</table>
Hornung, Alexander  Autonomous Real-Time Camera Agents in Interactive Narratives and Games (Lakemeyer, Trogemann)

Jansen, Norman  Entwurf eines Rahmenwerkes zur Entwicklung von deliberativen Komponenten für unsichere, hochgradig dynamische Umgebungen mit Echtzeitanforderung (Lakemeyer, Jarke)

Kämmerling, Peter  Entwurf und Implementierung einer Cache Schicht im System Global-Arrays (Hoßfeld, Bischof)

Kienitz, Andr  Untersuchungen zum Einsatz von Taylormodellen bei der verifizierten Lösung von Gleichungssystemen (Lang, Bischof)

Kiesow, Sven  Entwurf und Implementierung einer Web-basierten Navigationskomponente für Projekt-Repositorys (Jarke, Lakemeyer)


Kruschwitz, Guido  Katalogisierung von Leistungsmerkmalen und ihre Spezifizierung für MPI und OpenMP (Hoßfeld, Bischof)

Küpper, Stephan Aloys  Gleichungsdefinierte Abstraktionen für Erlang-Programme (Indermark, Giesl)

Latz, Achim Josef  Eignung von Embedded Linux für kleine und mittlere in vitro-Diagnostikgeräte (Haverkort, Jarke)

Lazaridis, Michail  Bildbasierte Hindernisvermeidung für einen Manipulator in einer virtuellen Umgebung (Vision-Based Collision Avoidance for a Manipulator in a Virtual Environment) (Kraiss, Lakemeyer)

Lethen, Christian  Eine Plattform für das kooperative klinische Wissensmanagement in der pädiatrischen Therapie (Spitzer, Jarke)

Linnenbrügger, Nick  Automatisierte Hybrid TACT Volumen-Rekonstruktionen mittels digitaler Bildverarbeitung (Spitzer, Kobbelt)

Manevitch, Serguei  Kanalzuweisungsstrategien in EGPRS Netzen (Channel assignment strategies in EGPRS networks) (Walke, Haverkort)

Matusov, Evgeni  Statistical Methods for Text Segmentation and Topic Detection (Ney, Hromkovic)
Matzutt, Michael
Entwicklung eines Werkzeugs zur Anforderungsmodellierung bei Software-Produktlinien (Lichter, Nagl)

Matzutt, Stefan
Identifizierung von Modellierungselementen für Software-Produktlinienarchitekturen (Lichter, Nagl)

Michels, Volker
Analyse und Optimierung eines Real-Time Event Service für künftige Kommunikationsnetze (Evaluation and Optimization of a real-time Event service in future communication networks)(Spaniol, Nagl)

Moh, Yvonne
Speaker Clustering for Large Vocabulary Continuous Speech Recognition (Ney, Haverkort)

Ohlenburg, Jan
Efficient Collision Detection for Dynamic Objects in Distributed Virtual Environments (Jarke, Prinz)

Otyakmaz, Arif
Interferenzuntersuchung eines pico-zellulären Systems basierend auf IEEE 802.11 (Interference investigation of a pico cellular system based on IEEE 802.11)(Walke, Spaniol)

Peters, Michael
Implementierung und Vergleich verschiedener Meta-Heuristiken für das Vehicle Routing Problem mit Zeitfenstern (Sebastian, Hromkovic)

Pimenidis, Alexis
Struktur und Analyse von Chaum-Mixen (Structure and Analysis of Chaumian Mixes)(Spaniol, Nagl)

Pöschmann, Martin
Management von Vertrauensdiensten auf elektronischen Marktplätzen (Jarke, Lakemeyer)

Raddatz, Marcus
Semi-automatisierte Testcodegenerierung aus UML-Sequenzdiagrammen für CORBA-Komponenten am Beispiel von CAPE-Open (Jarke, Lakemeyer)

Raschka, Robert
Entwurf und Gestaltung der Benutzungsschnittstelle einer integrierten Kommunikationsumgebung (Luczak, Spaniol)

Razen, Wolfgang
Video-on-Demand Systeme: Architektur und Leistungsbewertung (Haverkort, Spaniol)

Riedel, Björn
Entwicklung von Ähnlichkeitsmaßen für den Vergleich von Spielsituationen im Robo Cup (Lakemeyer, Jarke)

Rukasz, Dorothea
Objektorientierter Softwareframework für die Visualisierung und Verfolgung von CDF Strömungsmerkmalen (Bischof, Hoßfeld)
Samulowitz, Horst  The Efficiency and Implementation of an Evaluation-Based Reasoning Procedure with Disjunctive Information in First-Order Knowledge Bases (Lakemeyer, Giesl)

Schall, Oliver  Automatic texture atlas generation for manifold surfaces (Automatische Erzeugung von Textur-Atlanten für mannigfaltige Flächen (Kobbelt, Lakemeyer)

Schiffer, Thomas  Integration des CAE-Planungswerkzeuges PLANEDS über standardisierte Schnittstellen in Form von Web Services (Jarke, Berlage)

Schlebusch, Elmar  Adaptive Farb-Kalibrierung zur Gesichtsdetektion (Adaptive Color Calibration for Face Detection) (Kraiss, Kobbelt)

Schmitz, Dominik  Eine Erweiterung des Agentenmodells in SNet um eine Planungskomponente unter Verwendung von Nutzentheorie (Lakemeyer, Jarke)

Schmitz, David  Adressierung digitaler Medien mittels community-basierter Agententechnik (Jarke, Lakemeyer)

Schneider-Kamp, Peter  Automatisierung von Terminierungsbeweisen mit Dependency Pairs und rekursiven Pfadordnungen (Giesl, Indermark)

Sevenich, Bernd  Paralleles Volume-Rendering auf PC-Clustern mit lokal verfügbarer Graphik-Hardware (Westermann, Bischof)

Smyczek, Adam  Integration von Kollisionserkennung und Physikalisch Basierter Modellierung in Virtuellen Umgebungen (Bischof, Kraiss)

Spelmezan, Daniel  The mobility of GPRS users (Haverkort, Jarke)

Staskiewicz, Dirk  Logikbasierte Überwachung der Vertragserfüllungsphase im elektronischen Handel (Jarke, Lakemeyer)

Thoma, Jerome  Interaktive, nicht-photorealistiche Techniken zur Darstellung animierter Charaktere in virtuellen Umgebungen (Westermann, Trogemann)

Uthke, Thorsten  Untersuchung von Spezifikations- und Entwurfsmethoden für Komponenten anhand des EJB Komponentenmodells (Lichter, Siedersleben)

Vetter, Christoph  Echtzeitfähige, physikalisch basierte 3D Billiardsimulation (Westermann, Bischof)
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<tr>
<td>Volovelsky, Yariv</td>
<td>Entwurf, Implementierung und Leistungsbewertung eines aktiven Videocaches zur Videoübertragung in drahtlosen multi-hop Netzen (Design, Implementation and Performance Evaluation of an Active Packet Video-Cache for Video Streaming in Wireless multi-hop Networks) (Spaniol, Nagl)</td>
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<td>von Studnitz, Andreas</td>
<td>Adaptive Subdivision-Algorithmen (Kobbelt, Bischof)</td>
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<td>Voss, Markus</td>
<td>Rapid Prototyping für die Steuerung simulierter Roboter (Rapid Prototyping for the Control of Simulated Robots) (Kraiss, Lakemeyer)</td>
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<td>Wallmeier, Nico</td>
<td>Symbolische Synthese zustandsbasierter reaktiver Programme (Thomas, Giesl)</td>
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<tr>
<td>Yin, Wie</td>
<td>Entwicklung eines datenbankgestützten Softwarewerkzeuges für die rechnergestützte Generierung statistischer Versuchspläne (Pfeifer, Jarke)</td>
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<td>Yu, Xinghan</td>
<td>Erweiterungen einer CORBA-Implementierung zur Kommunikation mobiler Endgeräte (Bemmerl, Haverkort)</td>
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<td>Zollorsch, Andreas</td>
<td>Volumenvisualisierung zeitabhängiger, unstrukturierter Gitterdaten in Virtuellen Umgebungen (Bischof, Kobbelt)</td>
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Statistics

The following table gives the total number of students enrolled in the “Computer Science” program, 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
Staff

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- Senior Lecturer:
  Dr. Walter Unger

- Researchers:
  Dr. Hans-Joachim Böckenhauer
  Dirk Bongartz
  Joachim Kupke (funded by DFG)
  Dr. Sebastian Seibert

- Guest Researchers:
  Dr. Luca Forlizzi (January - February, October - December 2003)
  Dr. Ralf Klasing (July 2003)
  Yvonne Moh (April - May 2003)

- Technical Staff:
  Viktor Keil
Overview

Regarding both research and teaching, the department deals with the following topics:

- Mathematical foundations of computer science
- Complexity theory
- Algorithmics
- Formal languages and automata theory

Main research topics in the area of complexity theory:

- Quantitative relationships between different complexity measures.
- Comparison of the computational power of deterministic, non-deterministic and probabilistic computations.
- Lower bounds on the complexity of concrete algorithmic problems.
- Study of communication complexity as an abstract complexity measure.

Main research topics in the area of algorithmics:

- Design and development of approximative, randomized and heuristic algorithms for hard computational problems (e.g. NP-hard problems).
- Distributed algorithms, in particular communication algorithms in networks.

Main research topics in the area of formal languages and automata theory:

- Comparison of descriptive complexity measures of regular language representations.
- Descriptive and computational complexity of infinite word generation.

Teaching includes the presentation of basic scientific knowledge of computer science within the following lectures:

- Foundations of theoretical computer science,
- Formal languages, computability, and complexity theory.
Here, fundamental results on the edge between possible and impossible in algorithmic data processing can be found, as well as quantitative laws of information processing, storing, and transmission.

The second emphasis in teaching is devoted to the application of theoretical “know-how”, complexity theory and algorithmics. The department regularly offers lectures covering the following areas:

- Design of algorithms,
- Approximative, randomized, and heuristic algorithms,
- Parallel algorithms,
- Cryptography,
- Computational Biology.

Research Projects

**On the computational power of randomization and nondeterminism**

*J. Hromkovič, J. Kupke, S. Seibert*

[Funding: DAAD]

*External cooperations: Prof. Dr. M. Dietzfelbinger (Ilmenau), Prof. Dr. G. Schnitger (Frankfurt)*

The project mainly investigates the following two fields:

(a) **Communication complexity**

Recently, abstract communication complexity has become as important as the fundamental complexity measures like time and space complexity. Reasons include a significant progress achieved in the study of the power and the properties of randomized and non-deterministic computations in the framework of communication protocols, and the possibility to transfer results regarding communication complexity to the study of fundamental complexity measures of basic computing models. The aim of this project is to find new applications of communication complexity in order to solve some of the basic open problems in complexity theory. The main emphasis is devoted to proving lower bounds on the complexity of solving concrete problems and to the study of the nature of randomness.
(b) The role of the number of non-deterministic decisions in non-deterministic computations

One of the basic tasks of complexity theory is the investigation of the difference between deterministic and non-deterministic computations with respect to computational power. (The best-known topic of this kind is the comparison of $P$ to $NP$.) Here, we try to determine the number of non-deterministic decisions for which the computational power of non-determinism significantly exceeds that of determinism in the framework of different computing models.

**Communication algorithms in networks**

*H.-J. Böckenhauer, J. Hromkovič, W. Unger*

*External cooperations: Dr. R. Klasing (Nice), Prof. Dr. X. Muñoz (Barcelona)*

The goal of this project is the investigation of different types of networks as candidates for parallel architectures or communication networks. The quality is measured in terms of the efficiency of basic communication types such as broadcasting, routing, gossiping, and accumulation. As a result of our work, we would like to develop efficient algorithms for communication in networks or to prove lower bounds on the complexity of the considered communication tasks. In this way we give recommendations for interconnection structures with good communication characteristics.

**Specification of the class of practically solvable algorithmic tasks**

*H.-J. Böckenhauer, D. Bongartz, J. Hromkovič, J. Kupke, S. Seibert, W. Unger*

*[Funding: DFG]*

*External cooperations: Dr. R. Klasing (Nice), Prof. Dr. G. Proietti (L'Aquila), Prof. Dr. P. Widmayer (Zurich)*

In this project, we aim at the development of algorithms for solving hard (e.g. NP-hard) problems. The first central topic is to develop approximative methods and to prove the non-existence of efficient approximation algorithms. The second central topic deals with expediting known approximation algorithms for various tasks arising in practical applications.
In the area of formal languages and automata theory, there are different formalisms for representing of regular languages (e.g., various finite automata models, regular expressions, regular grammars, etc.). The quality of these formalisms can be measured in terms of:

1. Descriptive complexity (the size of the representation of concrete languages) and
2. Computational complexity (how costly it is to work with this formalism, e.g. what is the time complexity of solving basic problems in this formalism).

Although these problems belong to one of the oldest research areas in theoretical computer science, several basic questions still remain open. We focus on representations of regular languages and infinite words.

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, good approximation algorithms or heuristics are required. Special focus is given to the design and investigation of algorithmic solutions to problems arising in DNA sequencing.

Other Activities

Besides the work in projects the department participates in a number of further activities. They concern the work in boards, and scientific services in terms of editorial and refereeing activities.

Editorial and refereeing activities

J. Hromkovič is a member of the editorial board of the following journals and book series:
• R.A.I.R.O. Theoretical Informatics and Applications
• Grammars
• Computers and Artificial Intelligence
• Advances in Mathematics and Physics
• Acta Mathematica et Informatica Universitatis Ostraviensis
• EATCS Texts in Theoretical Computer Science, Springer

J. Hromkovič was a member of the program committee of the following conferences: CIAA 2003, DCFS 2003, SOFSEM 2004, and WG 2003.

H.-J. Böckenhauer has been active as a referee for CIAA 2003, SOFSEM 2004, WG 2003, and TCS.

D. Bongartz has been active as a referee for CIAA 2003, SOFSEM 2004, WG 2003, and TCS.

J. Kupke has been active as a referee for SOFSEM 2004 and WG 2003.

S. Seibert has been active as a referee for CIAA 2003, DCFS 2003, SOFSEM 2004, and Journal of Automata, Languages and Combinatorics.

W. Unger has been active as a referee for CIAA 2003, SOFSEM 2004, and WG 2003.

Research stays

H.-J. Böckenhauer stayed with Peter Widmayer’s group at ETH Zurich from October 1st through December 31th, 2003.

D. Bongartz stayed with Peter Widmayer’s group at ETH Zurich from October 1st through December 31th, 2003.
Publications

Monographs


Publications in journals


Publications in refereed books and proceedings


Theoretical Computer Science

Staff

- Faculty:
  Prof. Dr. Peter Rossmanith

- Secretary:
  Valentina Elsner

- Guest Researchers:
  Bolette Ammitzbøll Madsen, M.Sc., (BRICS Aarhus)

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

- Technical Staff:
  Sami Okasha
Overview

The Theoretical Computer Science Group 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 and are 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. Sometimes we 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 surprisingly often be solved quite efficiently. In the paradigm of parameterized complexity 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 — they have in some way a “simple structure.”

The picture shows a medium-size graph together with an minimum size vertex cover, i.e., a set of nodes that covers all edges.

Research Projects

Optimization Variants of Exact Satisfiability

Bolette Ammitzbøll Madsen, Daniel Mölle, Stefan Richter, Peter Rossmanith
The Exact Satisfiability problem is the following: Given a boolean formula in conjunctive normal form, is there an assignment to the variables satisfying exactly one literal in each clause? We call such an assignment exactly satisfying. The Exact Satisfiability problem (also called XSAT and 1-in-k-SAT) is NP-complete even when restricted to the case where each clause contains at most 3 literals and there are no negations (reference). The best known algorithm for Exact Satisfiability has a running time of $O(2^{0.2325n})$, where $n$ is the number of variables (reference). A similar algorithm yields a running time of $O(2^{0.1550L})$, where $L$ is the number of literals in the formula. However no good algorithm for Exact Satisfiability in the number of clauses is known. If we restrict the length of clauses to three, good algorithms exist for all three parameters though.

We look at two variants of Maximum Exact Satisfiability inspired by Exact Satisfiability and Maximum Satisfiability problems. The Maximum Exact Satisfiability problem (Max-Exact-Sat) is: given a boolean formula in CNF, how many clauses can be exactly satisfied? This problem is NP-hard as it is a generalisation of the Max-Cut problem, which is known to be NP-hard (reference). The Max-Cut problem is equivalent to the Max-Exact-2-Sat (each clause contains only two literals) problem with no negations. We present an algorithm for Max-Exact-2-Sat (with negations) which has a running time of $\text{pol}(L) \cdot 2^{m/4}$, where $L$ is the length of the formula (number of literals) and $m$ is the number of clauses. This matches the best known algorithm for Max-Cut, which is $O(2^{m/4})$, where $m$ is the number of edges (reference).

The second variant we shall call Restricted Max-Exact-Sat (Max-Unique-Sat). The Restricted Max-Exact-Sat problem is: given a boolean formula in CNF, it is not allowed to ‘over-satisfy’, i.e. two literals in the same clause cannot both be true, now how many clauses can then be exactly satisfied? We show that the Restricted Max-Exact-Sat (Max-Unique-Sat) problem is also NP-hard even in the special case of Max-Unique-2-Sat with no negations. We give an algorithm for Restricted Max-Exact-Sat (Max-Unique-Sat) with time complexity $\text{pol}(L) \cdot 1.324718^n$, where $n$ is the number of variables.

Formalizing Integration Theory, with an Application to Probabilistic Algorithms

Stefan Richter

Inter alia, Lebesgue-style integration plays a major role in advanced probability. We formalize a significant part of its theory in Higher Order Logic using Isabelle/Isar. This involves concepts of elementary measure theory, real-valued random variables as Borel-measurable functions, and a stepwise inductive definition of the integral
Building on previous work about formal verification of probabilistic algorithms, we exhibit an example application in this domain; another primitive for randomized functional programming is developed to this end. All proofs have been carried out in human readable style using the Isar language.

**Identifying Realistic Instances for Hard Problems and Design of Efficient Algorithms**

*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 Beigel and Eppstein solves this problem in time $O(1.345^n)$, 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 Beigel and 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.
Talks and Publications

Talks

Publications


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  Dipl.-Inform. Volker Stolz  
  Dipl.-Inform. Michael Weber

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Overview

The research at Computer Science II covers many aspects of programming languages and is characterised by a fruitful interplay between theory and practice. Special areas of interest include semantics, implementation, analysis, and verification.

While for many years there has been a special focus on sequential and parallel functional languages, activities now concentrate on the analysis and efficient implementation of object-oriented programming languages and on the modelling, implementation, and verification of concurrent systems. Prominent representatives of the first kind are C++ and Java. With respect to the implementation of concurrent systems, mainly functional languages such as Erlang or Haskell are being studied.

As a particular event, we mention that Thomas Noll has obtained the degree “Privat-Dozent” presenting a habilitation thesis on Term-Rewriting Models of Concurrency.

Research Projects

Parallel Model Checking


The development of the software tool called TRUTH started in 1997. In its basic version it supports the specification and verification of concurrent systems described in the CCS process algebra. To support the understanding of the system’s behaviour, the specification can be graphically simulated in an interactive and process-oriented way.

TRUTH offers several model-checking algorithms such as a local tableau-based model checker, which has the advantage that in many cases only a part of the transition system has to be built in order to verify or to falsify a formula. Additionally, a game-based algorithm has been integrated which can be used to demonstrate the invalidity of a formula by means of an interactive construction of a counterexample. Again, the process visualisation component is used to play and visualise this game between the user and the TRUTH tool in order to support debugging of error-prone specifications.

The most recent component of the TRUTH verification platform is a dedicated parallel version running on workstation clusters, which is intended for high-end verification tasks. We designed a parallel model checking algorithm for the alternation-free fragment of the μ-calculus. It distributes in parallel the underlying transition system and the formula to check over a Networks Of Workstations (NOW) and determines, again in parallel, whether the transition system satisfies the formula.
Software written for telecommunication applications has to meet high quality demands, and due to its nondeterministic behaviour testing is 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:

- In cooperation with a research group at the Swedish Institute of Computer Science (SICS, Stockholm) we are developing a theorem–proving framework for Erlang programs. The main deliverable is the Erlang Verification Tool (EVT), a proof assistant which supports the user in establishing correctness properties of Erlang programs which are formulated in a specification logic. It supports a rich verification framework for goal–directed, proof system–based reasoning. Current research activities concentrate on the following aspects:
  - Investigating the problem of semi–automating the verification task by identifying the proof parameters crucial for successful proof search.
  - Implementing an extension of the EVT tool which allows to reason about the Erlang code on the architectural level of an application. In particular we are developing a verification method for client–server systems designed using generic server templates.

- To make Erlang systems amenable to automatic model checking techniques, another 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 Erlang in Rewriting Logic, a unified semantic framework for concurrency which is founded on conditional term rewriting modulo equational theories. In particular the latter allow us to define abstraction mappings on the state space. The results obtained so far are very promising, inviting to further investigate the benefits of equational abstractions for Erlang programs.
Message Sequence Charts

B. Bollig, M. Leucker

A prominent formalism to model communicating systems are message sequence charts (MSCs). They are standardised, can be denoted textually as well as graphically, and are often employed in industry. Furthermore, they are quite similar to UML’s sequence charts.

We develop analysis methods to support the early detection of errors during the design process of protocols. Our main focus lies on the expressivity of message-passing automata and related logics.

Model Checking Probabilistic Infinite-State Systems

B. Bollig

We address the model-checking problem for programs with nondeterministic and randomising states wrt. qualitative and quantitative properties, i.e., the question whether a probabilistic program almost surely satisfies its specification.

Existing approaches for the verification of finite probabilistic programs are extended towards programs with infinite state space. More precisely, we exhibit classes of infinite-state programs for which the model-checking problem is still decidable.

Runtime Verification of Concurrent Haskell

V. Stolz, F. Huch

The lazy functional programming language Haskell supports the creation of lightweight threads and a set of primitives for communicating among them. The API offers simple message passing through mutable variables and streams of messages through channels.

Concurrent programs may contain bugs like deadlocks which are hard to reproduce. Potentially bad behaviour of those programs can be detected through runtime verification where Linear-Time Logic (LTL) formulas are used to express high-level assertions. We implemented an LTL-checker in Haskell which, driven by annotations in the source program, checks those formulas.

If a violation is detected, the trace leading to this situation can be examined. For future work, we expect to integrate this approach into the graphical Concurrent Haskell Debugger to provide an extensive debugging facility for Concurrent Haskell.
**Generation of Typed Process Skeletons**

*V. Stolz*

Concurrent systems are usually first designed and then implemented. As these are two completely separate steps, the implementation may differ from the intended behaviour of the specification because of bugs or unforeseen complications in implementing e.g. the communication mechanism used in the specification. Furthermore, it should be possible to modify the protocol used in communication and code fragments unrelated to the protocol in an independent manner. In this approach we automatically generate code from a specification and provide the developer with the means to interface to this framework.

The behaviour of a concurrent system using message passing can be described with Message Sequence Charts (MSCs). We outline a framework of generating an executable Concurrent Haskell skeleton from an MSC which captures static properties of the MSC (definedness of variables, typed messages) and allows for combination of MSCs with well-defined interfaces (*gates*). These properties are checked by the target language compiler and make additional checks on the specification unnecessary.

We compiled a comprehensive list of tools for working with MSCs which can be found at [http://www-i2.informatik.rwth-aachen.de/AG/MCS/MSC/](http://www-i2.informatik.rwth-aachen.de/AG/MCS/MSC/). To make visualisation of MSCs easier, ‘Mu2L – MSC Textual to Graphical Representation Tool’ was developed.

**Program-Based Verification of Communication Protocols Modeled with SDL**

*M. Weber*

The goal of this project, which is supported by the graduate college “Software für Kommunikationssysteme”, is to evaluate the feasibility of using Model Checking techniques for the verification of communication protocols, with the focus on protocols formally specified in the *Specification and Description Language* (SDL).

Current research activities focus on finding a basic fragment of SDL which on the one hand covers enough of the language to be practically useful, but on the other hand reduces the complexity of SDL enough to keep it manageable for Model Checking techniques. Other points of interest are the evaluation and integration of various methods for timed Model Checking, reducing resp. handling large state spaces and exploiting modularity.
Other Activities

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)

B. Bollig

- Visiting Prof. Marta Kwiatkowska, School of Computer Science, University of Birmingham, October 2003 - March 2004, funded by the German Academic Exchange Service (DAAD)
- Editor of Kommentiertes Veranstaltungsverzeichnis

Th. Noll

- Programme committee member of the 3rd Workshop on Language Descriptions, Tools and Applications (ETAPS/LDTA'03)
- Organizing committee member of the 4th Workshop on Language Descriptions, Tools and Applications (ETAPS/LDTA'04)
- Member of the examination boards for Computer Science, Computational Engineering Science and Computational Material Science
- Student advisor for the following subsidiary subjects within CS: Electrical Engineering, Civil Engineering, and Medicine

V. Stolz

- Administrator of the web site for Aachener Informatik Berichte, the technical report series of the Department of Computer Science.
Talks and Publications

Talks

B. Bollig: A Hierarchy of MSC Languages, Theory Seminar Series, School of Computer Science, University of Birmingham, October 31st, 2003


Th. Noll: Equational Abstractions for Model Checking Erlang Programs, International Workshop on Software Verification and Validation (SVV ’03), Mumbai, India, December 14th, 2003

V. Stolz: Runtime Verification of Concurrent Haskell, 12th International Workshop on Functional and (Constraint) Logic Programming, Valencia, Spain, June 12th – 13th, 2003


V. Stolz: Generierung getypter Prozessgeräte, 20. Workshop der GI-Fachgruppe 2.1.4: Programmiersprachen und Rechnerkonzepte, Bad Honnef, Germany, May 7th – 9th, 2003

Publications


B. Bollig, M. Leucker: Deciding LTL over Mazurkiewicz Traces, Data & Knowledge Engineering, 44/2:221-240, February 2003


Th. Noll: Equational Abstractions for Model Checking Erlang Programs, International Workshop on Software Verification and Validation (SVV ’03). To be published


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  Achim Lücking
  Peter Schneider-Kamp
  Eugen Yu

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  Arnd Gehrmann
Overview

Our research group is concerned with several topics from the area of programming languages and verification. Therefore, we have a close cooperation with the group of Computer Science II (Prof. Dr. Indermark). 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 2003, we held the first-year course on Computer Science I – Programming Concepts for more than 600 students and lectures on Automated Program Verification and Functional Programming. Moreover, we offered seminars on Program Verification, Termination Analysis, and on IT-Security Concepts and Security in Java.
Research Projects

AProVE: Automatic Program Verification Environment
Jürgen Giesl, René Thiemann, Peter Schneider-Kamp et al.

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.

Extension and Application of Techniques for Termination Analysis
Jürgen Giesl, René Thiemann, Peter Schneider-Kamp, Stephan Falke, Andreas Capellmann, Achim Lücking

In an earlier project funded by the DFG, we developed powerful techniques for automated termination analysis. Based on these results we compare and extend termination techniques for different programming paradigms and develop them further in order to obtain efficient procedures which are applicable for programs in practice. To this end, we design and implement a powerful automated termination prover within our system AProVE. Experiments on large benchmarks of examples show that our system is among the most powerful ones currently available. The system can be obtained from

http://www-i2.informatik.rwth-aachen.de/AProVE
This project is a cooperation with the University of Tsukuba, Japan, resp. the University of Innsbruck, Austria, which was supported by the JSPS. The aim is to develop analysis techniques for evaluation strategies used in functional programming. For example, we are concerned with extending verification techniques in order to handle context-sensitive term rewrite systems, which are used to model lazy evaluation. For that purpose we work on transformations from context-sensitive to ordinary term rewrite systems. With these transformations, it is sufficient to prove desirable properties for the transformed ordinary rewrite system, because this implies that these properties hold for the original context-sensitive system as well.

This joint project with the Technical University 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.

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.
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 a special issue of the *Journal of Automated Reasoning* on “Techniques for Automated Termination Proofs” (together with Deepak Kapur, University of New Mexico, USA)
- Reviewer and member of the PhD committee for Olivier Fissore, University of Nancy, France
- Member of the PhD committee for Cristina Borralleras, University of Barcelona, Spain
- PC-member of the “3rd International Workshop on Reduction Strategies in Rewriting and Programming (WRS ’03)”, Valencia, Spain
- PC-member of the “6th International Workshop on Termination (WST ’03)”, Valencia, Spain
- Several research visits at the Technical University Eindhoven, The Netherlands
- Research visit at the University of Valencia, Spain
- Participant of the International Dagstuhl-Seminar “Deduction and Infinite-State Model Checking”, Dagstuhl, Germany
- Reviewer for many international journals and conferences

R. Thiemann:

- Participant of the Marktoberdorf Summer School (NATO Advanced Study Institute) on “Proof Technology and Computation”
Talks and Publications

Talks

J. Giesl: Deciding Inductive Validity of Equations, International Dagstuhl-Seminar “Deduction and Infinite-State Model Checking”, Dagstuhl, Germany, April 2003

J. Giesl: Simulating Liveness by Reduction Strategies, 3rd International Workshop on Reduction Strategies in Rewriting and Programming (WRS ’03), Valencia, Spain, June 2003

J. Giesl: Liveness in Rewriting, 14th International Conference on Rewriting Techniques and Applications (RTA ’03), Valencia, Spain, June 2003


J. Giesl: Termination of Term Rewriting Using Dependency Pairs, Invited talk at the University of Nancy, France, December 2003

J. Giesl: Termination Analysis for Functional Programs and Term Rewrite Systems, Invited talk at the University of Valencia, Spain, December 2003

R. Thiemann: Size-Change Termination for Term Rewriting, 14th International Conference on Rewriting Techniques and Applications (RTA ’03), Valencia, Spain, June 2003

R. Thiemann: Showing Non-Simple Termination Automatically, Marktoberdorf Summer School (NATO Advanced Study Institute), Germany, August 2003

R. Thiemann: Improving Dependency Pairs, 10th International Conference on Logic for Programming, Artificial Intelligence and Reasoning (LPAR ’03), Almaty, Kazakhstan, September 2003


P. Schneider-Kamp: AProVE: A system for Proving Termination, 6th International Workshop on Termination (WST ’03), Valencia, Spain, June 2003

P. Schneider-Kamp: Automatisierung von Terminierungsbeweisen mit Dependency Pairs und rekursiven Pfadordnungen, LuFG Informatik II, RWTH Aachen, October 2003


A. Capellmann: Suchverfahren zur automatischen Generierung von Polynomordnungen, LuFG Informatik II, RWTH Aachen, September 2003
Publications


R. Thiemann and J. Giesl: *Size-Change Termination for Term Rewriting*, *Proceedings of the 14th International Conference on Rewriting Techniques and Applications (RTA-03)*, Valencia, Spain, Lecture Notes in Computer Science 2706, Springer-Verlag, pages 264-278.


Software Engineering

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  Dipl.-Inform. M. Kirchhoff
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 studied concurrent and distributed systems in the
embedded systems domain, too. Project types are new development, reengineering, and reuse projects.

Most projects aim at improving general software engineering techniques or facilitating other 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 our 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, Multi Media Project CHASID, 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 a bunch of 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 nearly every second year:

- 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)


The AHEAD project is part of the IMPROVE project (CRC 476) 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 dynamics of development processes, which are continuously evolving during their enactment. The management model of AHEAD integrates three underlying models for the management of activities, products and resources. The management model of AHEAD is specified based on graph rewriting in PROGRES.

In 2003, we continued the work on process evolution and distributed process management. To increase the flexibility of the management system, an approach for process evolution was developed and realized within a Dissertation project. This approach supports the integrated evolution of process model definitions and process model instances. Several tools for process evolution support have been implemented. Because development processes are not always carried out within a single organization, a grey-box approach for process distribution was developed and realized within another Dissertation project. The approach is centered around a delegation relationship between two organizations where one organization delegates a part of the development process to another organization. A cooperation model was developed and appropriate tool support has been implemented. The AHEAD system is based on the UPGRADE framework which provides support for the development of graphical user interfaces for graph-based tools. In 2003, the UPGRADE framework has been consolidated and improved significantly.

In cooperation with other projects within the CRC project we have developed several concepts and tools, for example, an integrator between process flow diagrams describing the process structure within chemical processes and the task nets in the AHEAD system. In this way, a tighter coupling between the technical level of chemical processes and the administrative level of these processes has been achieved.

In April 2003, all developed features of the AHEAD system were presented at the CRC project review. Especially, in two separate scenarios we presented the process evolution
When designing a building, an experienced architect implicitly applies his aggregated knowledge to the new sketch. In this early design phase, called conceptual design, most architects do not elaborate their sketches using a CAD system. They rather work with pencil and paper. Without being directly aware of, the architect considers design rules, functional requirements, economic and legal restrictions. Constructive elements (like walls, windows, or doors) are used with their conceptual meaning, namely to form organizational areas or rooms, to guarantee light and ventilation, or to ensure accessibility. These conceptual elements, therefore, form a functional view of the design structure which, however, is not explicitly defined. Existing CAD systems give no support for this creative conceptual design.

In our idea, conceptual design support consists of two main parts. First, domain specific knowledge has to be formalized for a class of buildings by an experienced architect, called knowledge engineer. We therefore develop a visual language for knowledge definition, and a graph based application implementing this language. Second, an industrial CAD tool is extended to allow architects designing in a conceptual way. These extensions are easy to use and promote the architect’s creativity. Both parts are integrated through consistency analyses, so that the architect’s sketch can be checked against defined knowledge.

The Domain Knowledge Graph Editor, an application based on PROGRES and the UPGRADE framework, provides functionality to define conceptual knowledge. The application represents knowledge in a formal, but human readable form. The Domain Knowledge Graph Editor enables a knowledge engineer to dynamically elaborate a knowledge model and knowledge instances, based on a fixed PROGRES graph schema and parameterized graph rewriting rules. For knowledge representation, we introduce new conceptual design elements, which are more intuitive to use and are capable to store conceptual information. Such elements are rooms and areas. Rooms are the most important entities, as each building basically consists of rooms. Areas describe aggregations of several rooms. Both are instances of the PROGRES node class semantic object. To further describe properties of semantic object, we provide the node class attribute. The node class relation allows defining interrelationships between semantic objects. Based on this dynamic knowledge model, the knowledge engineer elaborates specific knowledge instances, i.e. attribute rules and relation rules, valid for a class of buildings.

To support the conceptual building design, we exemplarily extend the CAD tool ArchiCAD with new functionality. Our main extensions to ArchiCAD are roomobjects and roomlinks. These new design elements represent a room’s functionality and interrelationships between
rooms. Using roomobjects and roomlinks, the architect can explicitly design the conceptual and functional organization of a building. The ArchiCAD extensions support a more intuitive workflow; thus, conceptual information, which usually gets lost, is preserved in the sketch.

Based on the formalization of knowledge and design, a sketch elaborated in ArchiCAD can be checked against the defined knowledge to identify inconsistencies. The domain specific knowledge is exported from the Domain Knowledge Graph Editor into a RDF format then it is imported and interpreted by the new ArchiCAD constraint checker. The architect’s sketch is checked and the architect is informed in case of restriction violations.

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**Integrated eBusiness-Systems in Home Automation**


The domain of **eHome systems** is gaining more importance due to recent developments in hardware technology and the trend towards pervasive and ubiquitous computing. Growth in this area is also attractive due to its increasing market potential. However, there are a number of problems to be tackled 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 could 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 problem fields have been dealt with. Hence, suitable and reasonable models and structures for this new application domain still need be developed.

Our approach is to apply software engineering principles (such as requirements engineering, configuration management, and process management) to this problem domain. The tasks in eHome system development can be grouped into (1) service architectures and eProcesses, (2) configuration management and utilization, and (3) incorporation of resource constrained devices.

For evaluation and proof of the models, we developed several prototypes: The diversity of inter-provider and provider eHome communication is handled by a our Distributed Services Framework (DSF). We overcome the heterogeneity of the different appliances and protocols by a layered software architecture based on OSGi. The secure and distributed data access is provided by the Distributed Data Access (DDA) which is currently being developed. The realization of user interface for the services is eased by Power-Interact, an interaction description-based interface generator.
These infrastructures have been used to develop an imaging service providing arbitrary access to imaging devices (e.g. cameras), a wake-up service, and an alarm service. The latter two additionally have been realized based on PowerLogic, which offers rule-based development of services on a semantical high level. For multimedia-applications we developed a multimedia mapper based on OSGi which enables a transparent mapping of recorder components to player components. For the storage of semantic dependencies between appliances, frameworks, and components we developed an ontology and implemented a component preselector based on a knowledge base relying on this ontology. The component preselector is used in the deployment producer which helps refining an abstract scenario definition to a deployment configuration.

E-CARES (Ericsson Communication Architecture for Embedded Systems)

A. Marburger, S. Giesecke, M. Nagl, T. Eisbein, E. Schultchen, M. Sturm, B. Westfechtel, R. Wittek

D. Herzberg, A. Jeske, A. Thüllig (Ericsson Eurolab)

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 III, 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. The project is subdivided into two subprojects.

In the first subproject, a reverse and reengineering tool set is developed to enable semi-automated program comprehension. In this stage of work, the subproject focused on the detection, extraction, and visualization of information on system structure and behavior. Extraction from static information (code) and from runtime information (traces) is regarded. The static information is used to build a so-called system structure graph. This graph contains information on a systems decomposition into different units at different granularity, where the most fine-grained units are atomic units of execution plus some special statements. Furthermore, the system’s control flow and parts of its data flow are represented by the graph as well. Post-processing algorithms are used to condense parsing information in the graph and lift or lower informations between the different layers. In the user-interface, multi-layer abstraction and visualization is used to reduce the amount of information displayed at once or to focus on certain aspects of the system. The structural analysis is completed by a mapping of the structure graph onto a ROOM architecture graph.

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. Internally, the traces are represented by instance graphs whose elements are related to their counterparts in the structure graph. Furthermore, there are three different execution modes – step mode, run mode, and simulation mode with aging – for trace inspection available.

The most recent extension of the prototype considers an undo/redo feature that has been added to the dynamic analysis tool to allow stepwise interactive inspection of trace results in “forward” and “backward” direction. Moreover, a trace correction facility allows to detect and reproduce information missing in trace files due to a limited observation scope or non-observable events in the system. In addition, the existing tools and reverse engineering facilities have been improved and reorganized towards a modular, flexible, and extensible reverse engineering environment.

In the other E-CARES subproject, which finished in fall 2003, the modeling of system architectures, specifically of telecommunication systems is studied. The distributed nature of communicating systems and the use of protocol stacks as an abstraction for different levels of communication demand for modeling concepts. These requirements are not anchored in current modeling languages such as UML (Unified Modeling Language), SDL (Specification and Description Language) or ROOM (Real-time Object-Oriented Modeling). The dissertation offers a suitable modeling language and appropriate tool support. As a prominent candidate, ROOM was chosen as basis for this extension.

**PROGRES: A Suite For Specifying Prototypes**

*B. Böhlen, M. Breuer, M. Heller, T. Hermes, P. Kehren, T. Lettow, U. Ranger, G. Volkova, S. Wilms, in cooperation with A. Schürr, Technical University of Darmstadt*

PROGRES: A language for specifying graph transformations

PROGRES is a high level language which facilitates the specification of graph rewriting systems (GRS). The practical development of that kind of systems is supported by a dedicated PROGRES environment, which allows visual modelling of GRS. Developed at our department in 1995, both the PROGRES language and the PROGRES environment have been constantly improved to serve the needs of various application domains.

The increasing complexity of applications realized with the help of PROGRES demands the development of concepts to support specification in the large. These might include the distribution of graph transformations and the modularization of large specifications.

The majority of the projects at our department are based on PROGRES. They include cooperations with industry partners such as the Springer Verlag and Ericsson.

**PROGRES extension**

In 2003 we improved the PROGRES system. The most important improvement was the enhancement of object-oriented features, which allows the binding of methods to their re-
spective node types and classes. The usage of a 32 bit address space in the persistence layer (graph database GRAS) furthermore has increased the number of nodes in a host graph from 65536 to a million.

Besides minor improvements of the graphical user interface, PROGRES has been extended by a hierarchical view of the package structure. It enables the user to systematically explore the schema and transformations of certain packages.

**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. In 2003 the architecture of the framework was consolidated and substantial changes were performed to improve framework.

**GRAS: A database for software engineering environments**

Graph transformations systems like PROGRES modify complex documents and perform operations on them. Amongst these operations are not only complex manipulations of the internal data structures but also operations like undo or redo. Some of these operations are not offered by common database systems. Therefore, we have developed the GRAS database management system which provides operations like undo or redo and thus meets the requirements of PROGRES and similar applications. The primary purpose of GRAS is to store and manipulate graphs efficiently.

In 2003 we finished the application programming interface of the graph model and realized the implementation of a PROGRES graph model. The PROGRES graph model will be used by PROGRES and the UPGRADE framework to utilize the Gras/GXL database instead of the current GRAS database. We finished the implementation of the graph model for different database systems (FastObjects OODBMS, PostgreSQL RDBMS, and the in-memory storage). These implementations are tested by a couple of generic test cases. Based on our experience with the realization of the PROGRES graph model we are now trying to generate the mapping of graph model to the Gras/GXL graph model.

**Incremental Integration Tools Supporting Development Processes**

*S. Becker, M. Nagl, S. Herold, S. Lohmann, R. Sluiters, R. Wörzberger*

In development processes, the developed product is described by a lot of heterogeneous documents. These documents are closely related regarding their contents, but are handled independently by different tools. Nevertheless, it is important to keep them consistent to each other during the whole development process.
This project, which is part of the CRC 476 IMPROVE, deals with the construction of incremental integration tools. These tools can assist developers in keeping documents consistent by offering transformations of one document into another document and incremental change propagation between dependent documents.

Integration tools establish and maintain fine grained inter-document links between related entities of the documents, which mirror the relationships between the documents’ contents. These links are used to restore the documents’ consistency, if the documents have been modified. The handling of links and the documents’ contents is controlled by rules. Rule execution is based on graph transformations. In general, user interaction is required to choose among different possible options during the application of rules. Integration tools work incrementally, i.e. only modified parts of the documents are propagated into other documents by changing their corresponding parts.

In 2003, the definition of integration rules and their execution were further elaborated. A UML-based modeling formalism was defined and an extension of the commercial CASE tool Rational Rose implementing this formalism was developed. In contrast to former work, both formalism and implementation are application domain-independent. To gain further insights into the execution of integration rules, an integration tool was realized using formal specification based on graph rewriting in PROGRES. The resulting prototype can also be used for the evaluation of integration rule sets.

Several integration tools in the area of chemical engineering were implemented in cooperation with other projects of CRC 476. For instance, a tool was developed to ensure the consistency between process flow diagrams describing the structure of chemical processes and simulation models used to study their behaviour. All tools were part of the overall CRC 476 prototype presented at the CRC project review in April 2003. The project review has been successfully passed.

Software Integration and Framework Development

T. Haase, M. Nagl, A.-T. Körtgen

Concerning the tool support for development processes in engineering disciplines, the situation can be characterized in the following way: single 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.

Therefore, the CRC 476 IMPROVE deals on the software side with the construction of an integrated environment to support development processes, which takes the above deficit aspects into account. The existing engineering tools are integrated a-posteriori in a systematic
way with new tools realizing additional functionality for cooperation and coordination, e.g. process and consistency management.

Integration is realized by this subproject on the architectural level. 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.

In 2003 we focused on the development of an architecture design tool called FIRE3 (Friendly Integration Refinement Environment). In contrast to other architecture design tools, which claim to be applicable for every and any application domain, FIRE3 addresses the specific problems of a-posteriori tool integration as mentioned above. The software engineer, designing an architecture for an integrated tool environment, is guided by FIRE3 through this design process by various architectural patterns. These patterns expresses the domain-specific knowledge about a-posteriori integration, e.g. certain alternatives for wrapping a tool.

The tool as well as others was presented within the CRC project review in April 2003. The project was reviewed successfully.

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**Software Architectures for Embedded Systems**

*C. Fu*

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The subject of this project is to improve understanding of the design of embedded systems with integrative functionality and develop methods and tools to support the design process.

This project was launched in the last quarter of 2003 but roots can be traced back to the institute’s research in the early 80s done on possibilities to extend SA/RT to improve modelling of embedded systems. During the last years research was performed on embedded systems in the telecommunication branch within the E-CARES project.

This project’s focus is directed to complex, distributed systems with integrative functionality in the automotive industry. Currently, these systems are modeled mainly by electrical engineers and lack abstraction from bus signals and hardware topology. Without further abstraction the complexity of future vehicle onboard systems will become impossible to handle. Potentials for reuse, portability, extensibility and scalability cannot be accessed.
Our efforts in text structuring are twofold: in the aTool project, on the one hand, we model the structure of a text as it manifests itself in the typographic layout. This structure is semiautomatically and interactively derived from the layout. In the CHASID project, on the other hand, we model the semantical structure of a document. The additional structure is used to support an author in document creation.

The aTool (http://www11.in.tum.de/aTool) dissertation 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.

The tool and the structure can be used in different contexts. Its main goal is to support the publication process for scientific journals, so that authors create XML documents that can directly be fed into an automatic publication workflow at the publisher, thus reducing publication delay and costs. In another context, aTool is used to create parameterized manuals. A prototype demonstrating its feasibility has been finished in 2003. In a third application domain, the XML structure is used as a base for semantical modeling as it is investigated in CHASID.

CHASID blends itself in an existing conventional authoring environment (e.g. by using aTool) and maintains a semantical model of the document. It does so to address three tasks of the author: (a) Planning a document, (b) Upholding plans, and (c) Avoiding common structural problems. The semantical model is connected to the hierarchical structure of chapters, sections etc.

The semantical model contains the topics of the document, together with their relations. The connection to the document’s hierarchical structure is kept in exports and imports, indicating which divisions explain a topic, and which ones expect it to be known.

Planning, then, is supported by documentation objects called patterns and schemata. A pattern is overall authoring advice, while a schema contains a template to be instantiated in the document. These instances are continously checked for completeness, thus supporting upholding the plans. The model built using schemata and manual editing is also subject to general analyses which check for common structural problems.
Other Activities

International Workshop “Applications of Graph Transformation with Industrial Relevance” (AGTIVE ’03)

AGTIVE ’03 is the second event of the Graph Transformation (GT) community which aims at uniting people from research and industry interested in the application of Graph Transformation for practical problems. The workshop was held in historic Charlottesville, Virginia, USA, from September 28 to October 1, 2003. J. L. Pfaltz and M. Nagl acted as Program Co-Chairs and Co-Organizers.

Graphs are well-known, well-understood, and frequently used means to depict networks of related items in different application domains. Various types of graph transformation approaches - also called graph grammars or graph rewriting systems - have been proposed to specify, recognize, inspect, modify, and display certain classes of graphs representing structures of different domains. AGTIVE aims at demonstrating that GT approaches are mature enough to influence practice, even in industry. This ambitious goal is encouraged by the fact that the focus of GT research has changed within the last 15 years. Practical topics have gained considerable attention and usable GT implementations are available now. Furthermore, AGTIVE is intended to deliver an actual state-of-the-art report of the applications of GT and, therefore, also of GT implementations and their use for solving practical problems.

The workshop was attended by 47 participants from 12 countries who enjoyed 27 talks, 11 prototype presentations, and workshop summaries given by 5 participants from different perspectives. The success of the workshop is based on the activeness of all participants contributing to presentations and discussions. A considerable part of the workshop success was also due to the familiar Southern State atmosphere we recognized at Charlottesville. Omni Hotel, the workshop conference site. On Wednesday afternoon, the main social event was a visit to the homes of Thomas Jefferson (Monticello) and James Monroe (Ash Lawn), followed by the workshop dinner.

The proceedings of the workshop will published in the “Lecture Notes in Computer Science” series of Springer-Verlag.

Prototype demonstrations


B. Kraft: lexiCAD — Konzeptueller Gebude-Entwurf mit ArchiCAD, Projektvorstellung GRAPHISOFT, Mnchen, 07. 05. 2003

B. Kraft: CONDES — Conceptual design support using Graph-based Tools, AGTIVE 2003, Charlottesville, 29. 10. 2003


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**Conference Activities and Academic Administration**

F. Gatzemeier: Member of the Regina Testing group

A. Marburger: Member of the Regina Linux Group

N. Nagl: Speaker of the Computer Science Department; Speaker of Collaborative Research Center 476; Member of the Board of “Forum Informatik”; Member of the Board and Speaker Substitute of REGINA; 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 in Editorial Board “Journal of Networks and Computer Application”; Member of the Evaluation Board of the Bavarian Research Center on Software Engineering (FORSOFT II); Acquisition of industrial stipends for students and organizing the competition; Intl. Workshop AGTIVE ’03 “Applications of Graph Transformations with Industrial Relevance” (PC Co-Chair and Co-Org.); Intl. Workshop WG’04 Bad Honnef on “Graph-Theoretic Concepts in Computer Science” (PC Chair and organisation together with J. Hromkovic); PC-Memberships: Intl. Workshop WG ’03 on “Graphtheoretic Concepts in Computer Science”, Intl. Conference on Graph Transformation, Organization of the Symposium “Web Services: New Strategies and Techniques for EAI?” at Online Congress VI 2003.

B. Westfechtel: Student advisor in computer science (Graduate studies, since Nov 2002); Organizer of the ICSE Workshop “SCM 2003”.

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Talks and Publications

Talks


B. Bhlen: Specific Graph Models and Their Mappings to a Common Model, AGTIVE2003, Charlottesville, 28. 09. 2003

T. Haase: A-posteriori Integration verfahrenstechnischer Entwicklungswerkzeuge, WSR 2003, Bad Honnef, 08. 05. 2003


B. Kraft: Konzeptueller Gebüde-Entwurf in ArchiCAD, Projektvorstellung GRAPHISOFT Deutschland, München, 07. 05. 2003

B. Kraft: Neue Software-Werkzeuge zur Unterstützung des konzeptuellen Gebüde-Entwurfs, Berichtskolloquium DFG SPP 1103, Herrsching, 09. 05. 2003

B. Kraft: Support of Conceptual Design in Civil Engineering by Graph-based Tools, 1st. Workshop on Graph Transformation and Design, Jagiellonian University Cracow, 13. 06. 2003


A. Marburger: Tools for Understanding the Behavior of Telecommunication Systems, ICSE 2003, Portland, 08. 05. 2003

A. Marburger: Behavioral Analysis of Telecommunication Systems by Graph Transformations, AGTIVE 2003, Charlottesville, 30. 09. 2003

M. Nagl: Collaborative Research Centre 476: Results and Future Perspectives, Presentation for CRC 476 Review, 03. 04. 2003


M. Nagl: Support of Conceptual Design in Civil Engineering by Graph Tools, Workshop Graph Transformation and Design, Cracow, Poland, 13. 06. 2003


B. Westfechtel: *Subproject “Adaptable and Reactive Adminstration System For Project Coordination”*, Presentation for CRC Review, 03. 04. 2003


B. Westfechtel: *Graph-Based Specification of a Management System for Evolving Development Processes*, AGTIVE 2003, Charlottesville, 01. 10. 2003


**Publications**


Boris Bhlen: *Specific Graph Models and Their Mappings to a Common Model*, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

Felix Gatzemeier: **Authoring Support Based on User-Serviceable Graph Transformation**, Proceedings of 2nd International Workshop on Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

Felix Gatzemeier: **CHASID — A Graph-Based Authoring Support System**, Proceedings of 2nd International Workshop on Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear


Thomas Haase, Oliver Meyer, Boris Bhlen, Felix Gatzemeier: **A Domain Specific Architecture Tool: Rapid Prototyping with Graph Grammars**, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

Thomas Haase, Oliver Meyer, Boris Bhlen, Felix Gatzemeier: **Fire3 - Architecture Refinement for A-Posteriori Integration**, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

Markus Heller, Dirk Jger: **Graph-Based Tools for Distributed Cooperation in Dynamic Development Processes**, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

Markus Heller, Dirk Jger: **Interorganizational Management of Development Processes**, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

Markus Heller, Ansgar Schleicher, Bernhard Westfechtel: **Graph-Based Specification of a Management System for Evolving Development Processes**, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear


Dominikus Herzberg: Modelling Telecommunication Systems: From Standards to System Architectures, Dissertation RWTH Aachen, 303 pp., 2003


Bodo Kraft: Conceptual Design Tools for Civil Engineering, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

Bodo Kraft: Konzepteuer Gebude-Entwurf in ArchiCAD, GRAPHISOFT.NEWS, München, GRAPHISOFT Deutschland GmbH, 8-10, 2003


Bodo Kraft, Manfred Nagl: Support of Conceptual Design in Civil Engineering by Graph-based Tools, Proceedings of the 1st Workshop on Graph Transformation and Design, 10-11, Jagiellonian University Cracow, 2003


Andr Marburger, Bernhard Westfechtel: Behavioral Analysis of Telecommunication Systems by Graph Transformations, Proceedings of 2nd International Workshop Applications of Graph Transformation with Industrial Relevance (AGTIVE’03), Charlottesville, USA, LNCS, Springer Verlag, to appear

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Wolfgang Marquardt, Manfred Nagl: *Arbeitsprozess- und Infromationsmodell-orientierte Unterstützung verfahrenstechnischer Entwicklungsprozesse*, atp 45, 2, 52-58, 2003


Manfred Nagl: *Ada – eine Sprachinitialie mit weitem Horizont*, 16 pp., CD of German Ada Group


John L. Pfaltz, Manfred Nagl, Boris Bhlen (eds.): *Proceedings 2nd International Workshop Applications of Graph Transformations with Industrial Relevance (AGTIVE’03)*, LNCS, Springer Verlag, to appear


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Software Construction

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  Dipl.-Inform. Moritz Schnizler (until June)
  Dipl.-Inform. Axel Uhl
  (external at Interactive Objects, Freiburg, until November)
  Dipl.-Inform. Thomas Weiler
  (third-party funds position)

- Student Researchers:
  Holger Schackmann, Andreas Dornbusch

- Internet:
  Information about our research and teaching activities can be found at:
  http://www-lufgi3.informatik.rwth-aachen.de
Overview

Research

In 2003 we have intensified and expanded our research on software product line development. A first running prototype of a dedicated product line requirements engineering tool, called RequiLine, was developed. It supports both modelling features and requirements. It offers a semantical information model that can be used throughout the product line development process, e.g. during application development when new products are configured based on the product line’s platform. RequiLine was successfully presented in several contexts (conferences and industry companies). Currently we are enhancing its functionality and usability. In February Alexander Nyßen joined our group. He is funded by ABB Corporate Research and is doing research in the area of product line development of small embedded devices. A couple of workshops have been organized and an initial architecture modelling approach has been proposed and tried.

In the course of the year two research projects were completed. In the project Object Based Internet Search Axel Uhl has developed a new approach for organizing information in the web by means of searchable objects. The main results of this project are a conceptual model of internet search, an implementation of a Java framework supporting the construction of searchable internet application and a formal model regarding the bandwidth consumption of distributed search. Axel successfully passed his doctoral examination in December. Moritz Schnizler has finished his research on Role Based Testing of object collaborations. This testing technique uses role models describing the behaviour object collaborations to systematically derive test cases, that can be reused whenever the role models are implemented. This approach has shown to be very effective in detecting collaboration errors. Beside the conceptual work a set of tools based on the JUnit framework was developed to support the implementation and reuse of role based tests.

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:

- Lecture *Software Quality Assurance*
- Lecture *Component Technology*
- Lecture *Product Line Development*
- Lecture *Object-Oriented Software Construction*
- Seminars on various topics.
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 modelling of common and variable characteristics are an essential task during the requirements engineering process. Communicating variability to stakeholders affect the success of projects significantly.

Modelling variability can be done from different views and on different levels of abstraction. Whereas the level of abstraction determines the granularity of descriptions of characteristics, different views reveal information about perspectives on a system. Therefore the domain can be modelled from a static point of view to reveal information about structural hierarchies. Feature modelling is one methodology to express these hierarchies through compositional-relationships combined with variability information.

Modelling variability from a behavioral point of view has been neglected so far. To overcome this deficiency one aim of this project is to analyze methods and notations to express functional variability in variant operation sequences. Use Cases and Use Case diagrams have been chosen to be an adequate notation to express functional behavior, but have to be extended by concepts and modelling elements to express variability.

Our research group has developed a prototype of a requirements engineering tool, named RequiLine that supports the management of requirements and feature models, equally. The development of RequiLine has been mainly driven by the identified requirements for an adequate tool support for product lines and therefore to overcome the deficiencies existing requirements engineering tools have in managing variability and dependencies. Our experience shows, that requirements engineering tools are used together with graphical editors to draw feature models. Unfortunately the created drawings do lack of any semantic and could not be used for queries or consistency checks. RequiLine is a first study to close this gap.

As RequiLine currently supports only textual representations of features and requirements, a graphical editor for feature models is currently under development. The integration of Use Cases is possible but in a limited way. The extension of full variability support in Use Cases and the connection with features and requirements is a future task to work on.
Product line-based software development can only lead to full success if it is recognized as an integrated concept, which involves all phases of the software engineering process. This project concentrates on architecture modelling for SPLs.

We have developed a top-level process for SPL architecture modelling. Within the domain engineering initially the requirements for the entire PLP are collected together with the identified variability and afterwards compiled into a requirements model for the PLP, which among other things contains for example a feature model. This requirements model forms the basis for the top-level layer of the PLP architecture. Starting from this still abstract architecture layer, the PLP architecture gets more and more refined in further architecture layers. This procedure is according to the Model Driven Architecture (MDA) approach introduced by the OMG.
In the last step within the domain engineering the PLP architecture gets realized as far as possible. Thereby - according to the differentiation in common and variable components - both finished and incomplete components are placed in the PLP. At the beginning of the application engineering firstly the requirements for a concrete product are determined on base of the requirements for the PLP. Afterwards - similar to the domain engineering - a first coarse architecture layer for the product is developed, which is based on the layer of the same abstraction level as in the PLP architecture. In the following this top-level architecture becomes more and more refined and improved. Thereby the variability included in the PLP architecture is resolved conform to the previously identified product requirements. In the last step the executable system is implemented based on this product architecture.

At the moment we are analyzing, which inputs from the requirements process must be given to build an architecture model for a SPL. Therefore different approaches for using feature modelling are analyzed how far they can serve as a basis for SPL architecture modelling and which inputs are missing.

**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 focussed on methodical aspects and - furthermore inspired by the practical needs of our business corporation partners - resulted in the definition of an iterative development process and a detailed design method that are capable of forming the basis for the application of more far-reaching product line engineering practices.

Current work in this project is now focussed on concepts, languages, and tools for the development of product-line architectural models. As they are the major core assets of a product line, which form the basis for all succeeding development activities inside the product-line life cycle, they are investigated with high priority. The aim is to specify the architecture of an embedded systems product line in a component-based manner in the form of an architectural frame - a macro architecture - into which components (either newly developed or extracted from existing products) can be integrated. As the design of a product-line architectural model has to be embedded into a product-line development process, the integration of the design activities with the pre- and succeeding activities of the product-line life cycle are also of interest. Regarding the preceding activities, further research is needed on how a product-line architectural model can be inferred from existing product specific architectural models in a way consistent to the requirements and features gathered in earlier development steps. Taking the viewpoint of the succeeding steps in the product-line life cycle, it is of interest, how product instantiation (i.e. the deduction of a product specific model from the product-line architectural model) and product implementation can be supported (e.g. by code generation).
Other Activities

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

Member of the GI-Fachausschuss 2.1 Software Engineering and Programming Languages, H. Lichter

Member of the program committee, GI-Conference SEUH 2003, Berlin, 27.-28.2.2003, H. Lichter


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

Deputy of the Computer Science Department in the RWTH’s quality of teaching program, 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

Organization of the Beginner’s Course in Computer Science 2003, H. Lichter, T. Weiler

Member of the GI-Arbeitskreis Requirements Engineering für Produktfamilien of the GI-Fachgruppe Requirements Engineering, T. von der Maßen

Member of the GI-Arbeitskreis Featurelisten of the GI-Fachgruppe Requirements Engineering, T. von der Maßen

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

RequiLine demonstrations at IESE Kaiserslautern, BOSCH Stuttgart, ABB Ladenburg, T. von der Maßen

Research stay at ABB Corporate Resarch Germany, Ladenburg, April 2003 A. Nyßen
Talks and Publications

Talks

H. Lichter: *Einsatz der Feature-Modellierung bei der Entwicklung von Produktlinien - Konzepte und Werkzeuge*, ABB Corporate Research, Ladenburg

H. Lichter: *Softwareprozessverbesserung mit dem CMMI - Eine Einführung*, Kister AG, Aachen


H. Lichter: *Modellierung von Produktlinien-Architekturen*, University Trier


T. von der Maßen: *RequiLine - Ein Requirements Engineering Werkzeug für Software-Produktlinien*, Fraunhofer IESE, Kaiserslautern


T. von der Maßen: *RequiLine: A requirements engineering tool for software product lines*, Fifth International Workshop on Product Family Engineering PFE-5, Siena, Italy

T. von der Maßen: *Werkzeuge zur Feature-Modellierung bei der Entwicklung von Produktlinien*, ABB, Ladenburg

M. Schnizler: *Rollenbasierter Test objektorientierter Programme*, Universitt Hamburg, AB Softwaretechnik, Fachbereich Informatik


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 Benesson
  Dipl.-Inform. Imed Bouazizi
  Dipl.-Inform. Stefan Diepolder
  Dipl.-Ing. Markus Fidler
  Dipl.-Inform. Mesut Güneş
  Dipl.-Inform. Frank Imhoff
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  - Dipl.-Inform Michael Wallbaum
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- Technical Staff:
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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 Inter-netting, 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)
- Intelligent Networks (Virtual Home Environment, Personalized Services, Convergence to IP-based Networks)
- Security in Networks (Anonymity Protocols, Intrusion Detection)
- Applications and User Issues (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’, ‘Privacy Enhancing Techniques’), and standardisation (‘Standardisation in IT’). 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
The aim of the URMEL project (Ubiquitous RWTH for Mobile E-Learning) is 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. In addition, a set of basic services are being developed which facilitate authentication, secure communication, and location-aware services. The overall objective of these activities is to enhance conventional teaching at RWTH Aachen University and to make it more effective. The project is based on the university's wireless LAN called MoPS (Mobile Professors and Students) which is based on the IEEE 802.11b standard. This network currently comprises of 170 access points installed in RWTH buildings across Aachen. Using MoPS, students and staff of RWTH are able to access the Internet and university resources in a much more flexible manner than through fixed desktop computers and CIP-pool rooms. As the various departments have widely differing requirements with respect to eLearning, and as many institutes already have relevant software in use, it is difficult to satisfy these demands by a single software platform. To this end, a service platform is being developed which offers value-added services that can be integrated into existing eLearning 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 is still under development, but a prototype implementation has been integrated with myReiff, a collaboration platform used by the Department of Architecture. As an accompanying measure, and to ensure sustainability, the grant of the German 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. The project is carried out by six chairs and institutes of RWTH Aachen University. It is managed by the Chair for Communication and Distributed Systems which also carries out the technical and implementation work in collaboration with the Centre for Computing and Communication. The didactical aspects of learning and teaching with the URMEL system are covered by the Chair of Business Pedagogic. The Laboratory for Machine Tools and Production Engineering and the Chair of Computer Aided Architectural Design will carry out exemplary courses using the URMEL system and the MoPS network. The rollout phase is conducted by the Chair and Institute of Industrial Engineering and Ergonomics. URMEL is a two-year project and started in May.
MoPS (MObile Professors and Students)- 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 infrastructure. The existing coax and fibre network offer 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 more than 170 access points spread across some 40 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. Furthermore, partnerships with local businesses have been established to extend WLAN-coverage to areas where the university is not present. MoPS is based on the IEEE 802.11b/g standard 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 less 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. One example is the URMEL project which develops location-based and wireless multimedia services 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
Development of an Ad-hoc Service Management for Self-Organizing Mobile Networks

Stefan Penz

Mobile ad hoc networks consist of portable devices (PDAs, laptops etc.) that communicate directly via wireless connections without a fixed infrastructure such as base stations or access points to wired networks. Each mobile devices also performs tasks of a router to enable communication of devices that do not share a direct radio link. 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 easily discover, access, and use services (e.g. a printing service or an internet connection service) that are offered by other devices in the network. In order to allow inexperienced users to immediately utilise the service management, it should work transparently with a minimum of administration and configuration effort. Informatik 4 develops such a middleware system based on the IETF Service Location Protocol (SLP). It allows the user to find appropriate service providers based on static and dynamic attributes describing the capabilities and properties of these service providers. If more than one provider offers the requested service, the service management can choose one of those on the basis of quality-of-service characteristics such as service load or number of current users. To cope with the high dynamics and unreliability of ad-hoc networks the service management offers mechanisms that allow the users to change the current service provider when connection problems occur. Not only the high dynamic of ad hoc networks but also the resource-constrained nature of ad hoc networks poses several challenges for the communication protocols. Since radio and energy resources are usually scarce in wireless environments the communication overhead must be kept to a minimum. On the other hand, the network dynamics require the information about service availability to be kept up-to-date, which almost necessarily leads to additional traffic. Hence, a major goal of this project is to find a proper trade-off between network load and service information relevance. The project is part of the German Research Foundations (DFG) Priority Programme Basis Software for Self-Organizing Infrastructures for Networked Mobile Systems, which currently includes thirteen research projects at twelve 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/.

Universal Mobility Management for Nomadic Users

Stefan Diepolder

The goal of this project is to present a universal management framework that can cope with the new challenges in the area of service provisioning and enhanced mobility support
on top of a middleware layer, as offered by next generation networks. It has been estimated that data delivery services will supersede voice delivery services within the next few years. The evolving access networks providing higher bandwidth provide nomadic users with ubiquitous access to personalised services. In the area of converging networks not only the network evolves, but the services do, too. A new paradigm for creating and deploying services is needed to overcome the challenges of personalised communication services networks, because the demand for mobile services grows proportionally with the number of participants. Due to the ongoing integration of middleware concepts in data- and signalling networks use of object-aware techniques to abstract from users, services, and resources of hard- and software is a promising approach. It allows greater flexibility, can cope with service mobility, and may be used to open up the network to third party service providers. The management necessary in such a scenario consists of several components which also enable the use of services and the infrastructure of existing network technologies, like e.g. todays Intelligent Networks or GSM, and should be seamlessly adaptable to subsequent technologies like UMTS and next generation networks. Each Service is made available by an interplay of several distributed components, some of which manage sessions whereas others deliver services. Each component is affiliated with a specific domain, for example with a provider domain. It may also remain in the terminal of a user (the user domain). In such a scenario the variety of different mobility patterns and different service preferences pose the challenge to limit the signalling traffic. This additional traffic is produced by the interactions of the involved objects. One approach here is to position the service objects according to their mobility behaviours, users service preferences, and provider policies. As component migration is primarily caused by a users behaviour this has to be identified and classified. Ongoing simulations studies, applying different algorithms and different user patterns, have been evaluating if and how the management is able to adapt adequately.

**Mobile ad-hoc networks**

*Mesut Güneş*

Ad-hoc networks will play an important role in communications in the future. A mobile ad-hoc network (MANET) is a collection of mobile nodes which communicate over radio. Such networks have an important advantage in that they do not require any existing infrastructure or central administration. It is expected that ad-hoc networks will be self-organising in terms of addressing, routing and service discovery. Routing is still the most challenging problem in mobile multi-hop ad-hoc networks, which is further aggravated by the node mobility. This project introduced a new approach for routing in MANETS. The Ant-Routing-Algorithm (ARA) is based on swarm intelligence, especially on ant algorithms. This fascinating class of algorithms tries to map the solution capability of insect swarms onto mathematical problems. The Transport Control Protocol (TCP) and the Internet Protocol (IP) represent the glue of the world wide internet; most traffic Internet uses the TCP/IP stack. Unfortunately, due
to historical reasons TCP has been optimised for fixed networks, and therefore performs poorly if applied in mobile multi-hop ad-hoc networks. Our research group proposed an enhancement to standard TCP, TCP/RCWE - Restricted Congestion Window Enlargement - to improve the performance of TCP in this type of networks. TCP/RCWE tries to adapt the sender to the current network state, thus yielding a better performance. It is typically assumed that a MANET’s nodes have already been configured and have a valid IP-Address. However, there are no mechanisms which actually meet the needs of a MANET for dynamic configuration. Our research group proposes the Agent-Based Addressing of MANETs, thus allowing nodes to dynamically obtain a valid IP-Address in a mobile multi-hop ad-hoc network. Among other features Agent-Based Addressing provides a means to recognise the splitting and merging of mobile ad-hoc networks.

**Proxy Caching for Robust Video Delivery over Lossy Networks**

*Imed Bouazizi*

Video delivery is anticipated to become one of the most popular services in networking. The rapid advances in communication technologies, combined with the increasing efficiency of video compression techniques, have paved the way for innovative and exciting video communication applications. However, the acceptance of video communication services can suffer severely from variations in, and deterioration of, the video quality. Without of quality-of-service aware networks the communicating applications cannot control the service parameters offered by the underlying protocol layers. In consequence, the applications may witness varying packet delivery delays and also frequent packet losses. This results in severe degradation of the video quality as perceived by the user. In this project, we develop a framework for prioritised video delivery. We introduce a model for the estimation of distortion that results from video packet loss. Based on this model, we propose a video packet prioritisation mechanism which accurately reflects the importance of each packet of video data on the video quality at the end user side. Based on this model, we design error control and avoidance techniques which achieve near-to-optimal video quality. Given the trend towards wireless and mobile access to video services, we advocate the deployment of proxy caches in close proximity to the receivers. Proxy caches should adapt the video stream to the needs of each video receiver, thus ameliorating the perceived video quality, while still being in line with tight delay constraints and low device capabilities. We introduce the idea of proxy caching for robust video delivery, where the proxy caches implement adaptive error control and rate shaping algorithms in order to achieve optimal video quality. We introduce a selective retransmission scheme, based on size-distortion optimisation. We also give an algorithm to construct adaptive unequal loss protection FEC codes, which protects the different video packets based on their distortion value. We also introduce a rate shaping algorithm to adjust the output rate of the connection to the available network bandwidth. The focus is always on the minimising of the expected distortion, and thus
on achieving an acceptable quality at the receivers. For further information please see
www.vip.rwth-aachen.de http://www-i4.informatik.rwth-aachen.de/ imed/

Differentiated Services Traffic Engineering
Markus Fidler

Today’s Internet offers a single best-effort service. This service is adequate for well-known
interactive uses, such as Web browsing. However, it is not suitable to support emerging
real-time applications, which at present lack the provision of defined performance guar-
antees. Such applications requirements include guaranteed data rates, certain loss ratios,
and end-to-end delay boundaries, referred to as Quality of Service (QoS) parameters. The
Differentiated Services architecture allows to provide scalable QoS by aggregating flows
to different traffic classes. Here, a Premium Service aims at ensuring defined end-to-end
delay boundaries. However, in aggregate scheduling networks the derivation of the necessary
tight delay bounds is extremely complicated, and still subject to research. The problem is
caused by multiplexing effects which are hard to quantify and which a negative impact on
the achievable quality. One potential methodology to address this issue is to minimize the
impacts caused by interfering flows. Shaping incoming traffic in order to level bursts reduces
the queuing delay within the core of the network, whereas an additional shaping delay is
introduced at the edge. This project addresses the issue of traffic shaping is analytically.
Forms that allow to quantify the impacts of shaping are derived and resulting delay bounds
are investigated for different shaping options.

Quality of Service Traffic Engineering in packet based Radio Access
Networks
Rajendra Persaud

The increasing popularity of mobile communication has lead to the standardisation of the
Universal Mobile Telecommunications System (UMTS). A UMTS network is subdivided
into the so-called Radio Access Network (RAN) and the Core Network. In today’s 3G RANs,
Asynchronous Transfer Mode (ATM) technology is used to provide the necessary Quality
of Service (QoS). Since it is commonly assumed that the converging future networks are based
on packet switched protocols such as the Internet Protocol (IP), the 3GPP has also specified
the IP option for a RAN. However, the Best Effort service, which is generally used for trans-
mitting packets in the Internet, does not give any guarantees for delay, bandwidth, or loss
ratios. Of course, this service is not sufficient for today’s 3G RANs where traffic originating
from various user applications with various QoS requirements has to be transmitted. In order
to meet these heterogeneous QoS requirements in IP networks, Differentiated Services can be
deployed using priority queuing or weighted techniques to implement services for packets of various priorities. However, the transmission of relatively large packets (as opposed to ATM cells) on Plesiochronous Digital Hierarchy (PDH) links, like e.g. E1, entails the problem of large low-priority packets blocking high-priority packets. Therefore, the quantitative benefit of fragmentation has been studied in this project both analytically and with an ns-2 simulation. A further means to increase QoS in RANs is Multi-Protocol Label Switching (MPLS), offering the capability of Traffic Engineering and enhancing network availability, and thus also service availability, through techniques like Path Protection and Fast Reroute. Since MPLS is based on the set-up of explicit paths through the network, finding optimal paths with respect to QoS requirements and network utilisation is a non-trivial problem that is also studied in this project.

### Transport protocol with tuneable reliability for streaming (TPTR)

*Jan Kritzner*

Multimedia streaming applications based on data streams through a mixed wired-/ wireless network need a transport protocol with specific capabilities. Especially wireless access networks with restricted bandwidth, temporary link loss, and high jitter or packet loss require advanced support at the transport protocol level. The Internet’s Transmission Control Protocol (TCP) with its complex retransmission and congestion control mechanisms does not take into account real-time requirements, and is therefore not suitable for this class of applications. Therefore, real-time data streams typically use the User Datagram Protocol (UDP) in combination with the Real Time Protocol (RTP) and the Real Time Control Protocol (RTCP), which provide neither a retransmission scheme nor a congestion control mechanism. Furthermore, both protocols have been designed with wired networks in mind. Within the project a new transport protocol called Transport Protocol with Tunable Reliability is developed and refined. In 2003 the work focused on the development of advanced scheduling techniques and the calculation of priority values. The characteristics of the transmission system, like e.g. packet loss, temporary link loss, temporarily or permanently restricted bandwidth, and jitter resulted in a new scheduling algorithm where the reliability of a packet, i.e. the probability of its reception, depends on its priority value, and can be adjusted by tuning parameters. These allow for better performance compared to conventional algorithms. For the calculation of priority values for video streaming the concept of decodability has been developed. A video stream consists of a number of frames. For the commonly used class of hybrid video codecs (like H.26x or MPEG) each frame consists of a number of blocks. The concept of decodability uses this structure and dependencies between the blocks to calculate priority values for the different video frames. Depending on the available processing power either static or dynamic priorities are possible. Further objectives for future project periods include the development of proxy-techniques, the integration of TCP-friendly congestion control algorithms, and other adaptation techniques like stream-switching.
Service Management and Trading for Design Tools

Dirk Thiessen, Yuri Babich

The Co-operative Research Centre IMPROVE (SFB 476) aims to improve design processes in chemical and plastic engineering through computer science concepts. It is comprised of several sub-projects carried out by computer science institutes working on such concepts for direct and indirect process support as well as sub-projects led by engineering institutes contributing their domain-specific knowledge. 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 involved components. To free the project partners from coping with faults and performance bottlenecks, alarm correlation is used to determine causes of abnormal situations. Strategic mobile agents are used to react to these situations. Such agents can decide whether or not to migrate to a target system in order to achieve maximum efficiency, thus realising a scalable management approach. The trading process and service management must also ensure a good execution performance of all tools. To this end, load balancing is performed for distribution of tasks. 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 tools to extract management information and perform management actions (monitoring and control) is a central aspect in an integrated engineering design environment. To this end, Management Proxies are used, encapsulating the tools and enabling uniform access as well as adapted management actions.

Virtual Computer Science Practical

Frank Imhoff, Michael Wallbaum, Carsten Pils, Tim Seipold

The main focus of the project Virtuelles Informatik Praktikum (VIP) is to provide an environment for virtual lab classes for computer science students. This learning environment is virtual in a twofold way. First, a virtual classroom is provided including well-know approaches used in existing tele-teaching solutions for synchronous communication between students and their tutors. The chat and digital whiteboards used for co-operative work are augmented by facilities for audio and video conferencing to improve acceptance of computer based training. Second, a virtual laboratory environment is provided, allowing students to deepen their knowledge by giving them the opportunity to experiment freely within it. Groups of students
working at remote places are given the opportunity to interactively conduct experiments with a complex technical system. The virtual environment instantaneously reflects all changes made to the system, giving the students a learning by doing experience without the need for expensive lab equipment. The data communications domain has been used during an initial course which started in Summer 03. However, the simulation environment is not restricted to any specific kind of application domain. This objectives of this initial course were to deepen the students knowledge about networking components and their interactions. To this end, the students had to solve various tasks within a virtual business network scenario, ranging from expanding an existing network to implementing security measures. The initial course was offered in co-operation with the LMU München, thus ensuring remote co-operation situations for both students and tutors. During this course, the effectiveness of coupling synchronous communications with a virtual environment was continuously assessed. For further information please visit: www.vip.rwth-aachen.de

Artificial Policy Agents Supporting Time Scheduling in Hospitals

Karl-Heinz Krempels

The project is part of the German Research Foundations (DFG) Priority Programme 'Intelligent Agents in Economical Applications'. Scheduling actions in a 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. The results of the Programme’s research in the area of Agent Systems are contributed to FIPA: http://www.fipa.org; Foundation of Intelligent Physical Agents.

Public Key Cryptography in Sensor Networks

Zinaida Benesson

Sensor networks may consist of thousands up to millions of small wireless devices which monitor their environment and co-operate in order to process and forward the collected data. These networks are different form traditional computer networks as the sensors are
very resource constrained and have to operate unattended in possible hostile environments. In some scenarios, information is requested from sensor networks by mobile devices, like e.g. PDAs. In this case, mutual authentication is an important issue. One of more secure ways to solve this problem in traditional networks are public-key cryptography and zero-knowledge proofs. However, an individual sensor does not have enough resources to perform the expensive operations necessary for e.g. RSA encryption. We investigate the possibility for the distribution of public key cryptography and zero knowledge proofs in a sensor network. For the above scenario, we designed several distributed authentication algorithms based on different techniques such as RSA encryption, ElGamal encryption, zero-knowledge proofs of knowledge of discrete logarithm, and of graph isomorphism. Now we are verifying their applicability via simulation with the TinyVIZ simulator.

Multimedia Communication for Supporting Developer Co-operation
Andre Schüppen, Dirk Thißen

This project is part of the Co-operative Research Centre IMPROVE (CRC 476). The goal of the CRC is to support development processes in chemical and plastic engineering through of computer science methodologies. This sub-project aims at improving the communication processes in collaborative work of distributed engineering teams by providing several techniques of communication technology in a user-friendly manner. The supporting technology to be provided for engineering collaboration needs to be able to provide for distributed developer meetings, the sharing of common data, and the sharing of entire workspaces including off-the-shelf tools used for the development process. As a result, a communication platform to enable collaborative synchronous work of the teams is being designed and evaluated. Using standardised communication protocols, tools for conference control, event sharing, and video conferencing were developed. All tools are integrated in one communication platform and can be used by developers via a user-friendly interface which hides the complex details of conference setup and communication management. This interface not only helps the developer in using different communication technologies, but is also equipped with an awareness functionality for the management of personal communication availability. The communication platform thus simplifies developer co-operation and contributes to shorter design processes.
Publications


Bouazizi, I.: *Selective Proxy Caching for Robust Video Transmission over Lossy Networks.*, Special Session for Robust Video Transmission within the IEEE ITRE, Newark, New Jersey, USA.


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Dependable Distributed Systems

Staff

- Faculty:
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- Research Assistants:
  Dipl.-Inform. Martin Mink

- Student Researcher:
  Andreas Sensen
Overview

The Laboratory of Dependable Distributed Systems (Verlässliche Verteilte Systeme) was established in October 2003. It 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.

Research Projects

New Teaching Concepts for Applied Computer Security

Martin Mink, Felix Gärtner

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 “Hacker contests”, to see which basic skills are most important and which ones can be learnt 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 computer science there exist two communities which have in isolation investigated issues of dependability on an abstract, algorithmical level. On one side are researchers in fault-tolerant distributed algorithms, which assume random but rather benign types of faults (e.g., crash, message losses) to happen. On the other side are researchers in cryptographic protocols which assume malicious and worst-case types of faults (e.g., arbitrary behavior, malicious network sniffers). Both fields share a lot of common concepts and goals but there are very few research projects which actively investigate the similarities and differences between both areas.

This research project aims at bridging the gap between the above two areas. It considers a new and practical model of dependable systems: a network of processes which are locally equipped with tamper-proof security modules. The model is practical since manufacturers have begun to produce such hardware (like smart cards or security subsystems in laptops). The model is also theoretically interesting since it is simple and poses non-trivial problems at the same time. It allows to investigate the connection between security problems and fault-tolerance problems because at the level of (untrusted) processes traditional security problems can be solved, and at the level of (trusted) security modules problems from fault-tolerant distributed algorithms can be solved. Moreover solutions to fault-tolerance problems (e.g., consensus, atomic commit) can be used to construct efficient solutions to security problems. This model promises to form the basis of a theory of dependable systems which includes issues of safety and security alike.

Other Activities

Members of the group were involved in organizing the Workshop on Principles of Dependable Systems (PoDSy) which was co-located with the International Symposium on Dependable Systems and Networks (DSN) held between June 22nd and 25th, 2003 in San Francisco, California.

Talks and Publications

Talks


Felix C. Gärtner: Entdecken globaler Prädikate in fehlerbehafteten verteilten Systemen, Talk held March 14, 2003, RWTH Aachen, Germany.


**Publications**


Information Systems and Database Technology

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- Professors:
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  Frank Köhne (since 1.7.2003)
  Jörg Köller (until 31.3.2003)
  Thomas List
  Dominik Lübbers
  Michael Miatidis
  Dr. Hans Wilhelm Nissen (since 4.3.2003)
  Christoph Quix
• Researchers continued:

Dr. Lemonia Ragia (since 1.4.2003)
Moez ur Rehman
Marcus Schlüter (15.01.2003 - 30.9.2003)
Dominik Schmitz (since 2.5.2003)
Priv.-Doz. Mareike Schoop, Ph.D.
Stefan Sklorz
Marc Spaniol
Dirk Staskiewicz (since 1.5.2003)

• Visiting Lecturers:

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Dr. Wolfgang Broll, Fraunhofer FIT
Dr. Kurt E. Fendt, MIT

• Technical Staff:

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Hasibether, R. Himmes, T. Huppertz, J. Huster,
H. Janßen, C. Maas, J. Mathieu, D. Mihaylov,
S. Okae, A. Passen, D. Peger, M. Pienkos, D.
Renzel, J. Renner, A. Roth, I. Sabir, A. Schlosser,
A. Schmidt, M. Schnitzler, T. Schöneberg, J.
Siekermann, S. Steinfels, P. Stojadinovic, J.
Terwey, A. Walter, C. Weidmann, X. Yu, B.
Zaman, J. Zhang
Overview

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

Informatik V cooperates closely with the Fraunhofer Institute for Applied Information Technology FIT of which Prof. Jarke is Executive Director. Two FIT area managers hold cross appointments as Professors of Cooperative Systems (Wolfgang Prinz) and Life Science Informatics (Thomas Berlage). A third joint appointment is planned in the context of building up B-IT, the Bonn-Aachen International Center for Information Technology. Under the direction of Prof. Jarke as one of the B-IT Founding Directors and assistant director Dr. Hans Nissen, Informatik V engaged heavily in B-IT, student selection, financial organization and administration, and faculty selection. Other joint activities between Informatik V and FIT include the joint semantic web EU project SEWASIE and a start-up project in eLearning. A Dagstuhl seminar on e-Accessibility, the challenges and opportunities of Universal Access to IT for an increasingly diverse and aging population in Europe was also organized jointly. Our cooperation with Microsoft Research was further strengthened by a two-month research visit of new team member Dr. Lemonia Ragia in Redmond to investigate the interaction of metadata management and geographical information systems.

2003 was characterized by a lot of personnel fluctuation. Dr. Mareike Schoop, leader of the electronic business negotiation group, not only started a Young Researcher Group Award in the prestigious DFG Action Plan Informatics with two new Ph.D. student Dirk Staskiewicz and Frank Köhne, but also successfully defended her habilitation thesis in the spring of 2003. During much of the year, she was on leave as substitute full professor at the University of Münster. Also, she organized an international e-Contracting conference in Aachen. In December 2003, Christoph Quix defended his doctoral thesis before also starting a research visit at Microsoft.

Dr. Ralf Klamma’s Internet Information Systems and Knowledge Management team continued their successful activities in SFB 427 and was instrumental in acquiring, once again jointly with Fraunhofer FIT, the new European Network of Excellence in Professional Technology-Enhanced Learning (ProLearn) which is coordinated by former Informatik V colleague Wolfgang Nejdl (TU Hannover). After the successful review of SFB 476, our team in the field of chemical engineering informatics also changed with departure of Jörg Köller into the chemical industry and of Oliver Fritzen to another university, and arrival of Dr. Marcus Schlüter and Sebastian Brandt as new team members. In the graduate college ‘Software for Communication Systems’, Valerie Bures left for Sweden and Dominik Schmitz, having just received one of the best paper awards of CAiSE 03 for a paper from his diploma thesis, joined as new doctoral student.
Research Projects

**Metadata and Cooperative Knowledge Management**

*M. Jarke, R. Klamma, A. Becks, C. Quix, T. List, S. Sklorz, C. Seeling*

*M. Jeusfeld (Uni Tilburg, NL), R. Linde, R. Klemke, A. Schlosser, T. Schöneberg*

**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. ConceptBase is used for research and teaching in more than 200 institutions worldwide. An interesting cooperation was begun with Microsoft Research in the field of model management, and development of a Windows version was started. In 2003, the implementation of the internal object storage has been optimized using C++ standard technologies. The user interface has been improved and stabilized. Several issues in the programming interfaces have been resolved. The team improved also the documentation of the whole system.

The **bureau42 Entrepreneurship project** has been extended for another year. Purpose of this project is to support the re-design of two FIT research results – the Brokers Lounge and the Adaptive Learning Environment – for commercial exploitation. In addition, the course HightechEntrepreneurship and New Media was organized in order to sensitize and prepare students from several disciplines for entrepreneurship, to tighten cooperation and exchange knowledge between start-ups and the university, and to network the regional entrepreneurship community.

**Internet-based community support**

*R. Klamma, T. List, J. Mathieu, R. Linde, H. Janßen, S. Steinfels*

**Sun SITE** [http://sunsite.informatik.rwth-aachen.de/](http://sunsite.informatik.rwth-aachen.de/) (*Sun Information and Technology Exchange*) is a programme sponsored by Sun Microsystems established at about 50 universities all over the world. Sun SITE’s aim is to use the Internet to distribute free software, to provide Sun-related information, and to research, develop, and introduce novel Internet applications. Informatik V has been managing Sun SITE Central Europe since 1995, focusing on the support of scientific communities. In addition, Sun SITE offers active hosting support for virtual communities in science, culture, and education, e.g. in the shape of a BSCW server providing shared workspaces.
The software archive of the SunSITE contains around 1 TB of open source software and is one of the biggest of its kind in Germany. Typically, the Sun SITE enjoys several million accesses per month.

As part of the federal WIS programme which aims at reducing the shortage of IT specialists in Germany, the four-year project **WWBIT** (Continuing Education Portal NRW) aims at organizing a portal and (virtual) communities for high-level university-based continuing education in computer science and information systems for the state of Nordrhein-Westfalen. In 2003 our work concentrates on the implementation of community support tools for three different kind of continuing education communities: a network of educational service provider, a network of human resource managers, and networks of actual learning communities. The technological basis of such support tools is the BSCW system.

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**SFB 427: Media and Cultural Communication**

*Networked multimedia information systems in cultural science communities*

R. Klamma, M. Spaniol, M. Jarke, D. Denev, H. Janßen M. Pienkos, D. Renzel
Z. Afzal, S. Conrad, C. Maas, D. Mihaylov, A. Falaleev, P. Stojadinovic

In Germany’s first Cultural Science Research College (SFB 427), our project is studying the 'Impact of multimedia information systems on communication and knowledge organisation in cultural science projects'. Together with our colleagues from the culture sciences we are studying the influence of media specific aspects on knowledge creation and knowledge organization based on the theory of transcription, localization, and (re-) addressing. Informatik V has strengthened its interdisciplinary cooperations by developing cultural science applications. In 2003, we presented our research results at major events such as CAiSE, WWW, ICALT, ICWL, and the E-Learning exhibitions in Karlsruhe and Bangkok. In parallel, a new cooperation project with electroacoustic music scientists has been launched by designing a multi-channel music analysis and representation software (MARS). The MPEG-7 based software is intented to bring together researchers of the electroacoustic music science communities in Cologne and Paris. In cooperation with Fraunhofer FIT the SWAP-it tool has been applied for the comprehensive investigation of cultural science communities by analyzing more than 30,000 mails from over 3,000 individuals. Altogether, the systems fit into our cultural science community portal MAVIS, offering an in depth analysis and simulation of cultural science projects, mailing-lists, and web-sites. The year was concluded by the guest professorship of Kurt Fendt from the MIT, Cambridge, in December.
Dr. Klamma presents e-learning software to her Royal Highness Crown Princess Maha Chakri Sirindhorn of Thailand at the E-learning Expo 2003 in Bangkok

**DFG Young Researcher Group: Electronic Negotiation Support in Business-to-Business Electronic Commerce**

*M. Schoop, F. Köhne, D. Staskiewicz, Y. Cao, J. Huster, J. Terwey*

The research group (DFG-Nachwuchsgruppe) is funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) in their ”Aktionsplan Informatik”. The group is led by Priv.-Doz. Dr. Mareike Schoop. Frank Köhne and Dirk Staskiewicz are the two PhD students working in the group. In addition, there are several student assistants. The main goal of the research is to develop comprehensive empirical and formal foundations for supporting human users in electronic commerce negotiations. The three prominent negotiation models (namely negotiation support, auctions, and negotiation agents) will be assessed and compared. The aim is to develop a decision support module that suggests the most appropriate model or combination of models in a given business context. Selected systems implementing one of the negotiation models will be combined into an integrated negotiation module that enables negotiations according to the suggestions of the decision support module. The
approach will be validated through the development of a significant prototype system of electronic negotiation with decision support and its evaluation in cooperation with industrial partners in regional networks of small and medium-sized enterprises. In 2003, the negotiation support system Negoisst developed in former projects has been extended by means of the development of a decision support module based on a hybrid conjoint approach. Negotiators can specify preferences which will then be used to compute utility functions. The decision support can be done in real-time, i.e. during the negotiation. Each negotiation step is assessed and the rating is shown to the negotiator. The approach can also deal with partly-specified offers which is a common phenomenon in electronic negotiations. Negoisst has taken part in the second annual negotiation tournament. Several hundred students from the USA, Canada, Germany, Russia, The Netherlands, Taiwan, Great Britain, and Austria negotiated in teams based on a specified scenario (negotiation between a union and a school management) using different negotiation systems such as Negoisst, Inspire, SmartSettle, WebNS, and SimpleNS. The team performance was rated. At the same time, the systems themselves competed. Negoisst won the tournament on the management side.

**SEW ASIE: Semantic Webs and AgentS in Integrated Economies**

*M. Jarke, M. Schoop, A. Jertila, C. Quix, M. Rehman, Y. Cao, K. Papadimitropoulos, M. Schnitzler, A. Becks (Fraunhofer FIT), C. Seeling (Fraunhofer FIT), D. Frese*

SEW ASIE is 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 overall goal of the project is to design and implement 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 develops a communication tool that will support 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 develops 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, will be included. FIT also provides functionalities to link observed information into decision support environments based on OLAP.
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. 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 via agent-based simulation through our SNet prototype environment. A key feature of SNet is the automatic translation of extended i* models into the process modeling environment ConGolog (via ConceptBase). This year’s work extended previous versions e.g. in that the resulting agents are not purely reactive any more but make use of a decision-theoretic planning component. The project is expanded in the context of the DFG-funded Graduate School 643 “Software for mobile communication systems”, with the goal to interlink agent-based simulation and execution environments in applications for mobile production engineering.
Process-Integrated Modelling Environments (PRIME)

M. Jarke, T. List, K. Pohl (Uni Essen)

This DFG-funded project develops architectures and object-oriented frameworks for the process integration of modeling tools in engineering environments. In this manner, formal process definitions can directly influence the behavior of tools in a situation-specific manner. In addition, the environment automatically traces development processes across tools for reuse of process experiences.

SFB 476 IMPROVE

Information Technology Support For Collaborative and Distributed Design Processes in Chemical Engineering

M. Jarke, M. Miatidis, O. Fritzen, S. Brandt, M. Schlüter, M. Schoop, T. List
A. Passen, B. Zaman, J. Renner

The collaborative research center 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 May 2003, the CRC underwent a successful review by the DFG, and received a project continuation for the third phase (till summer 2006). The new phase, centering on the aspect of synergetic interleaving, was started in mid-year. In this context, Informatik V works on two projects.

”Experience-Based Development Processes” aims at models, methods and tools to support the cooperative design of chemical processes at a direct and fine-grained level based on prior experience. A novel flowsheet editor has been developed to support the central role of flowsheets as design documents in chemical engineering and to capture and enable reuse of best-practices during design. This flowsheet editor tool is supported by our process integration environment PRIME that provides fine grained method guidance and process tracing to the engineering processes. In the next period, we are going to focus on the cooperation aspect by providing support to multiple users and address the challenge of providing a mechanism for continuous quality improvement by analysis and reuse of the process enactment experience.

”Goal-Driven Information Flow Management” aims at the improvement of information flows during chemical process design. To efficiently support the manifold information flows in a chemical process design from heterogeneous information sources a Process Data Warehouse (PDW) is developed, which collects and transforms selectively and incrementally required information from the engineering process. After
transferring the charge of the project from O. Fritzen to S. Brandt (a former student worker of the same project), the research focused on the design of ontology-based recording of product and process traces, to be used among other as the infrastructure for product-based cooperation support and analysis.

**GCO-Support (Next Generation Computer Aided Process Engineering Open Simulation Environment)**

*M. Jarke, J. Köller, R. Himmes, M. Raddatz, A. Schmidt, J. Zhang, B. Annangi*

This EU-funded project aimed at the uptake of the international CAPE-OPEN-Standard for open simulation environments in chemical engineering. We contributed several chapters on the CAPE-OPEN book summarizing the results of the earlier projects, and developed the website, quality assurance tools, and cooperation environment for members of the GCO support community. The project was successfully completed in March 2003.

**Other Activities**

**Service**

Prof. Jarke’s major administrative and service activities in 2003 included:

- Executive Director, Fraunhofer FIT, Birlinghoven
- Founding Director, Bonn-Aachen International Center for Information Technology (B-IT)
- Vice President and Treasurer, GI German Informatics Society
- member, extended management board of FIR Forschungsinstitut für Rationalisierung an der RWTH Aachen
- member Curatory Board and International Scientific Advisory Board, IBFI, Schloss Dagstuhl
- DFG elected reviewer for practical computer science
- member, evaluation board Information Sciences for the state of Baden-Württemberg
- BMBF steering committee for research program IT-2006
- responsible for room management, CS department RWTH Aachen
- chaired two faculty search committees at RWTH Aachen

Dr. Klamma served as study advisor of the master program Software Systems Engineering. Dr. Schoop co-organized ‘Girls Day’ and the ‘Schnupperstudium’ in 2003.
Editorial Boards

Together with D. Shasha (New York University) M. Jarke is Editor-in-Chief of Information Systems, the oldest European database journal (SCI Impact Factor: 3.0); R. Klamma served as Assistant Editor. M. Jarke also served on other editorial boards:

- Decision Support Systems
- (electronic) Journal of the AIS
- Requirements Engineering Journal
- Organizational Computing and Electronic Commerce
- Intelligent Information Systems
- Group Decision and Negotiation

Prof. Prinz is Chair of ACMSIGGROUP and Editor of SIGGROUP Bulletins. He is also editor of the i-com magazine and associate speaker of GI-department CSCW (5.14). Besides he is Editorial Collective member of the CSCW Computer Supported Cooperative Work International Journal by Kluwer.

Conference Organization

M. Jarke co-chaired the Dagstuhl Symposium 'e-Accessibility: new devices, new technologies, and new challenges in the information society' (Nov. 24-27, 2003) with A. Kobsa, K. Miesenberger, and C. Velasco. He also served as Technology Track Program Chair of the 24th International Conference on Information Systems, Seattle, Dec. 14-17, and as senior research advisor for its associated Junior Faculty Workshop and IS Theory Research Workshops. He co-chaired the Symposium on Conceptual Modeling, held in conjunction with CAiSE 03 in Velden/Austria in honor of the 60th birthday of John Mylopoulos (June 17, 2003), and the FIT Symposium on the 25th anniversary of CSCW research (Nov. 21, 2003). In addition, he was program committee member of the following conferences: Intl. Conf. Advanced Information Systems Engineering (CAiSE 03), Velden/Austria, 18.-20.6.2003; Data Mining and Data Warehouses (DMDW '03), Berlin, 8.9.2003; Intl. IEEE Conf. Requirements Engineering RE 03, Monterey, Ca, 8.-12.9.2003; Intl. Conf. Information Quality ICIQ 03, MIT Cambridge, Mass., 7.-9.11.2003; Workshop on Information Technologies and Systems WITS 2003, 13.-14.12.2003, Seattle.

Prof. Prinz was a member of the following program committees: Computer Human Interaction (CHI 2003), Fort Lauderdale Communities and Technologies (C&T 2003), Amsterdam 9th Intl. Workshop on Groupware (CRIWG03), Grenoble Language Action Perspective (LAP2003), CAiSE Workshop on Ubiquitous Mobile Information and Collaboration Systems (UMICS 2003).

Priv.-Doz. Dr. Schoop was chair of the Conference "E-Contracting", Aachen, 26 June 2003. She was also co-chair of the 10th International Workshop on Knowledge Representation Meets Databases (KRDB 2003). Furthermore she was a member of the following program committees: 11th European Conference on Information Systems (ECIS 2003, 2nd International Semantic Web Conference (ISWC 2003), Workshop
XML Technologien für Middleware - Middleware für XML-Anwendungen (XMIDX 2003), 5th International Conference on Enterprise Information Systems (ICEIS 2003), 8th International Workshop on the Language-Action Perspective on Communication Modelling (LAP 2003), Action in Language, Organisations, and Information Systems (ALOIS 2003). She was also a discussant at the International Conference on Information Systems (ICIS 2003), Seattle.


Marc Spaniol was peer reviewer of ICWL 2003.

**Software Demonstrations**

- SFB 476 Review, Aachen, April 3.
- SOCRATES end-user workshop, Cologne, June 11 and September 9.
- CESE and VEL: Demonstration; E-Learning 2003 Expo, Bangkok, September 4-7.
- VEL presentation, b-it Wirtschaftsforum, Siegburg, September 16.

**Talks and Publications**

**Talks**


M. Jarke: *Ambient Intelligence - Big Brother zu Hause, am Arbeitsplatz, überall?, Ringvorlesung Technikgestaltung für morgen - Chancen und Risiken*, RWTH Aachen, January 7.

M. Jarke: *Hightech Entrepreneurship and New Media*, Opening Statement, public final B-IT project course presentation, RWTH Aachen, February 10.


M. Jarke: Semantic web: Going beyond searching - SEWASIE value-added services, Review, EU project SEWASIE, Luxembourg, July 1.

M. Jarke: Quality-oriented design of data warehouses, Colloquium, SAP-BW Group, Walldorf, July 7.


D. Lübbers: Systematic Development of Data Mining-Based Data Quality Tools, 29th International Conference on Very Large Data Bases (VLDB 2003), Berlin, Germany, September 10.


W. Prinz: Virtual Communities: Cooperation and Awareness Support, Workshop on Computational Visualistics, Media Informatics, and Virtual Communities, Magdeburg.

W. Prinz: Awareness in Cooperative Work, Invited talk, University of Münster, June.


D. Schmitz: Deliberation in a Modeling and Simulation Environment for Inter-Organizational Networks, Fifteenth Conference on Advanced Information Systems Engineering (CAiSE 2003), Klagenfurt/Velden, Austria, June 19.

D. Schmitz: Eine Simulationsumgebung für Agenten-Netzwerke, Tag der Informatik, RWTH Aachen, December 5.

M. Schoop: Towards a Standardization Process for Component-Based Architectures, 10th International Conference on Concurrent Engineering, Madeira, 30 July.

M. Schoop: Practices and Standards in Electronic Negotiations, 10th International Conference on Concurrent Engineering, Madeira, 30 July.


Publications

Books and Edited Volumes


Journal Articles

Conference and Book Contributions


W. Prinz: *Virtual Communities: Cooperation and Awareness Support*, In J. Schneider (ed.): Computational Visualistics, Media Informatics, and Virtual Communities, 2003, pp. 25-35.


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  Andreas Strack
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.
Research Projects

A Deliberative Real-Time Component for Cooperating Multirobot Systems in Highly Dynamic Environments (RoboCup) (SPP 1125)

Frank Dylla, Alexander Ferrein, Gerhard Lakemeyer

The goal of this project is to develop a deliberative component supporting coordinated actions of multirobotic 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 the uncertainties arising in the domain into account, 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 a grant of the NRW ministry of Education and Research and in collaboration with the Department of Electrical Engineering (Prof. Kraiss). In 2003, we participated at the RoboCup World Championships in Padua, Italy, where we finished 10th out of 24, proving our concept.

TROPOS – Agent-Oriented Requirements Engineering in Strategic Networks (SPP 1077)

G. Gans, M. Jarke, G. Lakemeyer, D. Schmitz
C. Funken (TU Berlin)

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 Network.

### 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.

### Using Communication to Solve Problems of Navigation in Autonomous Multi-Robot Systems

_Vazha Amiranashvili, Gerhard Lakemeyer_

The autonomous robotics has been paid increasingly more attention 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 is to extend these single robot approaches to autonomous multi-robot systems. The extensions should work more efficiently be more robust and their complexity should not be more than of the single-robot algorithms. In addition they should enable the fusion of data, from various communicating robots. One such algorithm for multi-robot localization has already been developed and implemented as software. The algorithm represents an instance of MCMC (Markov Chain, Monte Carlo) approach with a dual sampling scheme. Its considerable advantage over the other multi-robot algorithms known from the literature is that it does not need data from cameras, which are used to detect other robots. Such detection was needed to fuse the data from various robots. First simulation show that the new approach works better than the single robot approaches. In this way the development of an algorithm for multi-robot mapping is also planned.

A New Situation Calculus

Gerhard Lakemeyer, Hector Levesque (University of Toronto)

The situation calculus, as proposed by McCarthy and Hayes, and developed over the last decade by Reiter and co-workers, is reconsidered. A new logical variant is proposed that captures much of the expressive power of the original, but where certain technical results are much more easily proven. This is illustrated using two existing non-trivial results: the regression theorem and the determinacy of knowledge theorem of Reiter. We also obtain a regression theorem for knowledge, and show how to reduce reasoning about knowledge and action to non-epistemic non-dynamic reasoning about the initial situation.

A Logic of Limited Belief

Yongmei Liu (University of Toronto), Gerhard Lakemeyer, Hector Levesque (University of Toronto)

The goal of producing a general purpose, semantically motivated, and computationally tractable deductive reasoning service remains surprisingly elusive. By and large, approaches that come equipped with a perspicuous model theory either result in reasoners that are too limited from a practical point of view or fall off the computational cliff. In this project, we propose a new logic of belief called $\mathcal{SL}$ which lies between the two extremes. We present a sound and complete axiomatization for propositional $\mathcal{SL}$. We show that query evaluation based on $\mathcal{SL}$ for a certain form of knowledge bases with disjunctive information is tractable in the propositional case and decidable in the first-order case.
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 interaural 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. We are currently investigating improvements of the algorithm. 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 workshop.

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 March and September 2003.
Publications


Books

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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. 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) and EUTRANS (European). The experimental comparisons with traditional rule–based and other competing approaches show that the statistical approach is competitive in terms of performance or even 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

- NIST 2003 Chinese–English machine translation evaluation
  In 2003, the Lehrstuhl für Informatik VI took part in the NIST machine translation evaluation for translation from Chinese into English. Among leading research groups from all over the world, our system was ranked among the best systems in this evaluation.

- EU project CORETEX (Improving Core Speech Recognition Technology)
  Nowadays commercial speech recognition systems work well for a very specific task and language. However, they are not able to adapt to new domains, acoustic environments and languages. The objectives of the CORETEX project are to develop generic speech recognition technology that works well for a wide range of tasks with essentially no exposure to task specific data and to develop methods for rapid porting to new domains and languages with limited, inaccurately or untranscribed training data. Another objective is to investigate techniques to produce an enriched symbolic speech transcription with extra information for higher level (symbolic) processing and for automatic pronunciation generation for vocabulary extension.

- EU project TransType2
  The aim of TransType2 is to develop a Computer-Assisted Translation (CAT) system, which will help to meet the growing demand for high-quality translation. The innovative solution proposed by TransType2 is to embed a data-driven machine
translation engine with an interactive translation environment. In this way, the system combines the best of two paradigms: the CAT paradigm, in which the human translator ensures high-quality output; and the machine translation paradigm, in which the machine ensures significant productivity gains. Six different versions of the system are developed for English, French, Spanish and German which are evaluated by two professional translation agencies.

- EU project LC-STAR (Lexica and Corpora for Speech-to-Speech Translation Technologies)
  The objective of LC-STAR is to improve human-to-human and man-machine communication in multilingual environments. The project aims to create lexica and corpora needed for speech-to-speech translation. A speech to speech translation demonstrator for the three languages English, Spanish and Catalan is developed. The Lehrstuhl für Informatik VI concentrates on the investigation of speech centered translation technologies focusing on required language resources and the creation of lexica for speech recognition in German.

- EU project PF-STAR (Preparing future multisensorial interaction research)
  The PF-STAR project intends to contribute to establish future activities in the field of multisensorial and multilingual communication (interface technologies) on firmer bases by providing technological baselines, comparative evaluations, and assessment of prospects of core technologies, which future research and development efforts can build from. To this end, the project addresses three crucial areas: technologies for speech-to-speech translation, the detection and expression of emotional states, and core speech technologies for children. The Lehrstuhl für Informatik VI is involved in the comparative evaluation and further development of speech translation technologies.

- EU project TC-STAR_P (Technology and Corpora for Speech to Speech Translation)
  The objective of the TC-STAR_P project was to prepare a future integrated project named “Technology and Corpora for Speech to Speech Translation” (TC-STAR), which aims at making speech to speech translation real. TC-STAR_P was driven by industrial requirements and involved industry key actors, academic research institutions, infrastructure centres, and small and medium enterprises. Roadmaps for the development of speech to speech translation were prepared, and further key actors have been involved. A new organisational model was developed.

- 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 grammars and morphological analysis, and adaption and improvement of training and search algorithms for statistical machine translation.

- DFG Project Structured Acoustic Models for Speech Recognition
  Within this project a better structuring of the acoustic models for automatic speech recognition systems is investigated. Speech signals can be influenced by many variable
factors like background noises, distortions in the transmission channel and speaker characteristics. The goal of the project is to improve the recognition by investigating and optimizing methods that allow a better adaptation to - or suppression of these undesired variabilities. These methods include: vocal tract length normalization which reduces the speaker dependent variability of the spectrum by applying a spectral warping function, histogram based transformations applied during feature extraction to increase the noise robustness, and adaptation of the acoustic model to different speakers and transmission channels based on maximum likelihood linear regression.

- DFG Project Statistical Modeling for Image Object Recognition
  The aim of the project is to investigate suitable statistical models for image object recognition on three levels: modeling of object appearance using maximum entropy models; modeling of the variability of image objects using hidden Markov models; modeling of complex scenes using holistic approaches.

- 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.

![Figure 1: Examples from the IRMA Database](image)

**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 2) are characterized as follows:

- The *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 context dependent.
3. The pronunciation lexicon, which defines the decomposition of the words into the sub-word units.

- The *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. Because of the stochastic nature of such redundancies, language models usually are based on statistical concepts.

- Search realizes *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 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.

At Lehrstuhl für Informatik VI, the following research directions related to the different main topics of automatic speech recognition were conducted. In the area of signal analysis, projects on acoustic normalization, noise robustness, as well as the development of new feature extraction methods were performed. Under the topic of acoustic modeling,
speaker normalization and adaptation, across-word modeling, pronunciation modeling, automatic phonetic transcription, discriminative training, and maximum entropy modeling were investigated. Finally, related to search, the following research directions were pursued: efficient search algorithms for speech recognition, transducer-based search architectures, and integration of speech recognition and machine translation search for speech-to-speech translation.

Figure 3: (a) Speech waveform of the utterance “Sollen wir am Sonntag nach Berlin fahren”, (b) the corresponding FFT spectrum

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 4). 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 different main topics of machine translation were conducted. A computer-aided translation system that aims at supporting human translators by an interactive machine translation environment was implemented. We developed confidence measures for statistical machine translation that try to detect errors in automatically generated translations.

Furthermore, the integration of different types of language resources into a statistical machine translation has been investigated. The focus was on translation from an inflected language into English. For languages like Japanese that are structurally different from English, we implemented special reordering constraints that resulted in significant improvements in translation quality.
Other research areas were corpus processing tasks like pre- and post-processing, automatic sentence alignment, and corpus filtering.

### Natural Language Processing

The goal of natural language processing (NLP) 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 NLP 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.

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.

Tagging is the task of labeling each word in a sentence with its appropriate tag. In part-of-speech tagging, for example, each word is labeled with its word class (noun, verb, adjective, etc.). At Lehrstuhl für Informatik VI 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.

### Image Recognition and Retrieval

At Lehrstuhl für Informatik VI, 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 (examples are shown in Figures 5 and 6). 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 the context of the Bayesian decision rule, Gaussian mixture or kernel densities are used, where models of the variability of the images allow reduction in error rate using prior knowledge or estimation from the data.

The methods designed for image classification are adapted to content-based image retrieval tasks as well.
Other Activities

- Demonstrations and Prototypes
  - Prototype speech-to-speech-translation system LC-STAR
  - Prototype dialogue system for telephone directory assistance

- Research stays
  - Klaus Macherey was invited to participate in the summer workshop at the Center for Language and Speech Processing at Johns Hopkins University, Baltimore, MD, from June to August 2003.
  - Nicola Ueffing was invited to participate in the summer workshop at the Center for Language and Speech Processing at Johns Hopkins University, Baltimore, MD, from June to August 2003.
  - Richard Zens was invited to visit the ATR Advanced Research Institute International, Kyoto, Japan, from May to August 2003.
Publications


T. Deselaers, D. Keysers, and H. Ney, “Clustering visually similar images to improve image search engines”, Informatiktag 2003 der Gesellschaft für Informatik, Bad Schussenried, Germany, Nov. 2003


D. Keysers, R. Paredes, E. Vidal, H. Ney, “Comparison of Log-Linear Models and Weighted Dissimilarity Measures”, 1st Iberian Conf. on Pattern Recognition and Image Analysis,
Puerto de Andratx, Spain, Volume LNCS 2652 of Lecture Notes in Computer Science, Springer-Verlag, pp. 370-377, June 2003


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D. Sündermann and H. Ney, “synther - a New M-Gram POS Tagger”, *Int. Conf. on Natural Language Processing and Knowledge Engineering (NLP-KE’03)*, Beijing, China, pp. 628-633, Oct. 2003


**Dissertations**

A. Sixtus: *Across-Word Phoneme Models for Large Vocabulary Continuous Speech Recognition*

Referent: Prof. Dr.-Ing. Hermann Ney

Coreferent: Prof. Dr. Reinhold Häb-Umbach

January 2003

S. Molau: *Normalization in the Acoustic Feature Space for Improved Speech Recognition*

Referent: Prof. Dr.-Ing. Hermann Ney

Coreferent: Prof. Dr. Harald Höge

February 2003

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Staff

- Faculty:
  
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  Prof. (em.) Dr. Walter Oberschelp

- Secretary:
  
  Marianne Kuckertz

- Research Assistants:
  
  Dipl.-Inform. Jan Altenbernd
  Thierry Cachat, inf. dip.
  Dr. Mikhail Kats
  Dr. Christof Löding
  Dr. Volker Penner
  Dipl.-Math. Philipp Rohde
  Dipl.-Inform. Nico Wallmeier
  Dipl.-Math. Stefan Wöhrle

- Technical Staff:
  
  Rolf Eschmann
Overview

The research area of the group is automata theory and logic in connection with the specification, automatic verification, and automatic synthesis of programs. A focus of our present research is

- an evolving algorithmic theory of infinite graphs, with applications to model-checking,
- 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).

Another important (and time-consuming) activity was the development of e-learning course material within the BMBF project “Universitärer Lehrverbund Informatik”, altogether for four courses, both for undergraduates and for advanced students.

As a researcher funded by Otto-Benecke-Stiftung, Dr. M. Kats joined our group and contributed both to teaching activities and research.

Research Projects

Infinite Graphs and Model-Checking

Ch. Löding, W. Thomas, S. Wöhrle

together with D. Caucal, Th. Colcombet, A. Carayol (Rennes)

One of the main challenges in model-checking is to extend the methodology to finitely presented infinite graphs. In a dissertation of 2002, Ch. Löding studied graphs which are generated by finite tree rewriting systems, characterized them by structural properties, and devised a logic for which model-checking over such graphs is decidable. This research was continued in 2003 in collaboration with Th. Colcombet (Rennes), and publications on it were completed but are to appear only next year.

In cooperation with the group of D. Cauca (Rennes) we obtained results on a different and quite extended class of graphs, the so-called higher-order pushdown graphs or “Caucal graphs”. These graphs provide a large arena of structures where the model-checking problem is decidable with respect to monadic second-order logic. In an invited talk at MFCS 2003, the basic theory on these graphs was presented (cf. [13]). Together with A. Carayol (Rennes), S. Wöhrle showed that the hierarchical construction of these graphs is robust, in the sense that a tight correspondence holds between three approaches: by iterated unfolding of graphs (starting from finite graphs) and interpretations via regular path expressions, by the corresponding process using monadic second-order interpretations, and by constructing the transition graphs of higher-order pushdown automata. In the conference contribution [4],

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these results were presented. Current work compares these graphs with other graphs (like automatic graphs, ground term rewriting graphs).

Automata over Generalized Structures

J. Altenbernd, M. Kats, W. Thomas, S. Wöhrle

In this research we study the connection between automata and logical formalisms over pictures (two-dimensional words) and other generalized structures.

In the paper [1], we use “automata” in the form of tiling systems over infinite pictures and compare them with monadic second-order logic. In particular, the power of different acceptance conditions is clarified. It turns out that for these nondeterministic acceptors, the same phenomena arise as known from the theory of $\omega$-languages, but that the proofs for these results are much more involved and diverge from the classical methods.

Further research was concerned with acceptors with dynamically changing transition functions, and with a general theory of recognizability which reconciles the deterministic and nondeterministic view in the framework of constraint satisfaction (cf. [14]).

Infinite Games

T. Cachat, Ch. Löding, Ph. Rohde, W. Thomas, S. Wöhrle

funded by EU

Infinite Games are a subject where our research group was active over the past years. The aim of this research is to develop an algorithmic theory of infinite games as

- a natural model of reactive and nonterminating systems,
- a framework for the automatic synthesis of controllers,
- a method which allows to construct verification procedures.

The research is supported by collaborations within the EU Training and Research Network GAMES, coordinated by E. Grädel, Aachen, in which teams from Aachen, Bordeaux, Paris, Uppsala, Vienna, Warsaw, and from Rice University (US) cooperate.

Since presently we pursue three distinct projects on games, they are treated in separate sections of this report.
Games over Pushdown Systems

*T. Cachat, W. Thomas*

This research was done in the doctoral project of Thierry Cachat, who finished his dissertation [3] at the end of 2003.

Two-player games are analysed which are played on different classes of infinite graphs. These “game arenas” are transition graphs of pushdown automata and the (more general) graphs of the “Caucal hierarchy” (transition graphs of higher-order pushdown automata). The study covered several types of winning conditions: reachability, Büchi (recurrence) condition, a $\Sigma_3$-condition, and the parity condition. The aim in solving a game is to determine the winner from a given start vertex and to compute a winning strategy. Two kinds of techniques are developed: a symbolic approach based on descriptions of vertex sets by finite automata, and techniques of game reduction. The symbolic approach allows to represent and handle infinite sets of configurations by finite presentations. The idea of the game reduction is to reduce a given game to a simpler one that we can solve, and to deduce from it the winner and a winning strategy in the original game.

Our results established a class of algorithmically solvable games over a much more extended range of infinite graphs than known before (cf. [2]).

Sabotage Games

*Ch. Löding, Ph. Rohde*

In this research project we analyze reachability 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.

The project has two subtopics: Algorithmic analysis of this two-player scenario, and corresponding logics and their model-theoretic properties. For the first aspect, it was shown that the reachability problem under the assumption of arbitrary saboteur moves is PSPACE-hard. For the second aspect, a modal logic was set up including an edge deletion modality, and it was shown that this new logic resembles first-order logic in many ways: Model-checking is PSPACE-hard, the satisfiability question is undecidable, and (compared to standard modal logic) the finite model property is lost.
The results are presented in [6, 7, 8]. Current work is concerned with more refined (and more realistic) assumptions on the saboteur, who would have to move also by local steps.

### Controller Synthesis

*N. Wallmeier, W. Thomas, in collaboration with Y. Bontemps (Université de Namur)*

*funded by Graduiertenkolleg “Software für Kommunikationssysteme”*

This project is concerned with an application of strategy constructions in infinite games for the automatic synthesis of finite-state controllers. Specifications to be met by the controllers are safety conditions plus conjunctions of liveness conditions of the form “if state property \(p\) holds, then later state property \(q\) must hold sometime”.

Several approaches were tested in order to transform and tune known theoretical algorithms such that practical problems can be attacked. We used BBD techniques and optimized procedures for solving so-called “generalized Büchi games”. We succeeded to apply controller synthesis (probably for the first time) in a nontrivial case study (a lift controller problem). The results were reported in the conference paper [15].

In parallel, we cooperated with Y. Bontemps and P. Y. Schobbens (Namur) in a study of “Live sequence charts” (Damm, Harel). The implementability of such charts can be rephrased as a game-theoretic problem. Previous work of Y. Bontemps and P. Y. Schobbens used a transformation of the implementability problem into parity games and a subsequent solution of these games developed in our group in 2001. Our ongoing work tries a possibly more efficient alternative via generalized Büchi games and the solution algorithms we developed in Aachen for these games.

### Distance Learning in Theoretical Computer Science

*Ph. Rohde, W. Thomas*

*funded by BMBF*

This project is part of the BMBF-funded framework “Universitärer Lehrverbund Informatik”, in which eleven universities from Germany and Switzerland participate. The aim is to provide on the internet a collection of courses of the computer science curriculum.

In Aachen, a special combination of software and hardware components was developed as a tool for presenting and recording lectures (known as “e-case”, or “die Aachener Kiste” in the German e-learning community). The docent user can prepare and present his lectures with digitalized slides, with live annotations which are recorded together with his voice. The student user can download such a recording of the lectures in a standard format to be
reproduced on standard players (independent of the operating system). The recordings are designed to occupy little storage. So a single CD can store a complete course with 30 lectures of 90 minutes each, together with a volume of lecture notes, interactively usable with the recordings, and the complete collection of slides.

In 2003, the Aachen group produced the following courses in the field of theoretical computer science:

- the advanced course “Angewandte Automatentheorie” (4 hours per week),
- the advanced course “Automata and Reactive Systems” (4 hours per week),
- the advanced course “Model-Checking” (2 hours per week),
- the basic course “Automaten, Sprachen, Komplexität” (for electrical engineers, without voice recording).

These courses are downloaded not only by Aachen students, but also by a wider German and international audience. The results of the project were presented at conferences (see [5, 10, 11]).

**Other Activities**

W. Thomas

- Vice Dean (Prodekan) of the Faculty of Mathematics, Computer Science, and Natural Sciences of RWTH Aachen
- Chairman of the Board of Referees in Computer Science of the German Science Foundation (DFG)
- Vice-Chairman of the GI-Council of University Professors
- Member of the steering committee of the International Conference on Developments in Language Theory (DLT)
- Program Committee Member of the following conferences:
  - 8th International Conference on Implementation and Applications of Automata, Santa Barbara, June 2003
  - 7th International Conference on Developments in Language Theory, Szeged, July 2003
- 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 the Advisory Board of the John von Neumann Research Center, Weizmann Institute, Rehovot, Israel
• Member of external commissions (Promotion, Habilitation, Selection of Professors)
• Deputy of the RWTH in the working group “Computer Science” of the IDEA-League
• External member of the Jury for the evaluation of LIAFA (Laboratoire d’Informatique Algorithmique, Fondements et Applications), Université Paris VII

W. Oberschelp

• Member of the interdisciplinary working group “Karolingisches Aachen (Carolingian Aachen)” at the RWTH Aachen
• Member of the preparing committee for the “Cologne Science Center”, guided by FAW Ulm (F. J. Radermacher) and sponsored by Stadtsparkasse Köln. Responsible for the topic “Computers” together with C. Drösser (Die Zeit)
• Member of the preparing committee and catalogue author for the exposition “Ex Oriente” (Aachen, June – September 2003)
• Member and author for the working committee “natural science and religion” with the bishop (Präses) of the Rhineland Protestant Church

Talks and Publications

Talks
T. Cachat: *Quelques aspects de la jeu-simulation*, Groupe de Travail Graphes et Logique, LaBRI, Bordeaux, March 2003
T. Cachat: *Méthodes symboliques pour les jeux à pile*, Séminaire Verimag, Grenoble, April 2003
T. Cachat: *Jeux sur des graphes infinis*, Séminaire général, Institut Gaspard-Monge, Marne-la-Vallée, April 2003
T. Cachat: *Higher Order Pushdown Automata, the Cauclal Hierarchy of Graphs and Parity Games*, Annual Meeting of the GAMES (Games and Automata for Synthesis and Validation) project, Vienna, Austria, September 2003

T. Cachat: *Games on Pushdown Graphs and Extensions*, Oberseminar Informatik, RWTH Aachen, December 2003

Ch. Löding: *Reachability Problems over Ground Term Rewriting Graphs*, Weekly seminar at IRISA Rennes, February 2003

Ch. Löding: *Reachability Problems over Ground Term Rewriting Graphs*, Séminaire automates, LIAFA, Université Paris 7, May 2003

Ch. Löding: *Computing Merciful Strategies in One-Pair Streett-Games*, Annual Meeting of the RTN “Games and Automata for Synthesis and Validation”, Vienna, September 2003


W. Oberschelp: *Astronomy as a Science in the Arabic medieval world (in German)*, Institut Français Aachen, July 22, 2003

W. Oberschelp: *The Stars at the Carolingian Sky (in German)*, Lecture accompanying the exposition “Ex Oriente”, August 27, 2003

W. Oberschelp: *An arithmetic lesson with Isaak (explaining Al Khwarizmi’s algorithms) (in German)*, A performance in collaboration with the “Arbeitskreis Karolingisches Aachen”, Aachen, September 26, 2003

W. Oberschelp: *Continuous and discrete methods of demography (in German)*, Symposium “Logic versus Approximation” in honor of M. M. Richter, Dagstuhl, October 23, 2003

W. Oberschelp: *Convolution techniques for demographic population numbers*, Colloquium on Combinatorics, Magdeburg, November 14, 2003

W. Oberschelp: *Introduction and opening of the exposition vernissage “The arts at the court of Charlemagne” (in German, Karolingisches Aachen)*, On the occasion of the inauguration of the Carolus Magnus Gymnasium Übach-Palenberg, November 20, 2003


Ph. Rohde: *Das Sabotage-Spiel und die Sabotage-Modallogik*, Oberseminar Mathematische Logik, Universität Bonn, July 4, 2003, Bonn, Germany


Ph. Rohde: *Sabotage Game and Sabotage Modal Logic*, GAMES 2003 – Annual Meeting of the RTN “Games and Automata for Synthesis and Validation”, August 30 – September 2, 2003, Vienna, Austria


W. Thomas: *Nonuniform recognizability and constraint satisfaction*, McGill Workshop on Constraint Satisfaction, Barbados, March 2–8, 2004


W. Thomas: *Constructing infinite graphs with decidable MSO-theory*, Ecole Normale Superieure de Cachan, June 24, 2003


S. Wöhrle: *Die Caucal Hierarchie unendlicher Graphen*, Seminar on Algorithmic Model Theory, Marburg, November 2003

S. Wöhrle: *Model Checking ad Infinitum*, Tag der Informatik, RWTH Aachen, December 2003

**Publications**


Mathematical Foundations of Computer Science

Staff

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- Secretary:
  Marianne Kuckertz

- Research Assistants:
  Vince Barany
  Dietmar Berwanger
  Dr. Achim Blumensath
  Dr. Jacques Duparc (until August 2003)
  Lukasz Kaiser
  Dr. Stephan Kreutzer (until March 2003)
  Antje Nowack
  Dr. Mariane Riss (until August 2003)
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.

For our research group, 2003 was quite a successful year.

- Jacques Duparc has become Professor for Mathematical Logic at the University of Lausanne, Switzerland.
- Stephan Kreutzer received the “Dissertationspreis der Gesellschaft für Informatik” for his dissertation “Pure and Applied Fixed-Point Logics”.
- Martin Otto, a former member of our group, who was meanwhile Lecturer at the University of Wales, has become Professor for Logic and Mathematical Foundations of Computer Science at TU Darmstadt.

Research Projects

Games and Automata for Synthesis and Validation (GAMES)

www.games.rwth-aachen.de

E. Grädel, D. Berwanger, A. Blumensath, J. Duparc, L. Kaiser, S. Kreutzer, M. Riss
(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, S. Kreutzer

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. Concerning the aspects related to knowledge representation (in particular to description logics) there is a joint project with the research group of Prof. F. Baader (now in Dresden), on Logic Algorithms for Knowledge Representation (funded by DFG).

Recently, substantial progress has been made concerning the algorithmic properties of modal logics (in the broad sense, including temporal logics, dynamic logics, the modal \( \mu \)-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.
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 and E. Grädel on automatic structures has been very influential for the development of this field.

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 Programme Committee of the Annual EACSL Conference on Computer Science Logic, CSL 2003, August 2003, Vienna.

- Member of the Programme Committee of the International Conference on Logic for Programming, Artificial Intelligence and Reasoning LPAR 2003, September 2003, Almaty (Kazakhstan).
Talks and Publications

Talks


J. Duparc: *Jeux sur Graphes d’automates à Pile avec condition de gain \( \Sigma_3 \)*, Paris 2003
J. Duparc: *Remarks on Positive Games and Persistent Strategies*, Aachen 2003
J. Duparc: *Positive Games and Persistent Strategies*, CSL Wien 2003

E. Grädel: *Model Checking Games*, Computer Science Colloquium, University of Wales, Swansea, May 2003
E. Grädel: *Il était une fois dans l’ouest. Détermination, définissabilité et complexité de jeux à itinéraires*, Université de Bordeaux, June 2003
E. Grädel: *Will Deflation Lead to Depletion? On non-monotone fixed-point inductions*, Theory seminar, University of Cambridge, October 2003
E. Grädel: *Führt die Deflation zum Kollaps?*, Jahrestreffen 2003 der GI-Fachgruppen 0.1.6 Logik in der Informatik und 1.2.1 Deduktionssysteme, Augsburg, October 2003.

A. Nowack: *Quantum Computing and Abstract State Machines*, 10th Workshop on Abstract State Machines (ASM 2003), Taormina, March 2003

A. Nowack: *Deciding the Verification Problem for Abstract State Machines*, 10th Workshop on Abstract State Machines (ASM 2003), Taormina, March 2003

**Publications**


M. Riss: Shintani Descent of Almost Characters - Application to the Unipotent Characters of the Principal Series of $Sp(4,q)$, Communications in Algebra, 31 (2003), 2869–2881.

M. Riss: Relevé d’isotypies de $Sp(4,q)$, $q$ impair, Communications in Algebra, to appear.
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- Technical Staff:
  Christoph Albrecht
Overview

The Computer Graphics and Multimedia group at the RWTH puts a focus on research projects in the areas of Geometry Processing 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 current 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. 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. 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 have attracted our interest since they allow for more robust and more efficient algorithms for various geometry processing tasks.

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. In all cases 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 organized the first international Symposium on Geometry Processing at our department. The event turned out to be very successful with participants from most internationally recognized research groups (e.g. Stanford, Harvard, Caltech, ETH, ...) and speakers including Fields-Medalist Shing-Tung Yau and other highly regarded scientist (e.g. Steven Gortler, Harvard University and Jonathan Shewchuk, Berkley University). Attendants from most major CAD companies attested that this research area is of high relevance to the manufacturing industry (such as e.g. automotive or rapid prototyping).
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 summer term and their second parts in the following winter term respectively. In the Computer Graphics courses we cover the basic as well as the advances techniques for image synthesis and lighting simulation, image based rendering techniques, and polygon mesh processing. The Geometric Modeling courses are more focussed on techniques and algorithms to efficiently process freeform curves (part I) and surfaces (part II). A new course on Computer Vision has been offered in the summer term. In parallel to this special course we started a new practical exercise project on Special Effects. Our goal in this project was to develop a software system that processes video streams from 20 digital cameras filming the same scene from different view points 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 third 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. This year our group was again able to publish innovative research papers on many internationally recognized conferences in Computer Graphics. At Eurographics 2003, the leading conference in Europe, Stephan Bischoff received the best paper award in the category “paper, first-authored by a student”.
Computer aided geometric design has become an important key technology in the industrial
design and development process. Especially in the conceptual design stages, the major
bottleneck is still the freeform design metaphor which should allow the user to convey an
imaginary shape to the computer in an intuitive fashion.

The fundamental problem here is that the shapes and deformations applied to them can
get arbitrary complex, while the user interaction to specify these tasks is still very limited.
On standard workstations, the designer uses the mouse to move control points on a two-
dimensional screen. Editing a shape is done by moving some handle object connect to it,
such that the deformed surface $S'$ can be computed from the original surface $S$ and a basis
function $B$ evaluating the handle transformation: $S' = S + B(\delta H)$.

If the user interaction is to be kept simple, the $\delta H$ is restricted to affine transforms. In order
to allow for sophisticated modifications, the bases function $B$ therefore has to incorportate
all the mathematical complexities. As a consequence, basis functions should be custom-
tailored to the desired deformation. In traditional CAD systems, however, the basis functions
associated to control points are fixed, what is the reason why complicated deformations
always require complicated user-interaction.

We propose a modeling framework that provides the construction of custom-tailored basis
functions by painting their support on the surface and choosing their stiffness, smoothness,
and boundary constraints. We are able to achieve realtime response in an interactive design
session even for complex meshes by precomputing a set of basis functions that correspond to
the degrees of freedom of a manipulator object by which the user controls the modification.
High-Quality Point-Based Rendering on Modern GPUs

Mario Botsch, Leif Kobbelt

Due to their simplicity and efficiency, triangle meshes are the de facto standard geometry representation in computer graphics today. As the hardware components for mesh generation, mesh processing and visualization get more and more powerful, the typical surface or scene complexity is steadily increasing. In contrast, the resolution of displays almost stays constant. Hence, rendering highly complex models results in triangles whose projected area is less than a few pixels, causing the standard rendering methods to become inefficient.

As a consequence, above a certain complexity points are the conceptually more efficient rendering primitive. Holes in the rendered image (e.g. when zooming in) can be avoided by so-called surface splatting: Each point is associated with a radius and a normal vector and therefore represents a small disc in 3-space, such that all splats slightly overlap each other.

Besides higher efficiency, point-based rendering also provides superior visual quality compared to standard polygon-based rendering, since lighting computations are performed on a per point basis, corresponding to high quality Phong shading in the surface case. For high-quality anti-aliased rendering sophisticated splatting techniques assign a Gaussian filter kernel to the splats, resulting in elliptically weighted average (EWA) filtering of the image — similar to anisotropic texture filtering.

Exploiting the increasing programmability of modern GPUs, we propose a point-based rendering framework that delegates all expensive rendering tasks to the GPU, thereby minimizing data transfer and saving CPU resources. The resulting implementation is able to process up to 30M mid-quality or up to 10M high-quality filtered surface splats per second on the latest graphics hardware. The images below show some examples of our point-based rendering system.
In recent years the visualization and processing of functional and structural magnetic resonance imaging data sets like those of a human brain has become an important tool for neuroanatomists and neuroscientists alike.

Extracting isosurfaces from a volumetric dataset is an essential part of many neuroimaging applications like automatic brain segmentation, surface reconstruction, cortex inflation and cortex flattening. However, due to noise and partial volume sampling, conventional extraction algorithms often introduce topological errors such as handles and cavities that are incompatible to what is known about cortical anatomy. These small geometric errors generally induce large distortions in the surface metric and have a devastating effect on many downstream applications, e.g. on the classification of intracortical areas by geodesic measurements and on subsequent inflation procedures. Hence, to achieve satisfactory results, we have to take into account some a-priori knowledge about the topology of the cortex, namely that the pial surface is homeomorphic to a sphere.

In this project we are exploring the use of geometric deformable models (GDM) to produce a topologically correct segmentation of the cortical sheet. GDMs represent an active contour as the level set of an implicit function and hence do not suffer from reparameterization artifacts like explicit polygonal representations. However, GDMs do not provide any topology control, i.e. contours may merge or split arbitrarily and hence change the genus of the reconstructed surface. This behavior is inadequate in settings like the segmentation of organic tissue or other objects whose genus is known beforehand. Our novel method overcomes this limitation while still offering the favorable properties of the GDM setup. We achieve this by adding (sparse) topological information to the volume representation at locations where it is necessary to locally resolve topological ambiguities. Since the sparse topology information is attached to the edges of the voxel grid, we can reconstruct the interfaces where the deformable surface touches itself at sub-voxel accuracy.
Hybrid geometry representations

Stephan Bischoff, Leif Kobbelt

A variety of representations exist for geometrical objects, each showing different strengths and drawbacks for analysis and manipulation. These representations range from explicit forms like piecewise polynomial representations, e.g. triangle meshes or higher-order splines, over implicit forms, where the object is given as the (zero-) level set of a real-valued function, to purely point-based representations. The combination of these different techniques into a general framework of hybrid geometry representations enables us to exploit the advantages of each method, resulting in efficient, flexible algorithms while minimizing the costs.

As a first application we considered the problem of image segmentation. Traditionally the segmentation problem is solved by using active contour models where contours are evolved such as to lock on the image features. Explicit representations of the contour typically show parameterization artifacts when the contour is shrunk or stretched too much and need elaborate collision detection procedures. Implicit contour representations, on the other hand, do not provide sufficient control over the topology of the contour, i.e. contours may merge or split.

Depending on the underlying application, r-snakes are either topology preserving or allow contours to merge.

We combined both approaches into a new representation, named r-snakes, which allows for complete control of the contour topology without common reparameterization problems. R-snakes are based on a polygonal representation whose vertices are constrained to the lines of a regular lattice. This restriction implicitly controls the (re-)parameterization of the contour (when a vertex crosses a grid-node) and hence makes it possible to employ parameterization independent evolution rules in terms of deformation forces in normal direction to the contour. Since collisions can only occur on the (finite) set of edges instead of in continuous space, collision detection is robust and efficient. Self-penetrations can be detected and prevented at sub-pixel precision, which gives us complete control over topology changes. Our hybrid method succeeds in areas like contour extraction in medical image analysis, where previous homogen approaches produced topologically inconsistent results.
One important step of the geometry processing pipeline is the actual acquisition of the 3-dimensional shape and appearance of real-world objects into a digitized form. From this data, one can digitally reproduce the geometry of such objects and thus make them available for further steps like geometric modeling. Alternatively, the captured information can be rendered directly into arbitrary new views using image-based methods, where no intermediate or exact geometrical representation is necessary. Applications range from industrial fields like prototype development, visualization in VR-environments, to movies or games.

Several methods to capture 3D data exist, each with different strengths and drawbacks. Laser scanners allow for the reconstruction of purely geometrical properties and result in very dense reconstructions. They fail, however, to capture animated scenes or visual properties of a surface, and are very inflexible and expensive. Other techniques are for example based on projecting structured light patterns onto a surface, or on calibrated standard stereo camera setups. The most flexible technique however is to capture real-world data by using simple, uncalibrated images or videos only.

This project aims at reconstructing the shape and appearance of objects from uncalibrated image sequences. In a first step, selected features are tracked through several frames of such a sequence (left image). Structure from Motion techniques are applied to these feature correspondences to get a first reconstruction of the camera motion and the position of the extracted feature points (right image). This coarse representation can then be refined by methods like standard stereo matching, or photometric stereo techniques. This purely image based approach allows us to capture geometrical as well as visual properties of objects in a flexible way.
In computer-aided design (CAD) and industrial development processes the concurrency and dependency of the various project stages are increasing the requirements for flexible exchange of geometry data. Here polygon models have established themselves as an universal language to communicate geometric information between different software systems in many computer graphics applications.

On the one hand, polygon meshes are quite easy to generate (since only a set of sample points on the object’s surface is needed that have to be connected in order to define a piecewise linear approximation of the underlying surface.) On the other hand, since different applications impose quite different requirements on the consistency and quality of geometry data, many compatibility problems occur in practice. For example polygon meshes are easily created from CAD drawings, but these meshes are not suitable for further processing (e.g. rapid prototyping) because they often have small holes, overlapping faces, degenerate triangles or topological inconsistencies.

This leads to application scenarios where more time is spent on converting and repairing geometry data between the different phases of the processing pipeline than on performing the actual computations. The variety of possible errors makes an automatic approach very difficult.

We have developed a fully automatic technique for the restoration of polygon meshes. A combination of a volumetric and polygonal representation is used in order to exploit the advantages of both. Our technique removes all typical mesh inconsistencies and generates a new triangle mesh that approximates the original mesh at least up to a prescribed error tolerance $\epsilon$. All gaps and holes contained in the original data that are larger than $\epsilon$ and smaller than an user-defined threshold $\rho$ are fixed automatically.
Scattered data approximation methods are a key technology for shape reconstruction and reverse engineering from measured geometry data. In a typical application scenario, raw data is generated, e.g., by some 3D scanning device and fitting a globally smooth surface to the set of sample points converts this data into a geometric representation of the original object that enables sophisticated downstream applications like, e.g., free-form shape editing. Most of the work in this area has been done based on classical tensor-product spline surfaces but with the availability of more flexible subdivision surfaces many ideas have been extended to this generalized setting during the last years. Instead of being constrained to rectangular patches, subdivision surfaces can represent globally smooth surfaces of arbitrary (manifold) topology by allowing for arbitrary irregular control meshes.

We developed a method for scattered data approximation with subdivision surfaces which actually uses the true analytical representation of the smooth subdivision surfaces. The method is fully automatic - the user of the our system just prescribes some maximum tolerance $\delta$ by which the fitted surface is allowed to deviate from the given data, and the system interleaves different techniques until an approximation with the desired quality is obtained. Various experiments show that we are able to obtain high-quality approximations, which in some cases require several times less information to represent the same geometrical data with the same precision in comparison to previous techniques.

Approximation of the Buddha model produced by our algorithm. The original model (a,c) consists of $546K$ vertices, while our approximation (b,d) requires only $18K$ vertices to represent the same object with maximum deviation only 0.05%.
Anisotropic surface remeshing is an important research field for many reasons. On one side, it has been proven that to construct an optimal polygonal mesh with respect to the approximation error, one has to place the mesh elements in correspondence to the surface’s principal curvature directions. This can be intuitively noticed by considering a canonical example, such as a cylinder: planar quads stretched along the lines of minimal curvature provide the best polygonal mesh description. Artists define implicitly the anisotropy of a model, by drawing line strokes in a way which best describes the desired shape. CAD systems users often compose a solid model by shapes such as cylinders, cones and spheres, thus again exploiting implicitly the natural anisotropy and isotropy of such primitives.

Particularly, we are interested in obtaining optimal approximations of the natural structure of geometric data sets. That is, given a raw triangle mesh, e.g., obtained by some 3D scanning device, to generate a polygonal representation for it, which best matches the intuitive notion of the natural construction of the modeled object. Such techniques are highly sought after, mainly due to their ability to provide significant time and cost savings during the rapid prototyping production cycle. Another area of application of such algorithms is reverse engineering, i.e., automatic CAD models reconstruction from already manufactured prototypes.

An original mesh representing a technical object (left) and the produced anisotropic remeshing by our algorithm (right).
The implicit signed distance field of a surface can effectively support many geometry processing tasks dealing with explicit models such as decimation, smoothing, and Boolean operations since it provides efficient access to volumetric distance (error) estimates, though most implicit volumetric representations need a large memory footprint. In this project, we present an algorithm to compute a piecewise linear, not necessarily continuous approximation of the signed distance field for a given object, i.e. the (implicit) volumetric fields can be derived from (explicit) piecewise linear functions. The proposed representation is more compact than previous ones and still offer fast distance evaluation.

Our approach is based on an adaptive hierarchical space partition that stores a linear distance function in every leaf node. We provide positive and negative criteria for selecting the splitting planes. Consequently the algorithm adapts the leaf cells of the space partition to the geometric shape of the underlying model better than previous methods. This results in a hierarchical representation with comparably low memory consumption and which allows for fast evaluation of the distance field function. The efficiency and flexibility of our representation is demonstrated in a number of applications including mesh decimation and smoothing with global error control, surface extraction and level of detail models.

The left two images compare typical Quadtree structure (102K cells) with our BSP tree (254 cells) to store the distance fields with same error (in 2D case). The right center is the original 3D model with 150K triangles and its distance field is approximated with only 23K linear segments shown on the right most with an error of 0.1% to its bounding box diagonal length.
Using surface *splats* as a rendering primitive has gained increasing attention recently due to its potential for high-performance and high-quality rendering of complex geometric models. However, as with any other rendering primitive, the processing costs are still proportional to the number of primitives that we use to represent a given object. This is why complexity reduction for point-sampled geometry is as important as it is, e.g., for triangle meshes.

In this project we present a new sub-sampling technique for dense point clouds which is specifically adjusted to the particular geometric properties of disk-shaped surface splats. Since no topological consistency conditions have to be satisfied, other than the *greedy strategy* that is adopted by most previous approaches, a post *global relaxation optimization* scheme can compute an approximately minimal set of splats that covers the entire surface while staying below a prescribed error tolerance $\varepsilon$. Since our algorithm converts pure point sample data into surface splats with normals and radius, it can also be considered as a surface reconstruction technique which generates a hole-free piecewise linear $C^{-1}$ continuous approximation of the input data. Compared to pure greedy approaches in this area we are able to obtain significantly lower splat numbers and uniform splat distribution for a given error tolerance. The scheme is not as fast as previous ones but the increased computation costs are paid off by a considerably improved output quality.

A Female-torso model (left, 171K points) is approximated by 422 splats after greedy selection (middle two). Global relaxation further reduces the number of splats to 333 (right two). The figures show both, EWA-filtered splats for approximation quality and smaller splats for distribution quality. The error tolerance is $\varepsilon = 0.47\%$ of the bounding box diagonal. Note the improved splat distribution after the global relaxation step.
Other Activities

Committees and Organization:

- Initiator, Program-Chair and Organizer of the First ACM SIGGRAPH and Eurographics Symposium on Geometry Processing 2003, Aachen
- Topic Chair at the internat. Program Committee of the Eurographics 2003 Conference, Granada, Spain
- Member of the internat. Program Committee of the Vision, Modeling, and Visualization Conference VMV2003
- Member of the internat. Program Committee of the Pacific Graphics 2003 Conference
- Member of the internat. Program Committee of the Shape Modeling International Conference 2003, Seoul, Korea
- Member of the internat. Program Committee of the WSCG Conference 2003, Pilzn, Tschechien
- Member of the internat. Program Committee of the Theory and Practice of Computer Graphics Conference 2003, Birmingham

Talks and Publications

Talks

Invited talks

- Geometric Modeling Workshop, Erbach, Germany (organized by Ulrich Reif and Nira Dyn)
- IGD / TU Darmstadt: Seminar on Geometric Modeling
- Pacific Graphics 2003 (Calgary, Canada)
- Shape Modeling International 2003 (Seoul, Korea)
- Theory and Practice of Computer Graphics 2003 (Birmingham, UK)
- SCCG 2003 conference (Budmerice, Solvenia)
- Eurographics 2003 (Granada, Spain)
- Israelian-Korean Bi-national Conference 2003 (Tel Aviv, Israel)
- SIAM Conference on Geometric Design 2003 (Seattle, USA)

Conference presentations

Mario Botsch: *Multiresolution Surface Representations Based on Displacement Volumes*, Eurographics 2003, Granada, August 2003

S. Bischoff: *Sub-Voxel Topology Control for Level Set Surfaces*, Eurographics, Granada, Spain, September 2003

L. Kobbelt: *Snakes with Topology Control*, Tel-Aviv, Israel, February 2003


**Publications**


L. Barthe, L. Kobbelt: *Subdivision Scheme Tuning Around Extraordinary Vertices*, submitted to CAGD 2003, to appear

L. Barthe, C. Gerot, M. A. Sabin, L. Kobbelt: *Simple computation of the eigencomponents of a subdivision matrix in the Fourier domain*, accepted to Mingle Workshop 2003

S. Bischoff, L. Kobbelt: *Parameterization free active contour models with topology control*, IK 2003 Conference Proceedings

S. Bischoff, L. Kobbelt: *Sub-Voxel Topology Control for Level-Set Surfaces*, Eurographics 2003 Conference Proceedings, 273 - 280; Best Student Paper Award Eurographics 2003

S. Bischoff, L. Kobbelt: *Teaching meshes, subdivision and multiresolution techniques*, to appear in CAD journal

M. Botsch, L. Kobbelt: *Multiresolution Surface Representation Based on Displacement Volumes*, Eurographics 2003 Conference Proceedings, 483 - 491

M. Botsch, L. Kobbelt: *High-Quality Point-Based Rendering on Modern GPUs*, Pacific Graphics 2003 Conference Proceedings, 335 - 343


D. Liersch, A. Sovakar. L. Kobbelt: *Parameter Reduction and Automatic Generation of Active Shape Model*, BVM 2003 (Workshop Bildverarbeitung für die Medizin)

N. Linnenbrügger, R. Webber, L. Kobbelt, T. Lehmann: *Automatic volume reconstruction für Hybrid TACT*, BVM 2003

N. Linnenbrügger, R. Webber, L. Kobbelt, T. Lehmann: *Automated hybrid TACT volume reconstruction*, to appear 14th ICDMFR
Martin Marinov, Nira Dyn, David Levin: *Geometrically Controlled 4-Point Interpolatory Schemes*, to appear in “Advances in Multiresolution for Geometric Modelling” N. A. Dodgson, M. S. Floater, M. A. Sabin (eds.)


Data Management and Exploration

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Overview

Research at Computer Science IX 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. Data exploration aims at problems of data mining and knowledge discovery in large databases.

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 taking relevance feedback into account in order to include the cognitive abilities of human experts.

Since the chair for Computer Science IX was established at the end of 2002, still a lot of administrative work had to be accomplished in the first half of 2003. After the installation of a powerful server and a modern working environment, research assistants and students started studies on various fields, especially in the areas of relational indexing and multimedia retrieval, yielding first diploma theses and publications.

Besides that, the chair offered several new courses related to data mining. In the lecture course Data Mining Algorithms and an associated seminar, algorithms for classical data mining tasks such as clustering, classification, and association rules were presented. We also performed a practical course on this topic, where the participating students had to implement some of the algorithms with different data mining tools and database systems. Another seminar dealt with techniques for efficient similarity searches in large databases.
Data exploration can be viewed as the next evolutionary step in data management. The major reason to research efficient algorithms for knowledge discovery in large databases is the huge amount of data and the immense need to turn such data into useful information and knowledge. The goal of data exploration is to develop and study algorithms for similarity search in modern databases. Often the complexity of traditional algorithms to analyse 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, multidimensional indexing structures like R-trees or X-trees are as useful for the retrieval of the required information as approximation techniques and methods to reduce the dimensionality.

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 presented below (see figure 1).

![Shape Histogram of a Molecule](image)

Figure 7: 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.

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.

Multimedia Databases

Multimedia Information Retrieval is an interdisciplinary research topic which calls for tools from database theory, algorithmics, digital signal processing, statistics, artificial intelligence, computer graphics, machine vision, computational geometry, musicology, and psychology among others.

More and more multimedia applications require effective and efficient support for similarity search in large databases, i.e. fast retrieval of objects that are similar to a given query object with respect to particular features including shape, appearance, color distribution, or scene composition.

Similarity queries support the exploration and classification of similar 2D or 3D shapes. Our new approach using shape histograms is an effective and efficient similarity model for which we have developed index-based query algorithms for large databases.

Another aspect concerning multimedia databases is content-based retrieval of documents. Several image and video database systems supporting content-based queries have been developed recently. These systems allow image or video indexing through the use of low-level image features such as shape, color histogram, and texture. Content-based retrieval is of fundamental importance for a number of applications including the search in text, image, audio, and video databases, scientific databases with collections of sensor data, medical databases, DNA databases and last but not least searching in the World Wide Web. Despite recent progress, there are a number of open problems that have to be solved in order to improve both the retrieval quality and the response time.

In order to develop new techniques for an efficient search in large multimedia databases (especially image databases) we approach to investigate the Earth Movers Distance that also regards correlations between different dimensions of the considered objects. Algorithms to compute the Earth Movers Distance exist but are not suited for an adoption in large present-day multimedia databases due to complexity reasons. Thus we try to adapt various enhancing techniques that have been proven to be beneficial for other distance functions to apply them in multimedia databases. In this context, we consider and develop new approaches for extending multi-dimensional index structures, reducing the dimensions of the considered objects, and approximating the Earth Movers Distance by other distance functions.
Shaped-based Retrieval from Biomolecular Databases

The currently very active research fields of genomics and proteomics have to investigate a rapidly growing number of data objects, as well as many other topics of biologic research. For example each year a large number of new 3D structures of molecules are determined by crystallography, by NMR techniques, by automated structure prediction. A fundamental question is to which class the new objects belong. The classes represent collections of objects that have characteristic properties in common and thus are similar, whereas different classes contain objects that have more or less strong dissimilarities. Such a structural classification is a basic task that can be successfully approached by nearest neighbor methods. The underlying similarity models consider spatial properties such as shape and extension as well as physical-chemical or biological attributes.

To find the corresponding class for a new 3D object, the geometry is mapped to shape histograms, thus performing a specific feature transform. The histogram model naturally is extensible to thematic attributes such as physical and chemical properties. For efficient query processing, a filter-refinement architecture is used that supports similarity query processing based on high-dimensional feature vectors and quadratic form distance functions.

Experiments demonstrate the high classification accuracy of our shape histogram model. Automatic class label assignment is performed with an accuracy of 90% for a large variety of 281 different class labels. On top of this high accuracy, our experiments reveal the good performance of the underlying query processor.

Furthermore, we plan to investigate the benefits of visualization techniques extending the classification. This is an important issue since any notion of similarity is highly subjective and users desire as much feedback as possible concerning the decision of the system depending on their queries and input parameters.
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 9: 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. In the future, we plan to enhance our algorithms to support additional selection predicates on scalar and temporal attributes as well as additional join predicates on scalar attributes. We will also investigate the applicability of our join algorithms to stream-based data.
Other Activities

Courses

Lectures:

• Models for Data Exploration (winter 02/03)
• Data Structures and Algorithms (summer 03, undergraduate)
• Data Mining Algorithms (winter 03/04)
• Interdisciplinary team-taught lecture series for Bionic I: Basics and Methods for Biologic and Technology (winter 02/03, winter 03/04)

Seminars:

• Complex Objects in Databases (winter 02/03)
• Algorithms for Data Mining (summer 03)
• Methods and Tools (winter 03/04, undergraduate)
• Similarity Search in Databases (winter 03/04)

Lab Courses:

• Data Structures (summer 03, undergraduate)
• Data Mining Algorithms (winter 03/04)

Reviewing

Conferences:

• ACM International Conference on Knowledge Discovery and Data Mining (SIGKDD)
• ACM International Conference on Management of Data (SIGMOD)
• International Conference on Very Large Data Bases (VLDB)
Journals:

- Bioinformatics
- Information Processing Letters (IPL)
- Knowledge and Information Systems (KAIS)
- IEEE Transactions on Knowledge and Data Engineering (TKDE)
- ACM Transactions on Database Systems (TODS)

Other:

- In 2003, Thomas Seidl had been a member of the Hiring committee for a professorship on Bioinformatics, Johannes-Kepler-University Linz, Austria

Publications


Enderle J., Hampel M., Seidl T.: Joining Interval Data in Relational Databases, Proc. ACM SIGMOD Int. Conf. on Management of Data (SIGMOD’04), Paris, France, 2004

Computer-supported Learning

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Overview

The group’s focus in research and teaching covers various topics in computer-supported learning, namely

- software engineering methods and tools for the analysis, specification, design and implementation of eLearning systems,
- the adaptation of computer science methods to the formalization of didactic scenarios,
- frameworks for the implementation of innovative instructional theories,
- didactics of computer science, and
- the role of IT and media competencies in teachers education.

That year’s activities were dominated by working out new lectures and seminars, developing a new study program and curriculum for secondary school teachers, the evaluation of courses in Computer Science Studies, and the definition of a strategy for the sustainable integration of eLearning into RWTH curricula within the eLearning working group of RWTH Aachen.

The graduate course Foundations of eLearning Systems were held for the first time as well as seminars about graphical user interface design, eLearning technologies, and situated learning scenarios. A period of practical training for the construction of situated learning environments was held during summer break. The undergraduate course Introduction to Computer Science (Java Programming for non-computer scientists; more than 550 students) was newly developed and supported by self-directed learning sequences implemented with the learning environment jBat. The weekly programming assignments of the course Introduction to Computer Science (C++ part) was supported by automatic feed back for assignments implemented with eLC.

Two dissertations supervised by professor Schroeder were concluded at Ludwigsburg University of Education: Michael Gans’ "Die poetische Werkstatt Rose Ausländers in einer Medialen Textwerkstatt Deutsch” and Michael Schäfer’s "Prozess der Entwicklung eines Lehr-Lern-Arrangements mit digitalen Medien am Beispiel einer Textwerkstatt Deutsch” together define a new instructional design process incorporating ideas of the Unified Process for incremental and iterative software engineering projects.

One of the most demanding and time consuming tasks was the foundation and establishment of the eLearning working group of RWTH, which held regular meetings, worked out several papers on strategies and recommendations for eLearning, evaluated eLearning platforms and tools, and systemizes eLearning scenarios and best practice examples.
Research Projects

**VIB - Virtualisierung im Bildungsbereich**  
*(Virtualization in Education)*

*Ulrik Schroeder, Michael Schäfer, Sven Wippermann - Project within the framework program "Virtuelle Hochschule Baden-Württemberg”*

The five-year joint project ViB (virtualization in education) between five Universities of Education in Baden-Württemberg, Germany investigates innovative didactic arrangements by integration of online learning systems into existing (face-to-face) university classes. ViB covers a wide variety of disciplines from Primary Education, German, English, Political Sciences, Health Education, Mathematics and Computer Science. As an abstraction of implementations within eight sub-projects in various disciplines, two main categories of learning systems have been distinguished:

- self-directed information-oriented learning supplementing (undergraduate) lectures and
- communication-oriented learning in virtual (advanced) seminars.

In order to make didactic innovation sustainable, the focus of our research has been laid on formal specification of didactic processes. For this purpose, software engineering methods (Design Patterns, UML and Unified Process) have been adapted to make didactic designs communicatable and to support the systematic process of virtualization.

**ITO - Information Technology Online**

*Ulrik Schroeder, Kerstin Kohl, Alfred Hurst - BMBF joint project within the framework "New media in university education”*

ITO aims at constructing multimedia, and web-based learning services for international curricula in information and communication technology. Learning objects are to be utilized in face to face lectures as well as self-directed (distance) learning sessions, and parts shall be reused in continuous education. The project develops an overall architecture for reusable learning objects, tools for constructing and managing these objects, and the content for the curricula. More specific topics are the research in learning objects for students with sensory disabilities, gender issues of learning, and the consideration of special requirements for international students. ITO is a joint project between University of Stuttgart, TU München, TU Hamburg-Harburg, TU Dresden & PH Ludwigsburg funded by BMBF.
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 technology 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 eLC project aims at the development of a distributed framework architecture for an evaluation and testing system, which allows for the automated evaluation of student tasks such as mathematical problems, answers to questions, UML specifications, or programs (or program fragments) written in different programming languages. The purpose of this system is the automatization of so far manual corrections of weekly assignments in the computer science program.

The framework is based on a distributed architecture utilizing web services in order to distribute various tasks to different computers within a local network (including authentication, security issues, keeping track of student profiles and marks etc.). It allows for the definition and integration of further types of tasks with formal results, such as specifications of automata, grammars as language descriptions and the like.
The jBat project aims at the development of a web-based learning environment, which supports the development of self-paced and collaborative learning scenarios. It is based on a constructivist learning theory and instructional models of situated learning such as anchored instruction.

Authentic learning projects are to be integrated into courses (blended learning approach) in order to optimize the effect of learning and to avoid tacit knowledge. In the case of an introductory programming course, weekly programming assignments are embedded into a background story: the (professional) development of an advanced tool for the management of digital images. At first, a pre-fabricated tool is only utilized by the students, later on, with growing knowledge students implement increasingly larger parts of the package themselves.

In this project a concept and authoring tools for the development of versions for situated learning tasks are developed.

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.

**Other Activities**

U. Schroeder:

- Head and founding member of the newly formed eLearning working group of RWTH Aachen, which has been defining a strategy for the sustainable integration of eLearning into RWTH curricula by developing an eLearning portal for RWTH, which gives background information, provides theory and best practice in eLearning, includes a network of experts, and systematically lists categories of reference eLearning projects. (see http://eLearning.rwth-aachen.de)
• Chair of the first ”RWTH eLearning Day in Aachen”, which brought together experts in eLearning from various projects.

• Head of the committee for the evaluation of studies in Computer Science at RWTH, which prepared a detailed report on the situation and possible improvement of the Computer Science courses as well as a list of measures for the improvement of studying conditions.

• 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)

• Member of the committee for diploma examinations in Computational Engineering Science, which developed new regulations for examinations and the organization of courses, and redefined the curriculum for the CES diploma course.

• Head of the committee for studies in Computer Science, currently discussing the introduction of Bachelor/Master degrees in Computer Science.

• Deputy of the RWTH in the working group ”eLearning” of the IDEA-League.

• Deputy of the department of Computer Science in the RWTH working group ”Students’ evaluations of classes”.

• Head of the committee for the evaluation of the Computer Science course for future teachers at secondary schools.

• Reviewer for the International conference on Knowledge Engineering, I-Know2004 to be held in Innsbruck, Austria in 2004.

Eva Giani:

• Member of the eLearning working group of RWTH Aachen.

Dieter Weckauf:

• Conception of the eLearning lab for the evaluation of eLearning platforms.

**Talks and Publications**

**Talks**


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 are currently building 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 more tractable.

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, 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, Stefan Werner

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 floor. 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.
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.

The Patch Panel solves a broader class of interoperability scenarios in ubicomp environments. Any event-based application, device, or service can be mapped through the Patch Panel to interoperate with other components without a priori knowledge of their interfaces. This leads us to another main research thrust: understanding what infrastructure requirements and architectures promote a positive user experience in these complex ubicomp environments. These include solutions for interoperability, system performance, and security that don’t compromise the user experience. Finally, we want to explore novel interfaces to allow end users to configure and establish these relationships between system components.
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 successfully completed *You’re the Conductor*, a second-generation interactive conducting exhibit with audio and video that is on permanent display in *The Children’s Museum* in Boston. The key contribution over our previous iteration (*The Virtual Conductor*, on display in the *HOUSE OF MUSIC VIENNA*) is an improved technical framework that allows control over playback of audio and video in real-time, without pitch-stretching artifacts, and without requiring offline preprocessing. We conducted user tests to compare our implementation of an improved phase vocoder algorithm used to perform the time-stretching against a widely known, professional algorithm that does not operate in real-time; the results of the survey showed that our algorithm was superior in some aspects of psychoacoustic quality, specifically for large time-stretching factors.

We continue to explore the design of multimedia systems that manipulate time. In particular, we are studying conducting gestures of professional vs. non-professional conductors, and how these differences could be modelled in a system that automatically adjusts to a user’s level of experience with conducting. We are also examining new possibilities for advanced time stretching algorithms, particularly for polyphonic, multi-channel audio. Finally, we are exploring the time design space for multimedia: for example, how to express time and time manipulation operators in a way that is intuitive for system designers and end users. We plan to build a framework and accompanying applications to allow us to explore this design space in more detail.
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 Mac OS 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. 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 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 23Cinema 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 40mobile 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 multimedia for our students and staff.

In 2003, 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 5th.

Our group co-organized the 2nd Usability Patterns workshop at INTERACT 2003, the UBI-HCISYS workshop at Ubicomp 2003, and the 5th HCI Patterns workshop at CHI 2004. We worked as reviewers for CHI 2003, CHI 2004, WWW 2004, and the MIT Press, and host the hchipatterns.org home page as heads of the IFIP task group on this topic.
Talks and Publications

Talks


Publications

Stavros Antifakos, Jan Borchers, and Bernt Schiele: Designing Physical Interfaces with Sensor Drawbacks in Mind, PI03 Physical Interaction Workshop on Real-World User Interfaces, MobileHCI 2003, Udine.


Software for Embedded Systems

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  Dipl.-Ing. Falk Salewski
  Dipl.-Inform. Bastian Schlich
  Dipl.-Inform. Dirk Wilking
Overview

Informatik XI began operation in November 2003. At the time of preparing this report, we still are in the middle of starting up the business. With the help of my first (and in 2003 only) associate, Herwig Lin, and plenty of support from the other Computer Science groups (first to mention Gabriele Hoeppermanns, Hedi Klee and Detlef Wetzeler) we spent the first months to acquire and install a large part of our computer infrastructure, furniture, and laboratory equipment. In the middle of January 2004 we made a big step forward when Marina Herkenrath joined our group and quickly built up a smoothly functioning secretariat. Dirk Wilking dared to become the first research associate in the middle of February 2004, soon to be joined by Daniel Klünder and Falk Salewski. Right now, we just filled our last two open positions with Maria Witte and Bastian Schlich. So, we are complete and equipped for now but, however, still waiting for our designated rooms.

Research at Informatik XI will be focussed on software engineering for embedded systems. Based on my experiences with the current practice in industry, our aim is to develop methods and technologies for embedded software which help practitioners to meet todays increasing quality demands. This will be built on a model-based engineering approach. 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, process organisation by agile methods, quality evaluation of architectures, and the application of formal methods to safety-critical systems.

Our research activities have not been casted into concrete projects, yet. But we identified four first areas of interest which are sketched in the sequel.

Research Projects

Automotive Software Engineering

Daniel Klünder, Stefan Kowalewski

The dramatically increasing amount and importance of software in automotive electronic systems pose new challenges to the engineering of such systems. We are interested in design and analysis methods which support the achievement of pre-defined quality goals and, in particular, meet current requirements like composability and exchangeability of software components from different sources and over the complete vehicle network.
Safety Critical Systems
Falk Salewski, Stefan Kowalewski

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.

Hybrid Systems
Bastian Schlich, Stefan Kowalewski

Hybrid systems are models of dynamic systems which comprise discrete and continuous state aspects. They arise, for example, when discrete controllers (like computers) interact with physical processes. Our interest lies in formal methods for designing and analysing such systems as well as making these methods applicable in practice. We are associated member of a EU-funded Network of Excellence on Hybrid Control (HyCon).

Agile Methods for Embedded Systems
Dirk Wilking, Stefan Kowalewski

Agile methods are a relatively new approach to structure and organize the development process of software systems. In many aspects they are in sharp contrast to most of the process frameworks that are favoured by the embedded systems industries. Based on empirical studies, we want to compare the applicability under industrial constraints and, if possible, improve current processes by combining the most successful elements.

Other Activities
Stefan Kowalewski is Associate Editor of the IEEE Transactions on Control Systems Technology. He has been member of the following program committees: IFAC Conference on Analysis and Design of Hybrid Systems, Saint Malo, France, 2003 (also member of the Organizing Comittee); Fachtagung Engineering komplexer Automatisierungssysteme, Braunschweig, 2003; IEEE Conference on Computer-aided Control Systems Design, Taipei, Tai-
Publications


Stefan Kowalewski: Über Kulturunterschiede – was Regelungstechnik und Informatik voneinander lernen können, Kolloquium „Rückblicke, Einblicke, Ausblicke“, Universität Dortmund, February 2004
Scientific Computing

Staff

- Faculty:
  Univ.-Prof. Christian H. Bischof, Ph.D.

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- Research Assistants:
  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 (funded by DFG within SFB 540)
  Dipl.-Inform. Andre Vehreschild
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 Numerische Algorithmen* (Parallel Numerical Algorithms),
- *Parallele Algorithmen und Software für iterative Methoden* (Parallel Algorithms and Software for Iterative Methods),
- *Semantische Transformationen* (Semantical Transformations),
- Computational Differentiation.

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 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.

It turns out that in such highly complex simulation codes with sophisticated numerical methods the structure of the program and of the underlying numerical algorithms must be taken into account in order to make best use of the AD tools. In particular, the mathematical structure should be exploited at a high level, which allows, for instance, not to do any derivative computations within the preconditioner of an iterative equation solver. In addition, the convergence of the derivative code must be investigated.
Once partial derivative information is available, it can be used for embedding the simulation software into an efficient optimization framework. We plan to investigate hybrid approaches combining evolutionary optimization algorithms with derivative-based numerical optimizers.

An Environment for Parameter Identification and Sensitivity Analysis

E. Slusanschi, C. Bischof, M. Bucker

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 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. Bücke

This project deals with the numerical simulation of reactive transport in porous media using the simulation package SHEMA T (Simulator for HEat and MAss Transport). SHEMA T 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 SHEMA T 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. Bücke

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 engineering. This project is funded by the Research Training Group (GK) “Hierarchy and Symmetry in Mathematical Models”.
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:

- Martin Schlegel, Process Systems Engineering, RWTH (January 8, 2003),
- Bruno Lang, BGH Wuppertal (June 3, 2003),
- Lars von Wedel, Process Systems Engineering, RWTH (July 24, 2003),
- Marek Behr, Rice University (May 9, 2003),
- Jörg Henrichs, NEC Australia (October 17, 2003),
- Uwe Naumann, Argonne National Laboratory, USA (December 4, 2003).


Christian Bischof is speaker of the Working Group “Parallelism” within the Forum Informatik and organizes — jointly with F. Hoßfeld (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, has since then established itself as a forum for discussion and information exchange among the Northrhine-Westphalian institutions concerned with parallel processing.

Christian Bischof, Martin Bücker and Paul Hovland (Argonne National Laboratory) organized the Second Workshop on Automatic Differentiation and Applications held in conjunction with the International Conference on Computational Science and its Applications, May 19, 2003, Montreal, Canada.

Martin Bücker served on the program committee for:

- Workshop on High Performance Scientific and Engineering Computing with Applications (HPSECA–03) held in conjunction with the 32nd International Conference on Parallel Processing 2003 (ICPP–2003), Kaohsiung, Taiwan, October 6–9, 2003,
- Workshop on Hardware/Software Support for Parallel and Distributed Scientific and Engineering Computing (SPDSECA–03) held in conjunction with the 12th International Conference on Parallel Architectures and Compilation Techniques (PACT–03), New Orleans, USA, September 27–October 1, 2003,
• Workshop on Parallel and Distributed Scientific and Engineering Computing with Applications (PDSECA–03) held in conjunction with the 17th International Parallel and Distributed Processing Symposium (IPDPS–2003), Nice, France, April 22–26, 2003.

Talks and Publications

Talks

C. H. Bischof: *Sensitivities for a Single Drop Simulation*, Joint University of Hertfordshire/Cranfield University Workshop on Automatic Differentiation, Hatfield, UK, November 27, 2003

E. Slusanschi: *Ableitungsberechnung für Simulationssoftware*, SFB 540, RWTH Aachen, Germany, November 11, 2003

A. Rasch: *Rechnergestütztes Differenzieren in der numerischen Strömungsanalyse*, Doktorandenkolloquium, RWTH Aachen, Germany, September 30, 2003


H. M. Bücker: *A Hybrid MPI-OpenMP Implementation of the Conjugate Gradient Method in Java*, Fifth European Workshop on OpenMP, Aachen, Germany, September 23, 2003

H. M. Bücker: *Algorithmische Ableitungen für elektrodynamische Feldsimulationen*, Institut für Allgemeine Elektrotechnik, Universität Rostock, Rostock, Germany, September 18, 2003


C. H. Bischof: *Recent Advances with Automatic Differentiation*, Dept. of Bioengineering, Syracuse University, USA, August 11, 2003


A. Vehreschild: *Computing efficient derivatives in MATLAB using automatic differentiation*, *EUROMECH 442, Colloquium on Computer-Aided Optimization of Mechanical Systems*, Erlangen, Germany, February 27, 2003

A. Rasch: *EFCOSS - An Interactive Environment for Combining Optimization and Simulation Software*, Computational Sciences and Mathematics Research Department, Sandia National Labs, Livermore, CA, USA, February 18, 2003

A. Rasch: *Automatic Differentiation of Industrial CFD Codes: A Case Study with FLUENT*, *SIAM Conference on Computational Science and Engineering*, San Diego, CA, USA, February 13, 2003

Publications


Dissertations
Optimizing the planning and the steering-control of production processes (PPS) is a hybrid task within many different frameworks with usually high complexity. This dissertation makes the somewhat desperate attempt to develop a general approach via genetic algorithms.

The theoretical status of genetic optimization is rather poor: The schema-theorem and the building block hypothesis are conceptual formalizations of monotonicity and independence-experience in the phylogenetic evolution model, which is based on the intuitive notions of genes, mutation, crossover and fitness. Not much more theory is available.

Since a natural genetic model for PPS problems is not at hand, a new concept of a solution generator tries to exhaust the essence of genetic optimization. Modeling a conceptual level above the ordinary genes, the dissertation intends to breed good results somehow by implicit cooperation without an explicit low level evaluation. The main problem of defining a global fitness function of vector valued type requires non-linear comparisons and adapts from linear optimization the Pareto-paradigm.

The tools for this strategy are THOR-nets (in the notation of M. Sonnenschein), which arose from Petri nets. This concept combines flexibility with a wide model spectrum and contains special facilities to investigate time-processes. These nets are equipped in this dissertation with an additional database component, and PPS objects are defined as theoretic primitives for real applications.

The main realization for this framework is a repair and maintenance service center with typical PPS goals like passage-time, stock and vacancy control and readiness for delivery. Lot-size and machine-occupancy are now the objects for solution generators, and the familiar tools of Gantt diagrams become objects of high-level genetic operators.

As a general result the method of solution generators with implicit cooperation has significant advantages over the usual techniques to optimize by sequential and isolated scheduling. Moreover there exist tradeoffs between the quality of solutions and the calculation time of various types of solution generators.

Evaluator: Prof. Dr. Michael Sonnenschein (Univ. Oldenburg)
External Evaluator: Prof. (em.) Dr. Walter Oberschelp
Date of Oral Exam: January 15, 2003
Games on Pushdown Graphs and Extensions

Thierry Cachat

Two-player games are analysed which are played on different classes of infinite graphs. These “game arenas” are transition graphs of pushdown automata and the (more general) graphs of the “Caucal hierarchy” (transition graphs of higher-order pushdown automata). The study covered several types of winning conditions: reachability, Büchi (recurrence) condition, a $\Sigma_3$-condition, and the parity condition. The aim in solving a game is to determine the winner from a given start vertex and to compute a winning strategy. Two kinds of techniques are developed: a symbolic approach based on descriptions of vertex sets by finite automata, and techniques of game reduction. The idea of the symbolic approach is to represent and handle infinite sets of configurations by finite automata. The idea of the game reduction is to reduce a given game to a simpler one that we can solve, and to deduce from it the winner and a winning strategy in the original game. Our results established a class of algorithmically solvable games over a much more extended range of infinite graphs than known before.

Evaluator: Prof. Dr. W. Thomas
External Evaluator: D. Caucal
Date of Oral Exam: December 18, 2003
Providing Internet Quality of Service based on Differentiated Services
Traffic Engineering

Markus Fidler

The provision of network Quality of Service has become an extremely active area of research in recent years. A variety of architectures and complementing theories have evolved. Yet, it turned out that the fine-grained approaches to Quality of Service applied in early Integrated Services networks do not scale to the size of the Internet. This shortcoming is addressed by the current Differentiated Services architecture, which applies a coarse classification of individual data flows into a small number of traffic classes that are supported by a differentiated forwarding treatment. However, the architectural simplification applied by Differentiated Services creates significant problems when targeting at well-defined deterministic service guarantees. Effects that are due to multiplexing of flows and scheduling of aggregates worsen the efficiency and complicate the derivation of performance bounds.

Two types of services are of special interest in this context: These are a Guaranteed Rate Service that provides access to a certain amount of transport capacity and a Premium Service, which in addition targets at ensuring zero packet loss and defined end-to-end delay bounds. While the needs of the Guaranteed Rate Service can be addressed by known capacity constrained routing algorithms, the provision of the Premium Service is much more complicated. In case of aggregate scheduling any flow that is added to a traffic aggregate can impact the service offered to any other flow that belongs to the same aggregate. Effects that are due to multiplexing propagate through the network, so that interference can even occur between flows that are mapped onto completely disjoint paths. To address such scenarios, complex Network Calculus extensions that cover multiplexing, aggregate scheduling, and demultiplexing have to be applied. Here, an inductive approach is followed, which computes backlog and delay bounds at each network element. Traffic Engineering mechanisms that prevent from cyclic dependencies are incorporated into the applied routing algorithms to ensure that a certain, valid order for induction exists. Eventually end-to-end per-flow delay guarantees are derived.

Unfortunately, the known forms for aggregate scheduling are not tight, resulting in comparably weak service guarantees. Substantial enhancements to current Network Calculus principles are derived, which allow providing significantly tighter performance bounds.

A number of architectural options exist in Differentiated Services networks. Especially traffic shaping is of particular interest if the requirements of heterogeneous flows have to be fulfilled by an aggregate scheduling network. Network Calculus extensions that cover traffic shaping are deduced and an adaptive shaping scheme is evolved, which allows fine-tuning performance guarantees for individual flows. Applying this approach, different nuances of, for example, the Guaranteed Rate Service and the Premium Service, can be efficiently implemented applying the same traffic aggregate.
A thorough simulative evaluation of the implemented control procedures proves the feasibility of the approach and gives detailed results on the achieved utility. Worst-case per-packet delays are obtained from state-event simulation to quantify the quality of the derived delay bounds.

**Evaluator:** Prof. Dr. O. Spaniol  
**External Evaluator:** Dr. Friedel Hoßfeld  
**Date of oral exam:** November 26, 2003
Modeling Telecommunication Systems: From Standards to System Architectures

Dominikus Herzberg

The architecture of a technical system reflects significant design decisions about the system’s organization and typically documents a description of key system elements (be they hardware or software), their composition, functioning, and interrelation. The process of creating a description of an architecture is called architecture modeling. In the telecommunication domain, the architecture level has always played an important role in the design and evolution of communication systems and networks.

However, the way how telecommunication engineers describe their architectures is surprisingly rudimentary: They use natural languages and conceptual drawings, as a look into old as well as recent standards unveils. Even in the transition phase from standards to the early design phases of system development, system designers do not go much beyond that level of informality. Therefore, as practice shows, in telecommunications, architecture modeling but not the understanding of architecture as such lacks (i) a suitable, consistent and formal modeling language, which is adapted to the needs of systems designers, and (ii) a methodology to support the modeling process. This work addresses these deficiencies.

In this thesis, a systematic approach is presented for modeling architectures of virtually any telecommunication system. This includes a methodology, a modeling language, and a prototype implementation of the language. A major contribution of this work is the statement that such an approach can be based upon as few as three basic cornerstones for a networked system: the types of communication and the design principles of distribution and layering. The investigation distills fundamental insights for the design and construction of modern communication systems.

The outcome can be summarized as follows: The aspect of control leads to the distinction of three elementary types of communication (control-oriented, data-oriented, and protocol-oriented communication) and provides the rational for greybox architecture descriptions. The aspect of distribution can be manifested by the notion of a complex connector, which is the key concept to model connection-oriented, connectionless and even space-based communication networks including quality of service. Layering in telecommunication systems is different from the ordinary understanding of the term. Layers in a distributed communication system follow a generic form of refinement, namely communication refinement. Communication refinement constitutes a true abstraction hierarchy, which can be interpreted from two perspectives: from a node-centric and from a network-centric viewpoint. The viewpoint chosen has an important impact on the systems understanding.

The foundation of this work is mathematical, its application is practical. The mathematics help giving precise definitions on the notions of distribution and layering; the resulting implications shape the methodology and the language. The language developed is based on ROOM (Real-Time Object-Oriented Modeling), an object-oriented but also component-based language. Key language features of ROOM will be integrated in the forthcoming 2.0
release of the Unified Modeling Language, UML. The extensions proposed to ROOM led to a careful redesign of the language and a prototype implementation. The accompanying methodology is organized in method blocks, each block being a self-contained methodological unit encompassing heuristics and architectural solution patterns.

The thesis statement is supported by a real-life case study on the SIGTRAN (SIGnaling TRANsport) architecture. In the case study, first the understanding of architecture models as imposed by standards is presented. At the end of this work, it is shown that systematic architecture modeling is relatively easy and comes at little costs - the gains in terms of clarity, preciseness and expressiveness are remarkable.

**Evaluator:** Prof. Dr.-Ing. Manfred Nagl  
**External Evaluator:** Prof. Dr. Manfred Broy (TU Munich)  
**Date of oral exam:** September 17, 2003
Rechnerunterstützte Konflikttermittlung und Entcheidungsunterstützung bei der Disposition des Zuglaufs

Jürgen Jacobs

Competition in traffic is a particular challenge to railway technics. While the hardware gives little room for saving time or material, the disposition of train courses and their safety-control will be automatized more and more. New situations occur: Different companies use the same rail system according to new German federal laws. This makes the automatic disposition of trains, which are now connected to a central server via wireless communication, desirable.

The Institute for Rail-Traffic-Research of the RWTH has developed software for the automatic construction of time-tables already some years ago. But for the disposition of a running train additional real time conditions have to be fulfilled. In contrast to methods from elsewhere, which use artificial intelligence or linear programming, the present dissertation uses a network-scheduling approach, which relies on the Aachen system FACTUS (Brünger) for time-table construction. As an extension of FACTUS now ASDIS is presented: Two auxiliary algorithms have been developed: The first inserts additional trains into an actual situation, which results from the radio reports of other trains. The second algorithm searches for a possible course for a train in this situation.

With the support of these algorithms the central algorithm is designed as a conflict solver. This solution has to take into consideration the operating philosophy of the leading DBNetzAG: Among other constraints, the priority of fast (and expensive) trains has to be brought into an adequate relation to the management of inferior (e.g. freight) trains. Moreover, the size of the influence of a disturbance (accident, material problems) in the whole system has to be estimated correctly.

In order to implement ASDIS for actual use, a test version ZLM has been successfully developed, which works well using an event-oriented time simulation. It might be speculated that ASDIS is a further step to eliminate human driven signal boxes from railway systems.

Evaluator: Prof. Dr. W. Schwanhäußer (Faculty of Civil Engineering, RWTH)
External Evaluator: Prof. (em.) Dr. W. Oberschelp
Date of Oral Exam: February 20, 2003
Normalization in the Acoustic Feature Space for Improved Speech Recognition

Sirko Molau

In this work, normalization techniques in the acoustic feature space are studied which improve the robustness of automatic speech recognition systems. It is shown that there is a fundamental mismatch between training and test data which causes degraded recognition performance. Adaptation and normalization, basic strategies to reduce the mismatch, are introduced and placed into the framework of statistical speech recognition. A classification scheme for different normalization techniques is introduced. Common normalization schemes proposed in the literature are motivated and discussed, and two promising techniques are implemented and studied in detail. Vocal tract length normalization relies on frequency axis warping during signal analysis to reduce inter-speaker variability. The baseline procedure for training and test data normalization is introduced and optimized so that consistently large improvements in recognition performance are achieved under a variety of acoustic conditions. A technique for fast parameter estimation is developed that gives the same improvements as the baseline technique without an increase in computation time. It is shown that vocal tract length normalization can be applied successfully in online applications. A novel approach for integrated frequency axis warping is developed that merges successive signal analysis steps into a single one. It simplifies signal analysis and gives a better control over the amount of spectral smoothing. The second set of techniques explored in detail are histogram normalization and feature space rotation. They aim at reducing the mismatch between training and test by matching the distributions of the training and test data. The effect of histogram normalization at different signal analysis stages, as well as training and test data normalization are investigated in detail. One of the basic assumptions of histogram normalization is relaxed by taking care of the variable silence fraction. Feature space rotation is introduced to account for undesired variations in the speech signal that are correlated in the feature space dimensions. The interaction of histogram normalization and feature space rotation is analyzed, and it is shown that both techniques significantly improve the recognition accuracy in scenarios with different degrees of mismatch. Finally, it is demonstrated how the application of several normalization schemes in presence of large mismatch between training and test data can make the difference from essentially zero recognition accuracy to a high level of 90%. Experimental results are reported for corpora with different acoustic conditions, vocabulary sizes, languages, and speaking styles: North American Business News is a large vocabulary task of English read speech, VerbMobil II is a German large vocabulary conversational speech task, EuTrans II is an Italian speech corpus of conversational speech over telephone, and CarNavigation a German isolated-word recognition task recorded partly in noisy car environments.

Evaluator: Prof. Dr.-Ing. Hermann Ney
External Evaluator: Prof. Dr. Harald Höge
Date of Oral Exam: February 14, 2003
Color and texture are two of the important fields of medical image processing, which are usually investigated separately, as yet. This dissertation presents methods for an integrated treatment of medical color images. Co-occurrence matrices and Gabor filters combine the statistical and the signal theoretic features. The gain from the integrated analysis of color-texture can be estimated quantitatively: The co-occurrence notation with the concept of Kolmogoroff-independence is a useful tool for both the integrated and the isolated approaches; on the other hand the local phase of the filter bank coefficients is one of the new features of color-texture analysis.

Thus the discussion whether these additional efforts make sense can be decided from the application context. Extensive classification tests with natural images demonstrate a significant improvement compared to classical methods, while the evaluation of dermatoscopic images exemplifies the broad field of possible applications in medical diagnostics.

Evaluator: Prof. (em.) Dr. Walter Oberschelp
External Evaluator: Prof. Dr. Dr. Klaus Spitzer (Faculty of Medical Sciences, RWTH)
Date of Oral Exam: February 6, 2003
The goal of a data warehouse system is to provide a comprehensive overview of the data available in a company, thereby supporting the management decisions. The integration of data coming from heterogeneous sources is one of the key problems in data warehousing. The technical foundations for the integration have been developed in recent years. However, an efficient technical infrastructure is not sufficient to address the following problems. Firstly, the data in the systems involved have different semantics. Secondly, there are different user requirements regarding the quality of data. Existing systems are unable to solve these problems.

The present thesis supports the development of data warehouse systems paying special attention to the problems regarding semantics and data quality. The approach is based on the explicit modelling of meta data of data warehouse systems. In particular, the conceptual context, the quality requirements, and the quality characteristics of the individual system components are represented in a formal model.

The main contributions of the present thesis are, firstly, an extended meta model of the architecture and processes of a data warehouse system and, secondly, a quality model for the systematic representation of quality requirements and measurements. Furthermore, a classification of quality dimensions and factors is developed that can be used for an extensive quality management in data warehouse systems.

The meta data is applied in a model for quality management as well as in a methodology for quality-oriented data integration. The methodology developed in this work uses the meta data by combining different existing approaches to data integration. The results of the present work are validated in various case studies in industrial contexts and in international research projects.

Evaluator: Prof. Dr. Matthias Jarke
External Evaluator: Prof. Johann-Christoph Freytag, Ph.D.
Date of Oral Exam: December 11, 2003
In this work, the application of across-word phoneme models during large vocabulary continuous speech recognition is studied. A recognition system will be developed which allows for the training of high performance across-word phoneme models, the efficient application of these across-word phoneme models in combination with long-span language models in one single search pass, and the construction of word graphs. In contrast to within-word phoneme models which consider the context dependency of the phonemes representing the words in the vocabulary only within the words and use a reduced phonetic context at word boundaries, across-word phoneme models consider the context dependency of the phonemes also across word boundaries. As it is known for many years, this results in significant word error rate improvements but also in a considerably higher computational effort. Today, across-word phoneme models are applied by a number of groups. However, the published descriptions of these recognition systems are often quite general, many implementation details needed for the successful application of across-word phoneme models are usually missing. In this work, all details about the transformation of a baseline within-word model system into an across-word model system will be discussed. It will be analyzed in detail how the introduction of across-word phoneme models affects word error rate, runtime and memory requirements of the recognition system. First, the across-word model paradigm will be integrated into the very general Bayes’ decision rule which is the basis of speech recognition. Taking all model assumptions and approximations needed for the application of across-word models into account, a specialized decision rule will be derived. Based on this specialized decision rule the across-word model system will be developed. Compared to the baseline within-word model system, the introduction of across-word phoneme models results in a significantly more complex search network. The efficient application of across-word phoneme models in combination with long-span language models in one single search pass requires a careful design of the search network as well as of the search algorithm which will be discussed in detail. In contrast to the baseline within-word model training, the phonetic representation of the training utterances is not unique anymore if across-word models are to be trained. Furthermore, the parameterization of the baseline within-word model training should be modified in order to obtain optimally performing across-word models. Finally, the introduction of across-word models affects also the construction of word graphs. In order to optimize the runtime of the developed across-word model search further, several acceleration methods will be applied which have partly already been discussed for within-word model systems in the literature. In addition, methods for further increasing the accuracy of across-word models will be studied which are based on a refined pronunciation modeling. The developed across-word system will be finally evaluated on three different speech corpora by comparing the recognition results of this system to the recognition results of the baseline within-word model system. On two of the corpora, these results will also be compared to the results of other research groups, as they are published in the literature. It will be seen that
the developed recognition system produces state-of-the-art word error rates.

**Evaluator:** Prof. Dr.-Ing. Hermann Ney  
**External Evaluator:** Prof. Dr. Reinhold Häb-Umbach  
**Date of Oral Exam:** January 10, 2003
Habilitations
Hierarchical Algorithms for Automatic Differentiation

Martin Bücke

Under a wide range of circumstances, the performance of computer programs generated in a black-box fashion by automatic differentiation (AD) often rivals or even exceeds that of numerical approaches based on divided differences. Yet, a little insight into the structure of the program to which automatic differentiation is applied may further increase the resulting AD code significantly. In the present work, the term “structure” is interpreted in the sense of a hierarchical approach to AD where a suitable layer of abstraction is determined by data dependence information or the semantics of the original program.

We first consider a technique called interface contraction that exploits data dependence information of the original program. The idea of interface contraction is to preaccumulate the local Jacobian of a subroutine whose number of variables passed is less than the number of directional derivatives propagated in a black-box AD approach. After demonstrating the significance of interface contraction in an actual application from neutron scattering, we show that, in addition to a syntactical analysis, a seemingly unrelated issue, namely graph drawing, may also be used to recognize those parts of the code to which interface contraction is potentially applied. Then, a performance model is proposed predicting the speedup of a code using interface contraction compared to a black-box generated AD code.

In a second part of this work, we exploit semantic information to increase the efficiency of derivative code. Here, we assume that automatic differentiation is applied on the level of standard numerical kernels rather than on intrinsic functions or elementary operations. The differentiation of a Fourier transform algorithm leading to a multiple Fourier transform problem is considered first. We show not only that the solution of the multiple Fourier transform problem is more efficient than a black-box application of AD but also that the potential degree of parallelism is increased enabling a rich set of automatic parallelization strategies for the AD code. Similarly, the differentiation of an algorithm to iteratively solve a system of linear equations leads to the problem of solving multiple linear systems with the same coefficient matrix but different right-hand sides. Here, block Krylov methods offer the potential to be more efficient than successively using standard Krylov methods designed for single right-hand sides. Furthermore, differentiation of left and right preconditioners is shown to be dispensable.

Finally, we analyze the subtle issue of applying automatic differentiation in a black-box fashion to iterative algorithms. Surprising results may occur because the mechanical AD process is not only applied to the solution of the algorithm, but also to the solution procedure itself. The crucial point of automatically differentiating trust-region algorithms turns out to be the gradient of the trust-region radius. If this gradient is zero, the derivatives obtained from a black-box application of automatic differentiation are equal to the desired derivatives, otherwise some manual interaction
is (currently) needed to obtain the desired results. **Referent:** Prof. Christian Bischof  
**Koreferenten:** Prof. Andreas Griewank, Technische Universität Dresden, Prof. Thomas Coleman, Cornell University  
**Habilitationskolloquium:** 3 June 2003
Term Rewriting Models of Concurrency: Foundations and Applications

Thomas Noll

The difficulty of designing and developing software and hardware for various forms of concurrent distributed computer systems, such as computer networks, process-control systems, telephony systems etc. is well experienced and forms part of the so-called software crisis. In the area of Formal Methods, techniques that aim to alleviate this situation are investigated. More precisely, the approach is to develop methods for constructing mathematical models of concurrent systems, and techniques for the algorithmic analysis of these models. Preferably the models should be abstractions (i.e., simplifications) of the system under consideration, which capture the essential aspects of its behavior.

Over the last decades, the research community has produced a variety of tools which can efficiently analyze models of concurrent and distributed systems. Each of these tools requires that the system under study be specified in a modeling language which is tool-specific. A problem is then that a certain modeling language may not be suitable for capturing the essence of a particular system.

In the habilitation thesis this problem is tackled by developing a technique for defining modeling languages, in a way that allows the specification of the language to be used also by an analysis tool. The approach is based on the Rewriting Logic formalism, a unified semantic framework for concurrency which rests upon conditional term rewriting modulo equational theories. The thesis addresses several theoretical questions related to this formalism as well as practical implementation issues. Moreover it presents a prototype implementation of a compiler generator for Rewriting Logic specifications and demonstrates its usefulness by studying a larger case study, the formalization of the functional programming language Erlang.

Referent: Prof. Dr. Klaus Indermark, RWTH Aachen University
Koreferenten: Prof. Dr. Helmut Seidl (University of Trier, now Technical University of Munich), Prof. Dr. Bengt Jonsson (Uppsala University, Sweden)
Habilitationskolloquium: 24 July 2003
Successful applications of electronic commerce deal mainly with the electronic purchase and sale of standardised products of a low trade value between customers and suppliers in restricted networks, i.e. one big supplier and many customers (as in the case of electronic shops) or one big customer and many suppliers (as in the case of electronic procurement systems). To enable the purchase of complex and valuable goods and to develop marketplaces as a forum of bringing together suppliers and customers, two main research challenges can be identified. Firstly, the data exchange on a marketplace needs to be homogenised since there is no longer one large participant dictating a standard. Secondly, the lack of trust in electronic trading, already a huge problem, gets more problematic if more complex and valuable products are purchased and sold via electronic channels.

These challenges can be met by developing efficient electronic negotiation support that links the product-oriented phase of search with the process-oriented phase of fulfilment. Our approach to electronic negotiations provides the means for a dynamic specification of product characteristics through communicative enrichment processes, thereby enabling commerce processes with complex goods that can be specified and agreed on during negotiation processes and then traded following the agreement. Our approach to increasing trust in electronic negotiations is threefold. Firstly, negotiation processes are enabled through flexible communication which helps to tackle actual problems rather than forcing negotiators to adhere to inflexible bureaucratic structures. Secondly, by combining speech acts and actions, reliability of the business partner can be judged through checking the fulfilment of commitment. Thirdly, traceability is aimed at eliminating distrust among business partners through transparent business processes that can be traced back in case of conflicts.

Our approach to negotiation support combines the advantages of the three main classes of existing negotiation systems, namely communication-oriented, document-oriented, and multi-attribute systems. The static content-based integration of communication data and documentation data is performed through a shared meta model. The dynamic integration specifies the negotiation protocol and traces obligations in a business contract as the result of a successful negotiation.

The conceptual and formal foundations of our approach have been implemented in the negotiation support system Negoisst which has been successfully validated in different application areas such as electronic negotiations between architects and trades in cooperative construction teams in the construction industry.

Referent: Prof. Dr. Matthias Jarke
Koreferenten: Prof. Dr. Gregory Kersten, Concordia University, Montreal, Canada, Prof. Dr. Stefan Klein, Westfälische Wilhelms-Universität Münster
Habilitationskolloquium: 13 February 2003
Central Services
• Faculty:
  
  Prof. Dr.-Ing. Hermann Ney

• Research Assistants:
  
  Dipl.-Inform. Willi Geffers

• Technical Staff:
  
  Marion Brandt-Röhrig
  Stefanie Höckelmann
  Frank Tammer
  Karl-Heinz Thevis

• Trainees:
  
  Ulrich Althaus

• Student Workers:
  
  Luan Ahmeti
  Sebastian Günther
  Askin Kirmizi
  Sebastian Krämer
  Dirk Meul
  Thorsten Ottmann
  Faruk Sari
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 fileservers, a database server, mailserver, and webserver. 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 Sun workstations and PCs based on Sun Solaris, Debian GNU/Linux, and Microsoft Windows. 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

- 12 Sun workstations were put out of operation and replaced by Debian/GNU Linux PCs with 2.6-2.8 GHz Intel Pentium IV CPU, 2 GB memory, 80 GB harddisk, and gigabit ethernet.

- The Sun Enterprie 3000 Server has been extended. An additional CPU board with 2 CPUs and 1 GB memory and a gigabit ethernet adaptor have been installed.

- The main router of the department has been upgraded. A second management module provides redundancy and a higher throughput and another fast ethernet module provides 48 additional network ports.

- The wireless network has been further extended. Currently it is available in all public areas of the department - e.g. lounge, library, lecture halls, student rooms, and computer labs - and at most chairs and research areas.

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 and operating systems.

\textsuperscript{1}Rechnerbetrieb Informatik
Also available are several 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, staff offices, and the user administration office are located in the basement of building E2. The labs are particularly intended for practical courses and student research projects.

On Linux and Solaris most GNU tools and many other free- and shareware tools are installed. For documentation purposes the typesetting system \LaTeX{} and publishers StarOffice/OpenOffice are available. Programming languages are particularly important and C, C++, Fortran, Pascal, and JAVA including extension libraries, source code management systems like SCCS and CVS 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, Prolog, and Modula 3 are installed.

### Server Equipment

- Currently the RBI operates 3 fileservers, a Sun Fire 280R, a Sun Enterprise 250, and a Sun Enterprise 3000, with a total harddisk capacity of almost 2 terabyte.

- Install servers for Solaris and Linux speed up and simplify the installation of the computers in the labs. The operating system are 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.
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 802.11b standard and operates at a maximum speed of 11 Mbit/s.

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:
during terms
mon 9 a.m. - 7 p.m.
tue - thu 9 a.m. - 9 p.m.
    fri 9 a.m. - 6 p.m.

between terms
mon - thu 9 a.m. - 7 p.m.
    fri 9 a.m. - 5 p.m.

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.
Computer Science Library
RWTH Aachen

Staff

- Head:
  Dipl.-Bibl. Renate Eschenbach

- Assistants:
  Kerstin Billen (until 31.07.03)
  Shaohui Li
  Andrea Reinhart (from 02.06.03)
  Michael Rose (from 02.01.03)
  Denitza Tinkova
  Ralitza Vantcheva
  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 32,000 books and conference proceedings, recorded in an online public access catalogue (OPAC)
- “Handapparate”: required readings for the courses, compiled by the professors for the students
- All diploma theses, recorded in a separate database
- Complete stock of the Springer series “Lecture Notes in Computer Science” and “Informatik-Fachberichte / Informatik aktuell”
- More than 300 journals
- Always up to date: Magazines C’t, iX, PC Professionell, Linux-Magazin, Die ZEIT, Wirtschaftswoche, . . .
- Technical reports from our 59 exchange partners from German and foreign universities
- Service for our staff to provide books and articles which we don’t have in our library, from the local university library or from international library suppliers
- Website with many informations about our stock and interesting computer science links
- 4 workstations and 60 comfortable work places, also for groups of students in separate rooms
- Scanner and copy machine
- Weekly guided tours through our library with informations about searching and finding literature
- Friendly and qualified consulting and assistance for the users

2 News

Staff

The representative of the library on the professor level changed: at the end of the year, Prof. Dr. P. Rossmanith took over the job from Prof. J. Hromkovic.

This year one of our student assistants (Kerstin Billen) left us after four years of working in our library. We welcomed Andrea Reinhart and Michael Rose new as members in our team.
New Services
A main focus of our work is the literature search training for seminar groups:

- literature search in local and international databases
- literature acquisition: from our stock (with an extensive guided tour of our library) and from external libraries
- instructions for writing seminar papers

We arranged also guided tours for new professors (4) and assistants (25) of our department.

A new link on our website shows all publishers from which we have free access to electronic fulltexts.
Further News

Staff of other libraries visited us to obtain information about the management and the services of our library. The visitors came from other libraries of RWTH Aachen and from the computer science library of ETH Zürich.

Our configuration was completed by a very functional new laser printer.

After the talks of our “Kolloquium”, the speaker and interested members of the audience gather for an informal discussion in the library and have a glass of wine.

Again we were very successful in obtaining good discounts from book suppliers, as an advantage to our central budget and those of the research groups of the department.

Stock of books and journals

From a former student we received a donation of nearly 500 books and more than 100 slipcases. Furthermore, two publishing houses gave us book presents, amounting to 500 € each. We were also very pleased to get 32 volumes of the “Brockhaus”-Encyclopaedia from one of our professors.

Again our stock could be extended by obtaining free books (duplicates) from other libraries: 20 books and 21 journal volumes.

We started to collect the annual reports of selected departments of computer science in German universities.

Our reference books for the current lectures and seminars (“Handapparate”), were rearranged completely: for the basic study period by semester, for the advanced study period ordered by research groups.

We started a subscription of the ACM Digital Library: free online access to all ACM journals, transactions, magazines, newsletters and proceedings.
Fachschaft I/1

Assmann, Andrea
Brauer, Richard
Brauner, Phillip
Deifuß Georg
Günther, Sebastian
Haselbach, Christian
Hattenbach, Jan
Hink, Gregor
Kampa, Adam
Kaleß, Benedikt
Kaufmann, Nils
Kesselheim, Stefan
Langejürgen, Jens
Lehnen, Patrick
Martini, Andrea
Matheisen, Axel
Mura, Benedikt
Pieczykolan, Aleksandra
Pimenides, Alexis
Runte, Sven
Schneider, Victor
Schwark, Christoph
Spillner, Robert
Skopalik, Alexander
Vorwerk, Volker
Wallrafen, Thomas
Wangerin, Iris
Weber, Regina

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Overview

Fachschaft Mathematik, Physik, Informatik  
Tel. (0241) 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 sell scripts and have a collection of old exercises and protocols of exams which can be viewed in our rooms. We are implementing a digital collection of old exercises and protocols which is currently useable, but still worked on. 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.
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 ErstsemesterInnen-AG publishes a magazine (*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 ones 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 bi-weekly

*Open-Source-AG*: The goal of this work group is to spread the idea of free software and to give students the possibility to install a good system on their computer at low cost. Beside GNU/Linux, the work group encourages and supports installing Free-/NetBSD and other systems, as well as lots of free software like \LaTeX, gimp and emacs.

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


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Joint Projects and Organizations
B-IT is a joint institute of RWTH Aachen and University of Bonn in cooperation with the Fraunhofer Institute Center Birlinghoven Castle and the FH Bonn-Rhein-Sieg in Sankt Augustin, aiming at the acceleration and internationalization of studies in applied computer science. Supported by the B-IT Foundation and complementary federal and state resources, B-IT offers highly selective English-language international Master Programmes in Media Informatics, Life Science Informatics, and Autonomous Systems. Moreover, B-IT offers summer and winter schools for qualified undergraduate computer science university students from RWTH Aachen, University of Bonn, and in the future other universities. The B-IT programmes are distinguished by their international orientation and a deep integration of research and teaching through close cooperation with the participating Fraunhofer Institutes of Applied IT (FIT), Autonomous Intelligent Systems (AIS), Media Communications (IMK), and Scientific Computing and Algorithms (SCAI). Curricula are fully integrated in the European ECTS system.
Founding Directors Cremers, Jarke, and Witt discuss with Landrat Frithjof Kühn and MWF representative Burkhart Reith at the first B-IT Business Forum

After funding for B-IT was approved in October 2002 and Professors Armin Cremers (Bonn), Matthias Jarke (RWTH Aachen), and Kurt-Ulrich Witt (FH Bonn-Rhein-Sieg) were appointed as Founding Directors, several milestones in the build-up of B-IT were achieved in 2003:

- In July, the founding treaty for the B-IT Universities Institute was signed by the Rectors of both universities in the presence of NRW Minister of Research, Hannelore Kraft. The fact that this is the first joint institute of two universities in NRW marks the legal complexity that had to be addressed to get this done.

- Joint study commissions were set up for both university master degrees to define curricula and actual teaching schedules. The commission on Media Informatics is chaired by Professor Otto Spaniol (RWTH Aachen), the commission on Life Science Informatics by Professor Rainer Manthey (University of Bonn).

- In spring and summer, the first batch of B-IT Master students was selected from a large number of applicants. Finally, almost seventy students from 15 countries were selected, more than half of them in the Media Informatics programme coordinated by RWTH Aachen. Several mutual visits with top international university organizations and ministries, most importantly in India and China, were conducted to improve even further the quality of future applicants.

- In October, the first B-IT-funded faculty positions were filled with Professors Jan Borchers (C4 Media Informatics, formerly Stanford and ETH Zurich) and Stefan Kowalewski (C4 Software for Embedded Systems, formerly Bosch Research); the selection processes for the other seven endowed faculty positions, three of them joint appointments with Fraunhofer Institutes, were also largely completed. As a consequence, an almost complete course program could be offered in B-IT from the beginning, including several innovative methods of teaching such as project lectures.
• An international Science and Business Advisory Council for B-IT was defined to ensure long-term alignment with employer needs and international standards, and Professor Gerhard Barth, former Management Board member of Dresdner Bank and former GI President, was elected as its Founding President.

The planning of the reconstruction work for the B-IT building, the beautiful former NRW Representation in Bonn, was also completed; for financial and administrative reasons, the actual reconstruction can take place only in 2004. Together with the complexity of cross-organizational studies and the special needs of international students, this caused some novel problems of administration and student assistance which were detected and overcome in a highly cooperative manner when the first full class of international master students arrived in the fall of 2003. Further major plans for 2004 include the completion of B-IT research and student labs in the participating organizations, and the further strengthening of the international cooperation networks.
The mission of the Fraunhofer FIT Institute of Applied Information Technology in Birlinghoven Castle near Bonn 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. With a research staff of about 100 (more than 30 of them have a doctoral degree), FIT pursues this mission in three major research areas:

- **FIT.CSCW** (Cooperation Systems, area leader: Prof. Wolfgang Prinz, Ph.D.)
  BSCW, our web based groupware platform has been significantly enhanced in 2003. Novel features include distributed task management, user-definable workflows and improved community support. Its web service interface makes BSCW well-suited as an open middleware for cooperation systems. This new service is also used in several student projects.

  Three EU-funded projects were completed successfully:
  In the ITCOLE project we developed Synergeia, a platform for collaborative learning on top of BSCW. After extensive field-tests in schools in several European countries, more than 1,000 teachers and a large number of students now use the Synergeia service that we provide over the Internet. The CYCLADES project prototyped a communityware for interdisciplinary e-paper archives. A study on Future Workspaces worked out a roadmap of research for collaborative design and engineering environments.

  Two books on knowledge management were published based on BMBF-funded
project. One discusses organizational learning and knowledge sharing in virtual organizations while the other looks at knowledge management concepts and systems deployed in various organizational settings from a user perspective.

- **FIT.LIFE** (Life Science Informatics, area leader: Prof. Dr. rer nat Thomas Berlage) investigates system analysis and solutions for diagnostic and interventional image processing / visualization in medicine, especially minimally invasive and robot-assisted surgery, in pharmaceutical research and biotechnology, but also in the compensation of individual health challenges. In 2003, first elements of an architecture to support image-based high-throughput experiments in drug discovery were evaluated in an industrial setting. The quality control workflow for a Proteomics project could be successfully supported in a visually interactive application. A second group of projects concerned image-based iterative navigation in minimally-invasive surgery. In this area, the prototype of an iterative navigation system using ultrasound as the intraoperative imaging modality was developed in the SUPPORT project supported by the German Ministry of Research. The prototype was evaluated with clinical partners in Kiel and Leipzig. Finally, an automatic checker (Imergo) to analyze barrier-free properties of large web sites was developed together with media providers for several public sites.

- **FIT.ICON** (Information in Context, area leader: Prof. Dr. Reinhard Oppermann) develops and evaluates context-adaptive information systems for eLearning, mobile work contexts, planning and decision support. The eLearning platform ALE supports learning on demand and case-based learning with strong personalization of learning goals. Within the EU-funded SEWASIE project (see research report Informatik V) a patent-pending method for semantically integrating text information with business reporting and planning data was developed. Other important research results include location-based services and models of user situational context. FIT.ICON’s decision support group provides the German federal government and parliament with microsimulation results by impact analyses for virtually all laws in the social sector, e.g. pension reforms, student loan reforms, and tax reforms. Major new projects in this area include the EU Network of Excellence ProLearn where FIT and i5 closely cooperate in e-learning research and development.

Across the domains of these three areas, FIT has set up two Competence Centers in its kernel methodological domains of expertise: The **Competence Center for User-Oriented Software Engineering**, part of the German Federal Virtual Software Engineering Research Center ViSEK, specializes in Requirements Engineering, Participative Design, Rapid Media-Assisted Prototyping, and Usability Engineering, whereas the **Competence Center for Internet Accessibility** develops adaptive compensatory solutions which help people with physical or mental disabilities access and exploit
the possibilities opened up by internet services for community-building, business, government and entertainment.
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 positive experiences from our first „Graduiertenkolleg“ „Informatics and Technology“ led to an intensive discussion concerning an initiative towards a successor. 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 an 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“ Software for mobile Communication Systems are as follows (for a full version of the proposal (in German language) please see http://www-i4.informatik.rwth-aachen.de/Kolleg/):

Information exchange over data networks is becoming ubiquitous. With UMTS we are entering a new era of mobile communication, networks are penetrating our homes, and the number and diversity of services provided over high-speed fixed networks is increasing dramatically. These new technologies and services enable a range of applications from various domains. In fact, in may be assumed that in the not-too-far future applications’ needs and requirements - as opposed to network technology - will largely drive research and development in communication systems. The application domains which may be expected to be the most influential ones include, but are certainly not limited to, electronic business, transport & tourism, new forms of work, as well as e-learning and e-government. Yet, these applications will have to function across all types of communication networks. In particular, wireless networks will need to provide access to those applications at ideally the same quality level as do fixed networks. Thus, research into both middleware architectures and protocols for mobile networks remains an essential research domain. Research undertaken
within the framework of the Graduate School 'Software for Communication Systems' will therefore concentrate on the three levels 'applications', 'middleware', and 'communication protocols'. New applications, based on well-defined sector requirements, will be designed, implemented, and tested. Middleware services, which de-couple applications from network technology, will be designed to adequately support the applications and to make best use of, and adapt to, the underlying networks' capabilities. Finally, in order to enable applications to work equally well over all types of networks, new communication protocols need to be designed and evaluated. These activities will primarily focus on mobile and ad-hoc networks. In addition, 'network management' will be a fourth focus. Here, aspects relevant to virtually all applications, such as, e.g., security mechanisms and quality of service aspects, will be addressed. Obviously, these individual domains are closely interlinked.

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' (see above).

2 Members of the „Graduiertenkolleg“

We are more than happy that all 14 positions have been taken by highly qualified students. The current (April 2004) grant holders include:

- Dr. Harald Albrecht, Chair Prozesstechnik, Prof. Dr. Eppe
- Dipl.-Phys. Vahza Amiranashvili, Chair Informatik IV Lab, Prof. Dr. Lakemeyer
- Dipl.-Ing. Lars Berlemann, Chair Comnets, Prof. Dr. Walke
- Dipl.-Inform. Zinaida Benenson, Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Inform. Imed Bouazizi, Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Inform. Dominik Schmitz, Chair Informatik V, Prof. Dr. Jarke
- Dipl.-Inform. Ulrich Norbisrath, Chair Informatik III, Prof. Dr. Nagl
- Janne Riihijaervi MSc, Chair Mobilfunknetze, Prof. Dr. Mhnen
- Dipl.-Inform. Ulrich Norbisrath, Chair Informatik III, Prof. Dr. Nagl
- Dipl.-Inform. Nico Wallmeier, Chair Informatik VII, Prof. Dr. Thomas
- Jianhua Wu MSc, 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, Hungary, and Tunisia. Four students left the ‘Graduiertenkolleg’ in the reporting period:

• Dipl.-Inform. Valerie Bures (Chair Informatik V), because of motherhood.
• Selin K. Cerav Erbas MSc (Stochastik Lab) is now with the Universite de Catholique de Louvain, Institut d’Administration et de Gestion/POMS.
• Dr. Markus Fidler (Chair Informatik IV) successfully finished his studies.
• Dipl.-Inform. Yu Jiao (Chair Informatik III returned home to China with her husband.
Organization

IMPROVE (Information Technology Support For Collaborative and Distributed Design Processes in Chemical Engineering) is a long-term research project (Collaborative Research Center, abbr. CRC) funded by the Deutsche Forschungsgemeinschaft (DFG) since August 1997. The project is reviewed every 3 years and will last at most 12 years in total. Up to now, we have successfully finished three review processes in 1997, 2000, and 2003.

The CRC is carried out by several institutes and departments of RWTH Aachen. The partners come from various domains, namely chemical engineering, plastic engineering, industrial engineering and ergonomics, software engineering, information systems, and communication systems.

Here is a list of all partners involved in the CRC IMPROVE:

- Department of Process Systems Engineering (Prof. Dr. W. Marquardt)
- Institute of Industrial Engineering and Ergonomics (Prof. Dr. H. Luczak)
- Institute of Plastics Processing (Prof. Dr. W. Michaeli, Prof. Dr. E. Haberstroh)
- Department of Computer Science III, Software Engineering (Prof. Dr. M. Nagl)
Goals

The goal of IMPROVE consists in improving design processes in chemical and plastic engineering. In particular, IMPROVE focuses on conceptual design and basic engineering, where the fundamental decisions concerning the design or redesign of a chemical plant are taken. Design processes are analyzed in collaboration with industrial partners.

The design of a plant for producing Polyamide6 is used as a reference scenario within the IMPROVE project. Based on this analysis, novel concepts, models, and tools for supporting design processes in chemical engineering are developed. The core integration approach is based on using existing tools by enriching their functionality. These results are evaluated in cooperation with industry, implying an iterative research approach.

Activities

In April 2003, the periodic review by the Deutsche Forschungsgemeinschaft took place (this review is carried out for a period of three years). The review included presentations of the work having been performed in the subprojects as well as a major demonstration of a research prototype to which all partners provided their respective contributions in terms of developed tools and supporting infrastructure. This milestone was passed with great success. Based on the positive judgement by the reviewers, the Deutsche Forschungsgemeinschaft decided to continue funding for another period of three years.

Some restructuring was performed in order to address new areas of research. A new sub-project was started by the Institute of Industrial Engineering and Ergonomics to study the modeling and simulation of work processes. In addition, a joint project — also funded by the Deutsche Forschungsgemeinschaft — was launched by the Virtual Reality Center and the Institute of Plastic Engineering to study the development and application of virtual reality in the context of engineering design processes. This project is associated to and therefore closely cooperates with the CRC IMPROVE.

Compared to the previous project review in 2000, IMPROVE demonstrated that significant progress was achieved in some key areas of research. One of these was concerned with inter-organizational and inter-disciplinary cooperation in the chemical engineering design process. The reference process — conceptual design and basic engineering of a plant for Polyamide6 — was extended accordingly to include the cooperation between chemical engineering and plastic engineering (the latter of which is concerned with the compounding step of the
A novel delegation-based approach was developed to manage the inter-organizational design process. On the design level, an overall simulation of the chemical plant was performed which in particular included the simulation of the extruder. In this way, it was possible to support an integrated simulation and evaluation of the chemical plant design, covering both chemical and plastic engineering.

A central goal of IMPROVE consists in the design of an integrated product and process model for chemical engineering. A step towards this goal was achieved by the CLIP model, which is based on system theory. CLIP provides a multi-stage metamodeling hierarchy. It mainly focuses on a clean modeling architecture defining partial models and their relationships and deliberately refrains from defining detailed partial models.

Another focus was set on the synergetic coupling of new tools for supporting chemical engineering design processes. These tools, which have been developed in the context of the IMPROVE project, provide direct, fine-grained process support, support for the management of design processes, inter-document consistency control, and multi-medial communication. The synergetic coupling was demonstrated by a prototype which was presented at the project review in April 2003 and clearly showed the close cooperation among the partners of the IMPROVE project.

In September 2001 an industrial working group was funded. In this way, contacts with industry were built up and continued in order to prepare technology transfer into industrial practice. The meeting scheduled for this year was postponed to February 2004. It will take place under the umbrella of an industrial workshop which was held in November 2000 for the first time.

**Contact Information**

Further information on IMPROVE may be retrieved from the web pages:
You may also contact the speakers of IMPROVE:

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Forum Informatik
at RWTH Aachen University

Organisation

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(Coordinator of the Interdisciplinary Fora)

Industrial partner

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 second phase (2002-2004) in 2002. 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.

- **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 will be reviewed every 3 years. It is carried out by several institutes and departments of Aachen University. The partners come from various domains, including chemical engineering, plastic engineering, software engineering, information systems, and communication systems. In the spring 2003 a review took place, carried out by about 10 peers coming to Aachen. It was successfully passed prolonging funding until mid 2006.

- **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 coordinated and combined in one work process. This leads to an improved physical understanding 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. Therefore, a new software tool for computational fluid dynamics has been developed and the commercial tools SEPRAN and FLUENT have been extended using automatic differentiation techniques in order to provide gradient information for parameter estimation and sensitivity analysis of the models.

- The “DFG Graduate College”, “Software for mobile Communication Systems” enables interdisciplinary research through grants to PhD students. 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 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’.

- A Working Group “Parallelism” focuses on the use of high-performance computers for scientific simulations. Numerical simulation has become the third cornerstone of science next to mathematical modelling and experimentation. In order to enhance competence in the area of high-performance computing and its use in the region, the Institute of Scientific Computing is collaborating with the Central Institute for Applied Mathematics at the Research Center in Jülich, the Institute for Computer Science at the University of Cologne (Prof. Speckenmeyer), and the Fraunhofer-Institute for Algorithms and Scientific Computing in St. Augustin (Prof. Trottenberg).

- The “Bonn-Aachen International Center for Information Technology (B-IT)”, an endowed-funder joint institute of Bonn University with RWTH Aachen, aims at the internationalization and acceleration of research-integrated studies in Applied Computer Science. In cooperation with the Fraunhofer research institutes at Birlinghoven Castle near Bonn, the B-IT Universities Institute currently offers English-language Master degrees in Media Informatics and Life Science Informatics, as well as summer
and winter schools who provide top-qualified undergraduate computer science students with a means to accelerate their studies at a highly demanding level. Highlights in 2003 include the signing of the B-IT Universities Institute founding agreement, the filling of the chairs endowed by the B-IT Foundation at RWTH Aachen, and the intake of an excellent group of master students from more than a dozen countries worldwide.

- The project **URMEL.** The aim of the project URMEL (Ubiquitous RWTH for Mobile E-Learning) is 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. In addition a set of basic services are being developed which facilitate authentication, secure communication and location-aware services. The overall objective of these activities is to enhance conventional teaching at RWTH Aachen University and to make it more effective.

- The project **“MoPS”**-Mobile Professors and Students. MoPS 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 infrastructure. The MoPS-network is based on the IEEE 802.11b/g standard, offers a bandwidth of up to 54 Mbps and currently comprises of more than 150 access points. Many central areas of RWTH are already covered by MoPS and the network is still expanding. Furthermore, partnerships with local businesses have been established to extend WLAN-coverage to areas where the university is not present.

- The project **“RoboCup”** is an international initiative to foster Artificial Intelligence and Robotics research. Teams of mobile robots or software agents play soccer against each other. In different leagues (hardware and software) many scientific areas are covered. The Chair of Technical Computer Science and the Knowledge-based Systems Group, Computer Science V, participate with their team “allemaniACs” in the Middle Size League where teams of four fully autonomous robots compete.

- The **Virtual Reality Center Aachen (VRCA)** coordinates and promotes the VR research and teaching activities at Aachen University. Right now, 34 institutes and 6 companies are organized within VRCA, and 26 research activities are being carried out in an interdisciplinary cooperation between RWTH institutes, primarily in mechanical engineering and medicine.

- **“ARVIKA”**-Augmented Reality for Development, Production and Service. The project ARVIKA aims to research and to realise Augmented-Reality-Technologies (AR) which will support development, production and servicing with relation to complex technical products in a user-oriented and application driven manner. Through the visual superimposition of real objects on computer generated virtual objects, Augmented Reality technology makes it possible, to act appropriately in real, in the sense of this extended reality, working situations.
The project “Application of Virtual Reality for the Analysis of Plastics Compounding Processes Considering the Chemical and Technical Context”. Simulations are of great importance in order to understand the flow in an extruder. To visualize the flow with virtual reality techniques is a new challenge. Virtual Environments promise an intuitive configuration of extruders and change of simulation parameters in addition to a stereoscopic way of viewing simulation results and their behaviour in time. In addition, new visualisations of non-newtonian fluids and new insights in an extruder will be developed.
Competence Network REGINA

Under the banner “Cooperation makes power”, REGINA has been engaged successfully for more than ten years in strengthening the region’s IT industry. REGINA is a combination of more than 90 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 IT 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
- 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).
Board:

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Prof. Dr.-Ing. M. Nagl, RWTH (chairman substitute)
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Activities in 2003

Meet you at REGINA’s!

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: Is China the land of unlimited opportunities, or unlimited problems? Is increased staff flexibility a trouble-shooting or strategic tool? What are the latest trends in the IT market? What can be done to assure quality in personnel recruitment? How to transfer technological topics to inexperienced users?

Meet Eastern Europe!

How will EU enlargement affect the IT sector in Germany? And, even more important, REGINA members ask, what affect this will have on IT companies of the Aachen region? Will members be strengthened by taking a positive approach to these new markets? What are the risks? These are just a few of the questions tackled in detail at a management get-together and round-table discussion in 2003.
Looking for partners?

Great interest was shown by IT companies in the region when REGINA organized the company presentation event INFOmatica. 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. The event included a presentation of the Flemish IT alliance and its potential as a new opportunity for cross-border collaboration.

Meeting and keeping high-quality talents

Research institutions such as RWTH Aachen University, Aachen University of Applied Sciences, and the Research Center Jülich, 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 the 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 90 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.
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
95-13 * M. Staudt / M. Jarke: Incremental Maintenance of Externally Materialized Views
95-14 * P. Peters / P. Scezurko / M. Jeusfeld: Business Process Oriented Information Management: Conceptual Models at Work
95-15 * S. Rams / M. Jarke: Proceedings of the Fifth Annual Workshop on Information Technologies & Systems
95-16 * W. Hans / St. Winkler / F. Sáenz: Distributed Execution in Functional Logic Programming
96-1 * Jahresbericht 1995
96-2 M. Hanus / Chr. Prehofer: Higher-Order Narrowing with Definitional Trees
96-3 * W. Scheufele / G. Moerkotte: Optimal Ordering of Selections and Joins in Acyclic Queries with Expensive Predicates
96-4 K. Pohl: PRO-ART: Enabling Requirements Pre-Traceability
96-5 K. Pohl: Requirements Engineering: An Overview
96-6 * M. Jarke / W. Marquardt: Design and Evaluation of Computer-Aided Process Modelling Tools
96-7 O. Chitil: The λ-Semantics: A Comprehensive Semantics for Functional Programs
96-8 * S. Sripada: On Entropy and the Limitations of the Second Law of Thermodynamics
96-9 M. Hanus (Ed.): Proceedings of the Poster Session of ALP’96 — Fifth International Conference on Algebraic and Logic Programming
96-10 R. Conradi / B. Westfechtel: Version Models for Software Configuration Management
96-11 * C. Weise / D. Lenzkes: A Fast Decision Algorithm for Timed Refinement


96-15 * H. Schimpe / M. Staudt: VAREX: An Environment for Validating and Refining Rule Bases

96-16 * M. Jarke / M. Gebhardt, S. Jacobs, H. Nissen: Conflict Analysis Across Heterogeneous Viewpoints: Formalization and Visualization

96-17 M. Jeusfeld / T. X. Bui: Decision Support Components on the Internet

96-18 M. Jeusfeld / M. Papazoglou: Information Brokering: Design, Search and Transformation

96-19 * P. Peters / M. Jarke: Simulating the impact of information flows in networked organizations

96-20 M. Jarke / P. Peters / M. Jeusfeld: Model-driven planning and design of cooperative information systems


96-22 * S. Jacobs / M. Gebhardt, S. Kethers, W. Rzasa: Filling HTML forms simultaneously: CoWeb architecture and functionality

96-23 * M. Gebhardt / S. Jacobs: Conflict Management in Design

97-01 Jahresbericht 1996

97-02 J. Faassen: Using full parallel Boltzmann Machines for Optimization

97-03 A. Winter / A. Schürr: Modules and Updatable Graph Views for PROgrammed Graph REwriting Systems

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

97-07 P. Höfstedt: Taskparallele Skelette für irregulär strukturierte Probleme in deklarativen Sprachen
D. Blostein / A. Schürr: Computing with Graphs and Graph Rewriting


M. Nicola / M. Jarke: Integrating Replication and Communication in Performance Models of Distributed Databases

M. Mohnen: Optimising the Memory Management of Higher-Order Functional Programs

R. Baumann: Client/Server Distribution in a Structure-Oriented Database Management System

G. H. Botorog: High-Level Parallel Programming and the Efficient Implementation of Numerical Algorithms

S. Gruner / M. Nagel / A. Schürr: Fine-grained and Structure-oriented Integration Tools are Needed for Product Development Processes

S. Gruner: Einige Anmerkungen zur graphgrammatischen Spezifikation von Integrationswerkzeugen nach Westfechtel, Janning, Lefering und Schürr

O. Kubitz: Mobile Robots in Dynamic Environments

M. Leucker / St. Tobies: Truth — A Verification Platform for Distributed Systems


H. Aust: Sprachverstehen und Dialogmodellierung in natürlichsprachlichen Informationssystemen

Th. Lehmann: Geometrische Ausrichtung medizinischer Bilder am Beispiel intraoraler Radiographien

M. Nicola / M. Jarke: Performance Modeling of Distributed and Replicated Databases

A. Schleicher / B. Westfechtel / D. Jäger: Modeling Dynamic Software Processes in UML


K. Indermark: Semantik rekursiver Funktionsdefinitionen mit Striktheitsinformation

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F. Huch: Verifcation of Erlang Programs using Abstract Interpretation and Model Checking — Extended Version

R. Gallersdörfer / M. Jarke / M. Nicola: The ADR Replication Manager
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