Annual Report 2004

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 2004, either in research, teaching, administration, or social life.

There are a lot of good news to report about. Especially, at the end of 2004 there was no vacant professorship in the Department. The Computer Science Department has got a remarkable size of 19 professors, all of them with tenure. They all have to supervise about 2800 students. So, there is still a heavy teaching load.

In addition, there are also colleagues in the Electrical Engineering and Information Technology Department and in other departments, mainly in Engineering disciplines, where Computer Science is applied. We actively cooperate with all of them (see section on Forum Informatik). Furthermore, there are strong relations to the local IT industry (see section on REGINA).

We now give a list of topics/highlights which had specific influence on the Department in 2004:

- Prof. Joost-Pieter Katoen, Computer Science Chair II “Programming Languages and Program Analysis”, Prof. Uwe Naumann, Group “Software and Tools for Computational Engineering”, and Prof. Berthold Vöcking, Computer Science Chair I “Algorithms and Complexity” are new at RWTH Aachen University. These persons are heartly welcome. They are expected to contribute to the further development of the Department. Furthermore, we also welcome Prof. Thomas Rose, being appointed in cooperation with Fraunhofer Institute of Applied Information Technology at St. Augustin near Bonn.

- Two young scientists of Aachen got professorships at other universities: PD M. Schoop joined the University of Hohenheim as Full Professor of Business Informatics. She also received Full Professor offers from the University of Koblenz and the University of Vienna and was recipient of the Friedrich Wilhelm Habilitation Prize at RWTH Aachen University. PD B. Westfechtel joined the University of Bayreuth as Full Professor. He now holds the Chair of Applied Computer Science (Software Engineering).

- Prof. L. Kobbelt, Computer Science VIII “Computer Graphic and Multimedia” got the “Outstanding Technical Achievement Award” of the Eurographics Association, which was given the first time this year. The Eurographics Association is an international community of scientists and companies dealing with Computer Graphics, Visualization, Virtual Reality, and Man-Machine Interfaces. It is one of the leading independent organizations in this specific area. The prize is given to scientists who contribute with results of specific importance for the further development of the above research areas.

- Prof. Jarke was re-elected as DFG Reviewer for Computer Science for the period 2004-2007.

- Dr. S. Seibert and Dr. W. Unger received their Habilitations in 2004.

- SFB 427 “Media and Cultural Communication” completed a successful third review and will continue with increased funding for the last four years 2005-2008. From RWTH Aachen, Informatik V is involved.

- The international Master Programs Media Informatics and Life Science Informatics within the Bonn-Aachen International Center for Information Technology (B-IT) were the first study programs at RWTH Aachen and University of Bonn to undergo a successful accreditation review in November 2004.

- A group of students from the Laboratory of Dependable Distributed Systems of Prof. Felix Freiling (former name Gaertner) finished second in the UCSB Capture The Flag Contest, a distributed, wide-area security exercise, whose goal is to test the security skills of students from both the attack and defense viewpoint.

- In September 2004 the Department was awarded a grant by the European Commission under the newly established Erasmus Mundus Program. The main purpose of Erasmus Mundus is to foster joint Master programs between European universities. In our case, the partners are the University of Edinburgh and the University of Trento. Together we are offering a European Master in Informatics, with specializations in Embedded Systems, Netcentric Computing and Life Science. Aachen participates in the framework of our already established international Master programs Software Systems Engineering and Media Informatics. Participating students study at two of the three universities and receive a double degree from both institutions at the end of their two-year program. In the first year, ten students and three post-graduate scholars are supported by Erasmus Mundus. This number is expected to grow to over 30 per year in the future.

- Persons of the Department have been members of numerous program committees, got best paper awards, have edited a number of books and special issues of journals, and gave a lot of invited talks. You will find the corresponding information in the sections of the research groups.

In total, the members of the Department have considerably increased the amount of money they get from external funding, namely German Research Foundation (DFG), European
Union, Federal and State Ministers for Research, and industrial companies. About half of the Department's total budget comes from these sources.

The members of the Department were active in organizing scientific workshops and conferences which are described in the sections of the organizing institutions. Here is a list of these events:

- Prof. Borchers co-organized the 5th HCI Patterns Workshop at CHI Conference.

- PD Dr. B¨ucker and Prof. Naumann co-organized the 5th International Conference on Automatic Differentiation in Chicago.

- Prof. Giesl organized the Federated Conference on Rewriting, Deduction, and Programming at Aachen, consisting of the 15th International Conference on Rewriting Techniques & Applications, and 6 further workshops.

- Prof. Hromkovic, now Swiss Federal Institute of Technology, and Prof. Nagl from RWTH organized the 30th International Workshop on Graphtheoretic Concepts in Computer Science at the German Physics Center, Bad Honnef.

- Prof. Lichter organized the Workshop on Use of Feature Modelling in Product Development at Marburg and the D.A.CH Workshop at Aachen.

- Prof. Schroeder organized the 2nd RWTH eLearning Day.

- Prof. Vöcking, together with M. Bläser, P. Krysta, and R. Reischuk, organized a GI research seminar on Game Theoretic Analysis of the Internet at Schloss Dagstuhl.

On behalf of the department I would like to thank Mrs. van Betteraey and Prof. Kobbelt for the engagement they showed in editing this report. They have taken over this duty several times in the last years.

Aachen, April 2005

Manfred Nagl

Speaker of the Computer Science Department
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Faculty Life
Tag der Informatik - Day of Computer Science
2004

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. This event gives the opportunity to gather information about the computer science department and to establish interdisciplinary contacts and is accompanied by poster, software and hardware exhibitions of a multitude of computer science chairs as well as industrial and research partners. It took place on December, 3rd and was organized by the Chair of Computer Science IX (Data Management and Data Exploration Group).

The welcome address was given by the Dean, Prof. Dr. Wolfgang Thomas, and by the spokesman of the computer science department, Prof. Dr. Manfred Nagl. In the following the new faculty members of the department gave introductory talks to present their respective fields of research, namely Prof. Dr. Berthold Vöcking (Lehrstuhl Informatik I, Algorithmen und Komplexität) and Prof. Dr. Uwe Naumann (Lehrgebiet Software & Tools for Computational Engineering).

The first of the following two technical sessions was themed “Interdisciplinary Research Projects” and was conducted by representatives of industry partners as well as RWTH chairs from outside the CS department. In detail, these were Dr. Pierre-Yves Saintoyant from Microsoft EMIC (“The European Microsoft Innovation Center: Why a New Lab in Aachen?”), Prof. Dr. Heribert Nacken (Lehrgebiet Ingenieurhydrologie, “Regelbasierte Modellierung zeitvarianter Naturprozesse: Was Bauingenieure von Informatikern erwarten”), Prof. Marek Behr, Ph.D. (Lehrstuhl für Modellbildung und rechnergestützte Analyse technischer Systeme, “Computational Biomedical Engineering: Flow Simulation and Model Development”) and Prof. Dr. Martin Zenke (Lehrstuhl für Zellbiologie, “Cells, DNA Chips and Functional Genomics: Employing Bioinformatics for Understanding Biology”).

The second session was entitled “Research in the Computer Science Department” and contained presentations of research activities inside the CS department held by research assistants from the respective chairs. Namely these included Dietmar Berwanger (Lehrgebiet Mathematische Grundlagen der Informatik, “Strategien für unendliche interaktive Prozesse”), Thomas von der Maßen (Lehrgebiet Informatik III, “Variabilitätsmodellierung in Produktlinien-Anforderungen”), Tico Ballagas (Lehrstuhl Informatik X, “Interacting with Large Public Displays using Camera Phones”) and Martin Mink (Lehrgebiet Informatik IV, “Das Hacker-Praktikum: IT-Sicherheit zwischen Lehre und Praxis”).

Finally, the talks were completed by an invited talk of Prof. Dr. E. Rahm (Universität Leipzig) entitled “Fusion verteilter Daten – Forschung, Anwendung und Perspektiven”.

After the scientific part of the day, this year’s student grants, which were sponsored by AMB Generali and SD&M, were awarded to the selected students Marcel Ochel and Marco Lange. Following this, the highly entertaining final rounds of the programming contest Shock Wave Blaster were played out. The prices were sponsored by Sun Microsystems and were
handed over by the company’s representative, Dr. Wilfried Stütten, to the winning team “FinalSandra” consisting of Andre Hegerath and Christian Terboven.

The afternoon programme was closed with a graduation ceremony including a laudation held by Prof. em. Dr. Walter Oberschelp, some historical thoughts by Prof. Dr. Otto Spaniol and the awarding of the diplomas to the recent graduates conducted by Prof. Dr. Leif Kobbelt. Accompanying music was delivered by the strings quartet “Archos Quartett”.

Following the official part of the day was the traditional evening banquet, provided with live background music by the “Boris Glavic Jazz Band”, which attracted roughly five hundred people including the graduates and their families, many current students and alumni, most of the CS department staff and many visitors from industry and academia. This informal get-together concluded a highly successful “Tag der Informatik” which is also indebted to the generous financial sponsorship of a variety of companies.
Graduation ceremony

Organization team

More information and pictures about the event can be found online at

http://www-i9.informatik.rwth-aachen.de/tdi04
Sommerfest der Informatik – Computer Science Summer Party 2004

Each year, in the mid of the summer term, the Computer Science Department organises a summer party for the ceremonial presentation of diploma certificates to the graduates of the first half of the year. The location of this event is Gut Melaten, an old estate owned by RWTH Aachen. The summer party 2004 took place on Wednesday, June 9th, 2004.

Gut Melaten.

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

Ceremonial presentation of diploma certificates.

After the official graduation celebration, the informal part of the summer party was started with a small 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.
The financing of the event was possible by the support of some sponsors, namely Ericsson, sd&m, and Kirchhof Software. Some of them had set out information stands to give interested students the chance to talk about job opportunities. With the help of this sponsoring, the summer party had gone on till late evening.
A Colloquium for Prof. M. Nagl

To the honor of Prof. Manfred Nagl who celebrated his 60th birthday, a colloquium was held on May 28th by the computer science department of RWTH Aachen University. The colloquium enjoyed lively participation. In addition to computer scientists from Aachen, many former members of Prof. Nagl’s team were present. During his long and productive academic career, Prof. Nagl “produced” quite a lot of researchers, including eight professors at universities, three at polytechnics, and more than 30 Ph.D.s in total.

The colloquium was opened by Prof. A. Krieg, the Dean of the Faculty of Mathematics, Computer Science, and Natural Sciences, who warmly welcomed all participants and emphasized the merits of Prof. Nagl concerning the development of computer science in Aachen. Subsequently, Prof. W. Thomas held a short speech on behalf of the computer science department, including several humoristic stories which he experienced during his long-term cooperation in the computer science faculty. It should be noted here that Prof. Nagl has been serving as the speaker of the computer science department for several years, and has managed to contribute significantly to the development of computer science (not only) during this period. Following a short coffee break, two main lectures were given, the first of which was given by Prof. G. Engels, University of Paderborn. In his lecture, Prof. Engels showed the influences of Prof. Nagl’s scientific work on the development of software engineering, based on formal methods (graph grammars), from the early beginnings up to the present. One of the major contributions was the IPSEN project on integrated software engineering environments. Prof. Engels’s talk was intermixed with a lot of anecdotes providing a “human perspective” - and a few early pictures which were particularly enjoyed by former members of Prof. Nagl’s team.
The first main speaker, Prof. G. Engels (center), and Prof. W. Schäfer, both IPSEN “pioneers” and now with University of Paderborn.

The second speaker, Prof. W. Marquardt, complemented the programme by reporting on one of the major successes of the computer science department - the Collaborative Research Center IMPROVE funded by the Deutsche Forschungsgemeinschaft. IMPROVE is concerned with the development of novel methods, tools, and architectures for supporting chemical engineering design. Based on long-term cooperation with mechanical engineers, Prof. Nagl managed to launch the IMPROVE project in 1997 in the application domain of chemical engineering. Since then, he has been serving as a speaker of the IMPROVE project - being well backed up by Prof. Marquardt, the Chair of Process Systems Engineering and second speaker. After that, it was felt that the “scientific part” of the colloquium was done. The program was enriched by a small performance which was arranged by Prof. O. Spaniol as a surprise. Two young cycling artists demonstrated their capabilities in the forum of the computer science building (surmounting technical difficulties caused by the uneven and slippery floor). Finally, a dinner was held at Castle Vaalsbroek - a well-known facility for both private and official events. All participants enjoyed the beautiful castle as well as the excellent food. And there was plenty of time for talking to each other.

B. Westfechtel

All guests of the dinner at Castle Vaalsbroek
1 New Professors

In 2004, three new colleagues joint our department: Joost-Pieter Katoen, Uwe Naumann, Thomas Rose and Berthold Vöcking.

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

1.1 Joost-Pieter Katoen

Joost-Pieter Katoen joined the Computer Science Department of the RWTH Aachen in December 2004. He is a full professor in Programming Languages and Software Validation and will succeed Prof. Dr. K. Indermark as chair of “Informatik II” from October 2005 on.

Being Dutch, it is not strange that most of my professional career so far took place in the Netherlands. I studied Computer Science at the University of Twente, The Netherlands and carried out my master's thesis at Philips Research in Eindhoven while working on parallel object-oriented programming languages (POOL). During my two-year postgraduate stay at the Technical University of Eindhoven I became “infected” by the calculational art of programming as advocated by Dijkstra et al. Under the supervision of Martin Rem, I worked on the systematic development of fine-grained parallel programs by means of correctness preserving transformations. These programs are mainly suited to act as skeletons for asynchronous hardware circuits. After a couple of years as researcher at Philips Research, I decided to go back to academia in Twente, where I (officially) worked on mobile communications systems while (in secret) finishing a PhD on true concurrency semantics of process algebras. In 1997, I moved as postdoctoral researcher to the group of Herzog at the
University of Erlangen-Nuremberg. Finally, in 1999 I obtained an associate professorship in the chair of Ed Brinksma at the University of Twente, The Netherlands. This was my last resort before coming to Aachen.

At Philips I worked on plug-and-play networks for in-house communication, in particular, communication protocol design and performance analysis. Although we were able to come up with new protocols and indications about their performance, it was frustrating that neither the correctness nor a formal proof of their efficiency was considered. This feeling became even stronger while being involved in Twente in some international projects that were aimed at the development of UMTS, the wireless system of the future (in 1993, at least). I therefore decided to work on formal specification languages, and try to extend these such that correctness and efficiency could be established hand-in-hand. Coming from the “Dutch school”, it is probably not a surprise that these formal languages turned out to be process algebras. While working in this field, I became more and more fascinated by it, and, as a result, considered not only specification languages but also extensions to temporal logics and verification algorithms to allow for the assessment of correctness guarantees as well as performance guarantees. In the meanwhile, several prototypical software tools have been developed that support these aspects, and are used to conduct industrial case studies. This challenging research will be continued in Aachen and several courses will be developed to learn students more about it! (I hope they get as fascinated by this field as I am.....)

To be at the prestigious and well-known Computer Science Department at the RWTH Aachen is a real honour for me. This applies even more for being “the successor of Indermark”. My first experiences so far, however, make me feel at home at the RWTH. In particular, the friendly atmosphere in the department and the great welcome by my colleagues eased my start considerably. Thanks for that.

1.2 Uwe Naumann

Prof. Dr. rer. nat. Uwe Naumann was born in Rodewisich on June, 24 1969. After having spent his childhood in Chemnitz he went to school in Chemnitz and Dubna, Russia followed by 2 years of service in the military. In 1990 he started studying mathematics at the Technical University Dresden until 1996 interrupted by a one-year visit at the University of York in the UK. After successfully completing his undergraduate studies with a diploma thesis on “Verified Global Optimization on Multiprocessor Systems” he joined Prof. Andreas Griewank’s research group at the Institute for Scientific Computing at TU Dresden in May 1996. In November 1998 he presented a Ph.D. thesis titled “Efficient Calculation of Jacobian Matrices by Optimized Application of the Chain Rule to Computational Graphs” and defended it successfully in February 1999. In January 1999 he went for one year as a post-doc to INRIA Sophia-Antipolis, France, followed by two years as a Senior Lecturer in Computer Science at the University of Hertfordshire, UK. From January 2002 until June 2004 he worked as an Assistant Scientist at Argonne National Laboratory’s Mathematics and Computer Science Division near Chicago, USA. Prof. Naumann has been at RWTH Aachen University as the

![Image]

Prof. Naumann’s research interests are in the field of Automatic Differentiation of numerical programs by source transformation. This interdisciplinary area aims to combine methods from modern applied mathematics and computer science for application to numerical models of real-world problems in science and engineering. Aspects of numerical analysis are automated using compiler technology and modern software engineering. Various combinatorial, graph-theoretical, and data-flow problems need to be solved. The above problems and approaches to their solution are the basis of courses offered by Prof. Naumann’s research group to students after the Vordiplom. The backbone consists of two lectures / tutorials: “Adjoints by Source Transformation (WS)” and “Combinatorial Problems in Scientific Computing” (SS).

Prof. Naumann is a co-editor of the proceedings of two international conferences dedicated to Automatic Differentiation. Moreover he has been co-authoring publications in scientific journals and on various conferences. Prof. Naumann is a referee for ACM and SIAM publications. Last but not least he is actively involved in the organization of conferences and minisymposia with focus on his research area.

1.3 Thomas Rose

Thomas Rose joined the computer Science Department of RWTH Aachen in October 2004. He is Associate Professor for Media Informatics.

He studied Computer Science at the University of Dortmund and received his Diploma in 1985. He started his professional carrier as a software engineer with a company in the then newly established Technology Centre in Dortmund. After one year of implementing Macintosh applications, he decided to re-join university. Yet, he kept infected with the Mac virus until today. In 1986 we started as research assistant in the research group of Prof.
Matthias Jarke at the Johann Wolfgang Goethe University in Frankfurt and moved later to the University of Passau. At the University of Passau, he was one of the co-founders of the ConceptBase system. His research interests have been data-intensive applications and conceptual modelling of software engineering processes. He received a Doctoral degree in Computer Science from the University of Passau in 1991. The thesis topic was “Decision-oriented Configuration Management” (Informatik Fachberichte 305, Springer-Verlag).

From 1990 through 1993 he was as a Research Associate with the Department of Computer Science in Prof. John Mylopoulos knowledge management group at the University of Toronto. His research interests included software repositories and the development of intelligent information systems. After 3 years in one of the most fascinating cities he returned to Germany in October 1993. He moved to the Wild South of Germany, which was a major cultural change for someone, who was born in Dortmund and has spent his entire life until graduation in the Ruhrgebiet. Thomas Rose has been a Senior Researcher with the Research Institute for Applied Knowledge Processing (FAW) in Ulm for nine years. He was head of the department of business processes and telematics. Particular emphasis has been put on applications of information and communication management technologies for process improvement and service enabling. Specific attention has been devoted to business partnerships and models for service implementation. At FAW, Thomas Rose has been managing several projects for industrial sponsors and publicly funded research projects. In addition to his research activities at FAW, he was a member of the Enquete Commission on Multimedia and Data Highways of the parliament of the State of Baden-Württemberg and a technical consultant to Minister Dr. Vetter for a technical visit to the United States.

Thomas Rose has moved to Fraunhofer FIT in 2002 and is head of the research group on business process management. His research interests include process management and media processes.

1.4 Berthold Vöcking

In October 2004, I joined the computer science faculty at RWTH Aachen University as the new head of the algorithms and complexity group. Thomas Franke, Simon Fischer, and Heiko Röglin accompanied me as PhD students from Dortmund University. Furthermore,
Alantha Newman joined our group as a postdoc from the Massachusetts Institute of Technology (MIT). Some other people from Dortmund, including a DFG research group headed by Matthias Westermann will join our group soon. Together with Dirk Bongartz and Walter Unger, we form the current research staff of the algorithms and complexity group. Our group is completed by the secretary Helga Jussen and the system administrator Viktor Keil.

My professional career started with an apprenticeship in industrial economics. I liked this job quite a lot, but I thought that it might not be satisfying enough to do this kind of work for the rest of my life. In 1990, I began studying computer science at Paderborn University, where I made my diploma in 1995. During my diploma studies, I became very enthusiastic about algorithms and other research topics from theoretical computer science. So I started working towards a PhD degree. I worked on several different topics related to algorithms and networks during my time as a PhD student. In particular, I learned to love randomized algorithms and solution concepts. In 1998, I finished my PhD thesis. It deals with distributed and randomized algorithms for communication and data management in large computer networks. After staying for eight years in Paderborn, it was definitely time to see some other places. At the beginning of the year 1999, I left for a one year Postdoc scholarship at International Computer Science Institute in Berkeley, California, funded by the DAAD. In spring 2000, I took a position as a visiting assistant professor at the Massachusetts University (UMASS) in Amherst. In summer 2000, I joined the Max-Planck-Institute in Saarbrücken, where I did my habilitation in January 2002. Right after my habilitation, I got a call for a professorship in Dortmund. I stayed for exactly two years in Dortmund before I moved to Aachen at the beginning of October 2004.

Our research is centered around the following questions: How good is an algorithm or data structure? How efficiently can a computational problem be solved? – Giving mathematically rigorous answers to such questions lies at the heart of computer science. Challenges are to identify fundamental problems and to design and analyze algorithm for them. Sometimes practically efficient algorithms are known, but their behavior is not understood in a rigorous way. Then it is important to develop sensible measures of computational complexity, and to analyze algorithms with respect to such measures. We believe that analyzing algorithms in a mathematical model leads to a deeper understanding of the algorithm and the underlying
problem and often facilitates its improvement. Probabilistic methods play a major role in our research. On one hand, we study randomized algorithms that use coin flips in order to efficiently solve problems. This concept is useful in particular in distributed settings that lack central control, e.g., for contention resolution in large networks. On the other hand, we study known algorithms and heuristics – like, e.g., the branch-and-bound for optimization problems – in random and semi-random input models in order to better understand their behavior and improve them if possible.
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:** 2051 (total number in fall term 2004)  
**Female rate:** approx. 13.5 %

**Required qualifications**

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

**Overall structure**

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

**Stage I (Vordiplom)**

The technical and methodical basic knowledge in computer science is taught over approx. 80 semester hours in total. The pre-degree examination, which extends over five individual exams, is passed study-attendant and comprises the topics compute 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.

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 prerequisites 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:

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E-Mail: Schroeder@informatik.rwth-aachen.de

Dr. V. Penner, Lehrstuhl Informatik VII, RWTH Aachen,
E-Mail: penner@informatik.rwth-aachen.de.
The International Master Programme
Software Systems Engineering

In 2000, the Computer Science Department launched the two-year Master programme Software Systems Engineering. It is primarily intended for international students holding a Bachelor degree in Computer Science, Computer Engineering, or a closely related field from an internationally recognized university-level institution. The programme aims to attract very good, if not the best students from all over the world in pursuit of a Master degree in Computer Science. In order to make the programme as attractive as possible to non-German speaking students, courses are offered entirely in English. To successfully complete the programme, students are required to earn 120 ECTS credits, including 30 credits for the Master thesis and 10 for German language classes. At present, about 80 students from 20 countries are enrolled in the programme.

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

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

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

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

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

Formal Entrance Requirements

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

Special Entrance Requirements

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

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

Career Opportunities

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

Language of Instruction

The Programme will be taught completely in English

Duration of the Programme

Two years
Beginning of the Programme
October

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

Further information
For further general information please check the RWTH webpages. If you have specific questions on course content please contact:
RWTH Aachen University
Department of Computer Science 4
Media Informatics Team
52056 Aachen, Germany

E-Mail: msc-mi@b-it-center.de
Webpage: http://mi.b-it-center.de/
The Girls’ Day is organized nationwide once a year to provide an opportunity for 10- to 16-year-old female pupils to get to know professions especially in technical areas and the domain of science.

In 2004, two different computer science workshops were offered by computer scientists from RWTH Aachen. In total, they were attended by about 50 pupils.

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

In the afternoon, the pupils visited different institutions of the Computer Science Faculty. The Computer Science Library gave an overview of their work and the services they offer. The System Administration Group provided an insight to the interior of a computer and gave an impression of the computational infrastructure and services within the Computer Science Faculty. Furthermore, prototypes from different computer science chairs such as the MoPS WLAN system were demonstrated.

The Girls’ Day workshop at the Media Computing Group allowed the girls to produce their own music video. They filmed short sequences in smaller groups that were made to fit to some favorite songs they had brought along. The editing and post-production was done entirely computer-based. The girls were able to do this mostly on their own after a short introduction. Whenever the video equipment was in use by another group, the girls could conduct a real orchestra using the “Personal Orchestra”-system developed by the Media Computing Group.
Schnupperstudium - Study Day for Girls

The Schnupperstudium is organized by RWTH once a year. It provides female pupils an opportunity to get to know programmes of study with a low ratio of female students – such as computer science.

In 2004, two computer science workshops were offered by female computer scientists from RWTH Aachen. The pupils of age 16 to 19 had the chance to get their own impression of computer science by experimenting with Conway’s “Game of Life”. This game simulates life in an amoeba culture and is well-suited for intuitively introducing some theoretical constructs of computer science such as binary numbers or even computability. The girls had the possibility to make up their own initial setting in the amoeba culture – a so-called “pattern” – and see how life developed. Starting from simple settings, more complex ideas were introduced:

- stable figures which never change their shape
- figures which get caught in cycles after a few iterations
- patterns which die or which grow very fast
- A “paradise” is a pattern which does not have any predecessor pattern.
- A “glider gun” is a pattern which produces small figures which move across the screen in regular distances. They can be used to build e.g. binary adders.

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

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.
# 1 Courses in Summer term (Sommersemester 04)

## 1.1 Undergraduate Courses 2nd semester

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<td>Ney</td>
<td>Datenstrukturen und Algorithmen (Data structures and algorithms)</td>
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<tr>
<td>Esser</td>
<td>Differentialgleichungen und Numerik (Differential Equations and Numerics)</td>
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<tr>
<td>Schoenwaelder</td>
<td>Diskrete Strukturen (Discrete structures)</td>
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## 1.2 Undergraduate Courses 4th semester

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<td>Thomas</td>
<td>Automatentheorie und Formale Sprachen (Automata Theory and Formal Languages)</td>
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<tr>
<td>Kamps</td>
<td>Einführung in die Stochastik für Informatiker (Introduction to Stochastics for Computer Scientists)</td>
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<tr>
<td>Noll</td>
<td>Praktikum Informatik (f. Informatiker 4. Semester)</td>
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<tr>
<td>Giesl, Schneider-Kamp, Thiemann</td>
<td>Proseminar: IT-Sicherheitskonzepte und Sicherheit in Java (IT-Security Concepts and Security in Java)</td>
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<tr>
<td>Westfechtel, Haase</td>
<td>Technologien zur Entwicklung von Webanwendungen (Technologies for the development of web applications)</td>
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<td>Spaniol, Günes</td>
<td>Proseminar Rechnerarithmetik</td>
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<td>Jarke, Jertila</td>
<td>Semantic Web: Grundlagen und Anwendungen</td>
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<tr>
<td>Lakemeyer, Iwan</td>
<td>Proseminar Künstliche Intelligenz (Artificial Intelligence)</td>
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<tr>
<td>Kobbelt, Bischoff</td>
<td>Ausgewählte Kapitel der Computergraphik (Selected Topics in Computer Graphics)</td>
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<tr>
<td>Borchers, Spelmezan</td>
<td>Media Spaces</td>
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<tr>
<td>Rossmanith, Richter, Mölle</td>
<td>Netzwerkanalyse (Network Analysis)</td>
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<td>Kowalewski</td>
<td>Software Fundamentals</td>
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<tr>
<td>Indermark, Stolz</td>
<td>Softwarepraktikum: Funktionales Programmieren in Haskell (Practical Course: Functional Programming in Haskell)</td>
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Ney  
*Softwarepraktikum: Muster- und Bilderkennung (Software Lab Pattern and Image Recognition)*

Penner, Wallmeier, Wöhrle  
*Softwarepraktikum: Webprogrammierung und das Satzsystem Latex*

Seidl, Brochhaus, Enderle  
*Softwarepraktikum: Datenstrukturen*

Bischof, Vehreschild  
*Softwarepraktikum Paralleles Programmieren in Java (Software Lab Parallel Programming in Java)*

Spaniol, Krempels  
*Agententechnologie (Agent Technology)*

Lichter, von der Maßen, Nyßen  
*Use-Case basierte Anwendungsentwicklung mit Java (Use-Case based application development with Java)*

### 1.3 Graduate Courses

**Indermark**  
*Compilerbau (Compiler Construction)*

**Giesl**  
*Termersetzungssysteme (Term Rewriting Systems)*

**Thomas**  
*Applied Automata Theory*

**Grädel**  
*Komplexitätstheorie (Complexity Theory)*

**Rossmanith**  
*Analyse von Algorithmen (Analysis of Algorithms)*

**Lohrey**  
*Ausgewählte Gebiete der Algorithmen Theorie (Selected topics of the theory of algorithm)*

**Nagl, Fuß, Giesecke**  
*Modellierung von Software-Architekturen (Modeling of Software Architectures)*

**Westfechtel**  
*Management von Software-Entwicklungsprozessen (Management of Software Development Processes)*

**Lichter**  
*Software-Qualitätssicherung und Projektmanagement (Software Quality Assurance and Project Management)*

**Spaniol, Thißen, Wienzek**  
*Verteilte Systeme (Distributed Systems)*

**Spaniol, Günes**  
*Modellierung und Bewertung von Kommunikationssystemen (Modeling and Evaluation of Communication Systems)*

**Kesdogan, Spaniol**  
*Web Protocols and Practice*

**Gärtner**  
*Verlässliche Verteilte Systeme (Dependable Distributed Systems)*
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<td>Jarke</td>
<td>Implementation of Databases</td>
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<td>Schlüter, Ney</td>
<td>Spracherkennung (Automatic Speech Recognition)</td>
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<td>Seidl, Enderle, Brochhaus, Assent, Krieger</td>
<td>Indexstrukturen für Datenbanken (Indexing Structures for Databases)</td>
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<td>Borchers, Lee, Werner</td>
<td>Designing Interactive Systems II</td>
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<td>Borchers, Ballagas, Spelmezan</td>
<td>HCI Design Patterns</td>
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<td>Kowalewski</td>
<td>Entwurf eingebetteter Software (Embedded Software Design)</td>
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<td>Bischof</td>
<td>Rechnergestütztes Differenzieren (Computational Differentiation)</td>
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<td>Bücker</td>
<td>Parallele Algorithmen und Software für iterative Methoden (Parallel Algorithms and Software for Iterative Methods)</td>
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<td>Kraiss</td>
<td>Mensch-Maschine Systeme II (Human Maschine Systems II)</td>
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<td>Walke</td>
<td>Kommunikationssysteme und Verkehrstheorie II</td>
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<td>Niebert</td>
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<td>Einführung in eingebettete Systeme (Introduction to Embedded Systems)</td>
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<td>Bemmerl</td>
<td>Betriebssysteme II (Operating Systems II)</td>
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<td>Naumann</td>
<td>Automatische Modifikation der Semantik Numerischer Programme (Automatic Modification of Semantic of Numerical Programs)</td>
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<td>Unger</td>
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<td>Seminar über Automatentheorie (Seminar Automata Theory)</td>
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<td>Name</td>
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<td>Thomas, Wöhrle, Rohde, Altenbernd</td>
<td>Seminar über hybride und Echtzeit-Systeme</td>
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<td>Thomas</td>
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<td>Westfechtel, Ranger</td>
<td>Graph Grammatiken (Graph Grammars)</td>
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<td>Gärtner, Mink</td>
<td>Seminar Verlässliche Verteilte Systeme (Konferenzseminar) (Dependable Distributed Systems (Conference Seminar))</td>
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<td>Rossmanith, Richter, Mölle</td>
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<td>Lohrey</td>
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<td>Lohrey</td>
<td>Algorithmen aus der Bioinformatik</td>
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<td>Grädel</td>
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<td>Wissensverarbeitung als Herausforderung des Informationstellers</td>
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<td>Jarke, Becks, Seeling, Schlüter, Brandt</td>
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<td>Jarke, Lakemeyer</td>
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<td>Lakemeyer, Iwan</td>
<td>Kognitive Robotik (Cognitive Robotics)</td>
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<td>Prinz</td>
<td>CSCW und Groupware: Konzepte und Systeme zur computergestützten Zusammenarbeit (CSCW and Groupware: concepts and systems for computer supported cooperative work)</td>
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<td>Ney</td>
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<td>Kobbelt, Lehmann, Ney, Rossmanith, Seidl, Spitzer</td>
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<td>Kobbelt</td>
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<td>Seidl</td>
<td>Aktuelle Entwicklungen des Data Mining (Recent Developments in Data Mining)</td>
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LuFG Seminar

Borchers, Ballagas, Spelmezan  
Seminar Post-Desktop User Interfaces

Bücker  
Seminar Parallele iterative Methoden (Seminar Parallel Iterative Methods)

Bücker  
Graphzeichnen (Graph Drawing)

Schroeder, Giani, Weckauf  
Seminar eLearning

Berlage  
Informationsmanagement für bildbasierte biologische Experimente (Information management for image-based biological experiments)

Naumann  
B-IT Seminar - Analyse von Numerischen Codes (Analysis of Numerical Codes)

Nagl, Norbirisrath, Heller, Kirchhof  
Softwaretechnik-Projektpraktikum: Werkzeugunterstützung für den eHome-Prozess (Lab Course Tool Support for the eHome-Process)

Spaniol, Krempels  
Agententechnologie (Agent Technology)

Spaniol, Imhoff, Seipold  
Virtuelles Informatik-Praktikum

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

Jarke, Lübbers  
Methoden des Music Information Retrieval (Methods of Music Information Retrieval)

Hornung, Kobbelt  
Hauptpraktikum: Spezialeffekte (Special Effects)

Kraiss, Gönner  
Praktikum Virtuelle Realität (Laboratory on Virtual Reality)

Imdermark, Giesl, Bollig, Noll, Stolz, Weber  
Arbeitsgemeinschaft Modellierung Verteilter Systeme (Working Group Modelling Concurrent Systems)

Imdermark, Giesl  
Arbeitsgemeinschaft Programmanalyse (Working Group Program Analysis)

Giesl, Thiemann, Schneider-Kamp  
Arbeitsgemeinschaft Programmverifikation

Grädel, Thomas  
Arbeitsgemeinschaft: Logik und Automaten

Nagl, Westfechtel  
Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge
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<td>Wallbaum, Pils, Günes,</td>
<td>Arbeitsgemeinschaft: Mobilkommunikation (Study Group: Mobile Communications)</td>
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<tr>
<td>Spaniol</td>
<td></td>
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<td>Seipold, Kritzner, Spaniol</td>
<td>Arbeitsgemeinschaft: Multimediakommunikation (Study Group: Multimedia Communication)</td>
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<td>Gärtner</td>
<td></td>
</tr>
<tr>
<td>Imhoff, Thißen, Diepolder,</td>
<td>Arbeitsgemeinschaft: Verteilte Systeme (Study Group: Distributed Systems)</td>
</tr>
<tr>
<td>Spaniol, Gärtner</td>
<td></td>
</tr>
<tr>
<td>Kesdogan, Spaniol, Gärtner</td>
<td>Arbeitsgemeinschaft: Privacy Enhancing Techniques (Study Group: Privacy Enhancing Techniques)</td>
</tr>
<tr>
<td>Jarke</td>
<td>Arbeitsgemeinschaft Informatische Unterstützung übergreifender Entwicklungsproz. i.d. Verfahrenstechnik</td>
</tr>
<tr>
<td>Jarke</td>
<td>Arbeitsgemeinschaft Deduktive Objektbanken (Working Group Deductive object bases)</td>
</tr>
<tr>
<td>Ney</td>
<td>Arbeitsgemeinschaft Bilderkennung (Study Group Image Recognition)</td>
</tr>
<tr>
<td>Ney</td>
<td>Arbeitsgemeinschaft Spracherkennung (Study Group Speech Recognition)</td>
</tr>
<tr>
<td>Ney</td>
<td>Arbeitsgemeinschaft Sprachübersetzung (Study Group Machine Translation)</td>
</tr>
<tr>
<td>Kobbelt</td>
<td>Arbeitsgemeinschaft Geometrische Modellierung (Working Group Geometric Modeling)</td>
</tr>
<tr>
<td>Spaniol</td>
<td>Graduiertenkolleg Software für Kommunikationssysteme (Graduate School Software for Communication Systems)</td>
</tr>
<tr>
<td>Gärtnert, Dornseif, Mink</td>
<td>Sommerschule angewandte IT-Sicherheit (summer school applied IT security)</td>
</tr>
</tbody>
</table>
2 Courses in Winter term (Wintersemester 04/05)

2.1 Undergraduate Courses 1st semester

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

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

Plesken Lineare Algebra (Linear Algebra) [VLAI]

2.2 Undergraduate Courses 3rd semester

Kowalewski Systemprogrammierung (System Programming)

Thomas Berechenbarkeit und Komplexität (Computability and Complexity)

Grädel Mathematische Logik (Mathematical Logic)

Schumacher Elektronische Grundlagen für Informatiker

Indermark, Weber Proseminar Programmiersprachen

Ney, Schlüter Proseminar Datenkompression (Seminar Data Compression)

Seidl Proseminar Methoden und Werkzeuge

Thomas, Penner, Altenbernd, Wallmeier Proseminar Internet-Protokolle

Prinz Computer-Supported Cooperative Work und Groupware: Konzepte und Systeme

Vöcking Proseminar Online Algorithmen

Nagl, Kirchhof, Kraft Softwarepraktikum im Grundstudium: Web-Technologien

Kobbelt, Pavic Basispraktikum Computergraphik (Basic practical course computer graphics)

Bemmerl, Finocchiaro Softwarepraktikum: Parallelrechner (Software Lab: Parallel Systems)

Spaniol, Krempels Agententechnologie (Agent Technology)

Spaniol, Wienzek Netzwerkprogrammierung (Network Programming)
2.3 Graduate Courses

Vöcking  
Effiziente Algorithmen (Algorithms Design)

Unger  
Algorithmische Kryptographie

Rossmanith  
Parametrisierte Algorithmen

Indermark  
Programmanalyse und Compileroptimierung (Program Analysis and Compiler Optimization)

Noll  
Semantik von Programmiersprachen (Semantics of Programming Languages)

Thomas  
Automaten auf unendlichen Wörtern

Löding, Thomas  
Baumautomaten und Anwendungen

Grädel  
Quanten Computer (Quantum Computing)

Grädel  
Automatische Strukturen (Automatic Structures)

Rossmanith  
Parametrisierte Algorithmen

Nagl, Haase, Heller  
Einführung in die Softwaretechnik (Introduction to Software Engineering)

Westfechtel  
Spezifikation von Softwaresystemen (Specification of Software Systems)

Lichter  
Objektorientierte SoftwareKonstruktion (Object-Oriented Software Construction)
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spaniol, Thißen</td>
<td>Datenkommunikation (Data Communication and Internet Technology)</td>
</tr>
<tr>
<td>Kesdogan, Spaniol</td>
<td>Privacy Enhancing Techniques</td>
</tr>
<tr>
<td>Thißen, Spaniol</td>
<td>Mobilkommunikation (Mobile Communications)</td>
</tr>
<tr>
<td>Gärtner, Dornseif</td>
<td>Computerforensik (Computer Forensics)</td>
</tr>
<tr>
<td>Gärtner, Mink, Dornseif</td>
<td>Verlässliche Verteilte Systeme 1 (Dependable Distributed Systems 1)</td>
</tr>
<tr>
<td>Jarke, Quix, Rose</td>
<td>Introduction to Database Systems</td>
</tr>
<tr>
<td>Jarke, Spaniol, Gans</td>
<td>Unternehmensgründung und neue Medien (Entrepreneurship and new Media)</td>
</tr>
<tr>
<td>Broll</td>
<td>Virtual and augmented Reality</td>
</tr>
<tr>
<td>Lakemeyer</td>
<td>Introduction to Knowledge Representation</td>
</tr>
<tr>
<td>Berlage</td>
<td>Einführung in die Bioinformatik (Introduction to Bioinformatics)</td>
</tr>
<tr>
<td>Ney</td>
<td>Statistical Methods in Natural Language Processing</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 I (Computergraphics I)</td>
</tr>
<tr>
<td>Kobbelt</td>
<td>Geometrische Modellierung II (Geometric Modeling II)</td>
</tr>
<tr>
<td>Seidl</td>
<td>Modelle der Datenexploration</td>
</tr>
<tr>
<td>Borchers, Ballagas, Spelmezan</td>
<td>Designing Interactive Systems I</td>
</tr>
<tr>
<td>Borchers, Lee, Spelmezan</td>
<td>Current Topics in Media Computing and HCI</td>
</tr>
<tr>
<td>Kowalewski</td>
<td>Automotive Software Engineering</td>
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<tr>
<td>Kowalewski</td>
<td>Einführung in eingebettete Systeme (Introduction to embedded systems)</td>
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<tr>
<td>Kowalewski</td>
<td>Entwurf eingebetteter Software (Embedded Software Design)</td>
</tr>
<tr>
<td>Naumann</td>
<td>Automatische Modifikation der Semantik Numerischer Programme (Automatic Modification of the Semantics of Numerical Programs)</td>
</tr>
<tr>
<td>Bucker</td>
<td>Einführung in High-Performance Computing (Introduction to High-Performance Computing)</td>
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<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>Walke</td>
<td>Grundgebiete der Informatik 3 (Basics of Computer Science 3)</td>
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<tr>
<td>Walke</td>
<td>Kommunikationsnetze I (Communication Networks I)</td>
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<tr>
<td>Rokitansky</td>
<td>Stochastische Simulation I</td>
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<tr>
<td>Luksch, Stoffel, Vorländer, Lentz, Schnakenberg, Seidl, Lakemeyer, Offenhäuser</td>
<td>Ringvorlesung Bionik I (Bionic: Basics and Methods for Biology and Technology)</td>
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<tr>
<td>Vöcking</td>
<td>Lehrstuhlseminar</td>
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<tr>
<td>Indermark, Bollig</td>
<td>Message Sequence Charts</td>
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<tr>
<td>Indermark, Giesl</td>
<td>Lehrstuhlseminar</td>
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<tr>
<td>Thomas, Altenbernd, Rohde, Wöhrle</td>
<td>Seminar Automatentheorie</td>
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<tr>
<td>Vöcking</td>
<td>Seminar Auktion, Spiele, Algorithmen - Algorithmische Spieltheorie und das Internet</td>
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<tr>
<td>Katoen</td>
<td>Validierung Stochastischer Systeme (Validation of Stochastic Systems)</td>
</tr>
<tr>
<td>Nagl, Fuß, Norbisrath</td>
<td>Komponentenbasierte eingebettete Systeme: Entwurf, Konfiguration und Deployment (Component Based Embedded Systems: Design, Configuration, and Development)</td>
</tr>
<tr>
<td>Lichter</td>
<td>Lehrgebietsseminar</td>
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<tr>
<td>Spaniol, Kesdogan</td>
<td>Seminar Security in Communication Networks</td>
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<tr>
<td>Spaniol. Thißen</td>
<td>Seminar Wireless Networks</td>
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<tr>
<td>Gärtnerte, Mink, Dornseif</td>
<td>Lehrgebietsseminar</td>
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<tr>
<td>Jarke, Lakemeyer</td>
<td>Lehrstuhlseminar</td>
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<tr>
<td>Jarke, Lakemeyer</td>
<td>Doktorandenseminar</td>
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<tr>
<td>Lakemeyer</td>
<td>Diplomandenseminar</td>
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<tr>
<td>Ney</td>
<td>Seminar Computer Vision (Seminar Computer Vision)</td>
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<table>
<thead>
<tr>
<th>Name</th>
<th>Seminar/Praktikum</th>
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<tbody>
<tr>
<td>Ney</td>
<td>Lehrstuhlseminar Fortgeschrittene Methoden in der Sprachverarbeitung (Advanced Topics in Speech and language Processing)</td>
</tr>
<tr>
<td>Kobbelt, Hornung</td>
<td>Seminar Point and image based rendering techniques</td>
</tr>
<tr>
<td>Kobbelt</td>
<td>Diplomanden- und Doktorandenseminar</td>
</tr>
<tr>
<td>Seidl</td>
<td>Seminar Aktuelle Entwicklung des Data Mining (Seminar Recent Developments in Data Mining)</td>
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<tr>
<td>Seidl</td>
<td>Lehrstuhlseminar</td>
</tr>
<tr>
<td>Kowalewski, Schlich</td>
<td>Anwendung von Model Checking auf eingebettete Systeme (Application of Model Checking to embedded systems)</td>
</tr>
<tr>
<td>Kuhlen, Bischof</td>
<td>Seminar Aktuelle Themen der Virtuellen Realität</td>
</tr>
<tr>
<td>Kraiss, Dörfler</td>
<td>Seminar: Machine Vision VI</td>
</tr>
<tr>
<td>Schumacher</td>
<td>Lokale Datennetze für industrielle Anwendungen (Local Area Networks for Industrial Applications)</td>
</tr>
<tr>
<td>Nagl, Böhlen, Ranger</td>
<td>Softwaretechnik-Projektpraktikum im Hauptstudium: Fujaba und die MDA-Generierung verteilter Anwendungen aus UML Diagrammen (Graduate lab Course: Fujaba and the MDA-Generating Distributed Applications from UML diagrams)</td>
</tr>
<tr>
<td>Lichter, Schackmann</td>
<td>Praktikum Software-Konstruktion (Software Construction)</td>
</tr>
<tr>
<td>Spaniol, Krempels</td>
<td>Agententechnologie (Agent Technology)</td>
</tr>
<tr>
<td>Gärtner, Mink, Dornseif, Pimenidis</td>
<td>Hacker Praktikum</td>
</tr>
<tr>
<td>Jarke, Oppermann</td>
<td>User-oriented system design and personalized information services for nomadic information and e-learning systems</td>
</tr>
<tr>
<td>Jarke, Spaniol, Gans</td>
<td>Projektpraktikum Unternehmensgründung und neue Medien (Lab Hightech entrepreneurship and new media)</td>
</tr>
<tr>
<td>Lakemeyer, Iwan</td>
<td>Robotersteuerung mit Golog (Moblie Robot Lab)</td>
</tr>
<tr>
<td>Ney</td>
<td>Praktikum Sprach- und Bildverarbeitung (Laboratory Course Speech and Image Recognition)</td>
</tr>
<tr>
<td>Ney, Bisani, Schlüter</td>
<td>Kurs Programmierung in der Forschung (Course Programming in Research)</td>
</tr>
<tr>
<td>Seidl</td>
<td>Praktikum Data Mining Algorithmen (Lab Course Data Mining Algorithms)</td>
</tr>
</tbody>
</table>
Schroeder

Projektpрактикум im Hauptstudium: Softwareunterstützung in der Moderation

Borchers, Ballaga, Werner

Praktikum im Hauptstudium: The Media Computing Project

Kowalewski, Salewski, Wilking

Hardwarenahe Programmierung eines eingebetteten Assisten-systems (Lab Course Driver Assistance System)

Kraiss, Fillbrandt, Bley

Praktikum Multimedia-Techniken (Laboratory on Multimedia Techniques)

Indermark

Arbeitsgemeinschaft Modellierung Verteilter Systeme (Working Group Modelling Concurrent Systems)

Indermark

Arbeitsgemeinschaft Programmanalyse (Working Group Program Analysis)

Giels, Thiemann, Schneider-Kamp

Arbeitsgemeinschaft Programmverifikation

Grädel, Thomas

Arbeitsgemeinschaft Logik und Automaten (Working Group on Logic in Computer Science)

Nagl, Westfechtel

Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge

Wallbaum, Pils, Spaniol

Arbeitsgemeinschaft Mobilkommunikation (Study Group Mobile Communication)

Seipold, Spaniol

Arbeitsgemeinschaft Multimediakommunikation (Study Group Multimedia Communication)

Kesdogan, Wienzek, Spaniol, Gärntner, Mink, Dornseif

Arbeitsgemeinschaft Sicherheit in der Kommunikationstechnik (Study Group Security in Communication Systems)

Imhoff, Thiesen, Diepolder, Spaniol, Gärntner, Mink, Dornseif

Arbeitsgemeinschaft Verteilte Systeme (Study Group Distributed Systems)

Kesdogan, Spaniol

Arbeitsgemeinschaft Privacy Enhancing Techniques (Study Group Privacy Enhancing Techniques)

Jarke, Quix

Arbeitsgemeinschaft Deduktive Objektbanken (Working group deductive object bases)

Lakemeyer, Iwan

Arbeitsgemeinschaft Kognitive Robotik (Working Group Cognitive Robotics)

Ney

Arbeitsgemeinschaft Bilderkennung (Working Group Image Recognition)
2.4 Other courses

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

Grädel  
Informatik-Kolloquium (Computer Science Colloquium)

Courses for Other Curricula (“Service Courses”)

Schroeder  
Programmierung für Alle (Java)

Freiling, Mink  
Anwendungssoftware und Internet

Seidl, Assent, Krieger  
Algorithmen und Datenstrukturen

Schroeder  
Software Entwicklung

Nagl, Becker, Böhlen  
Grundgebiete der Informatik II

Indermark  
Automaten, Sprachen, Komplexität

Epple  
C++-Kurs

Lichter  
Systematische Softwareentwicklung

Penner  
Informatik-Praktikum (für Mathematiker)
3 Talks within the Computer Science Colloquium

February, 9  Prof. Dr. Guoqing Chen, Tsinghua University, Beijing
Dealing with Uncertainty/Fuzziness in Knowledge Discovery

March, 25  Dr. Jobst Löffler, Fraunhofer IMK
Automatische Verfahren zur Medienanalyse: Das Media-Asset-Managementssystem iFinder

March, 25  Dr. Marina Kolesnik, Fraunhofer IMK
Digitale Bildverarbeitung: 3 ausgewählte Anwendungen

April, 25  Privatdozent Dr. Markus Lohrey, Universität Stuttgart
Validierung und Realisierung von Sequenzdiagrammgraphen

April, 29  Dr. Markus Mohnen, Cycos AG, Alsdorf
Vom wissenschaftlichen Assistenten zum General Project Manager

June, 17  Prof. Renchu Gan, School of Management and Economics, Beijing Institute of Technology
A framework of information service platform(ISP) in E-government systems

July, 1st  Prof. Dr. Martin Grohe, Humboldt-Universität zu Berlin
Gibt es Leben jenseits von P und NP - Ein Ausflug in Logik und Komplexität

July, 15  Prof. Dr. Gerhard Brewka, Universität Leipzig
Answer Set Optimization

July, 22  Prof. Lev Manovich, Ph.D., University of California in San Diego
Info-aesthetics

July, 29  Dr. Stefan Eickeler, Fraunhofer IMK
Automatische Bildfolgeanalyse mit statistischen Mustererkennungsverfahren

September, 30  Jeremy Dawson
A General Theorem on Termination of Rewriting

October, 7  Prof. Dr. Franz Baader, TU Dresden
Ein neuer Existenzquantor in Beschreibungslogiken, oder wie man mit syntaktischem Zucker Schlussfolgerungsprobleme schneller lösen kann

November, 23  Prof. Hector Levesque, University of Toronto
Planning with loops
4 Diploma and Master Theses

4.1 Diploma

Beier, Daniel  
*Multi-scale description of image content using a bottom-up image segmentation approach* (Spitzer, Seidl)

Brunner, Andre  
*Ontology-based navigation in textual annotations of business figures* (Jarke, Lakemeyer)

Butsch, Willi  
*Adaptive MAC Protocol with QoS Consideration for Multi-Carrier CDMA based Wireless LANs* (Walke, Gärtner)

Cerfontaine, Philippe  
*Modelbased motion capture using optical tracking* (Kobbelt, Bischof)

Debus, Alfi  
*Extension of the Relational Interval Tree to Floating Point Intervals* (Seidl, Jarke)

Deselaers, Thomas  
*Features for Image Retrieval* (Ney, Seidl)

Eckert, Frank  
*Hierarchical Methods for isotropic Remeshing of 3D Surfaces* (Kobbelt, Bischof)

Eiken, Alexander  
*Development of a tool for graphical modeling of product line architectures* (Lichter, Schroeder)

Eisbein, Thomas  
*Tool Support for the Analysis of Telecommunication Systems: Extraction of state Machines from Source Codes* (Nagl, Spaniol)

Eisold, Dirk  
*Performance Evaluation and Implementation of the ad hoc routing ToRA and the macro mobility extension* (Walke, Spaniol)

Evertz, Michael  
*Gestaltung und Evaluation der Benutzungsschnittstelle eines Administratorsystems für Verfahrenstechnische Entwickler* (Luczak, Nagl)

Falke, Stephan  
*Automated Termination Analysis for Equational Rewriting* (Giesl, Thomas)

Frese, Dino  
*Annotation von Datenwürfehn mit externen, heterogenen Daten* (Jarke, Lakemeyer)

Freudenstein, Jörg  
*Agentenbasierte Simulation individueller Tagesabläufe* (Spaniol, Beckmann)

Friedrich, Joachim  
*Construction of Large phylogenetic trees based on profile distances* (Rossmanith, Dandekar)
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabriel, Peter</td>
<td>Interactive User Interfaces for eHome-Systems (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Gollan, Christian</td>
<td>Nichtlineare Verformungsmodelle für die Bilderkennung (Ney, Seidl)</td>
</tr>
<tr>
<td>Görgen, Rene</td>
<td>Realtime approximation of physical shading models on programmable GPUs using the CgFX shading language (Kobbelt, Bischof)</td>
</tr>
<tr>
<td>Haack, Matthias</td>
<td>Interactive comparison of experimental, flow measurements and numerical flow simulations in virtual environments (Bischof, Schröder)</td>
</tr>
<tr>
<td>Habbecke, Martin</td>
<td>3D Reconstruction From Uncalibrated Image Sequences Using The Structure From Motion Approach (Kobbelt, Lakemeyer)</td>
</tr>
<tr>
<td>Hang, Christian</td>
<td>Semantic Labelling and String Rewriting Techniques for Automated Termination and Liveness Proofs (Giesl, Indermark)</td>
</tr>
<tr>
<td>Hartono, Budi</td>
<td>Performance Evaluation of the MAC Protocol of the WirelessMAN (IEEE 802.16) (Walke, Nagl)</td>
</tr>
<tr>
<td>Haselbach, Christian</td>
<td>Transformation techniques verification of imperative and functional programs (Giesl, Indermark)</td>
</tr>
<tr>
<td>Hermann, Lutz</td>
<td>Fusionierung unsicherer Umweltinformationen von kooperierenden Robotern zu einem globalen Weltmodell (Lakemeyer, Jarke)</td>
</tr>
<tr>
<td>Heß, Andreas</td>
<td>Gestaltung einer Retrievalkomponente für die kulturwissenschaftliche Forschungsdatenbank MAVIS (Jarke, Lakemeyer)</td>
</tr>
<tr>
<td>Heuer, Eiko</td>
<td>Development of Routing Strategies for Composable “Ambient Networks” (Walke, Spaniol)</td>
</tr>
<tr>
<td>Huppertz, Thomas</td>
<td>User interaction support by context-based tracking analysis (Kobbelt, Bischof)</td>
</tr>
<tr>
<td>Janecek, David</td>
<td>Integrating FiFiQueues into the Möbius Framework (Haverkort, Thomas)</td>
</tr>
<tr>
<td>Jensen, Thorben</td>
<td>Automatic Conversion of Spline Surfaces into Topologically Consistent Polygonal Meshes (Kobbelt, Bischof)</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
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</tr>
<tr>
<td>Karbiener, Armin</td>
<td>Einbindung einfacher Bildverarbeitungsverfahren in die Steuerungssoftware eines autonomen mobilen Roboters (Lakemeyer, Jarke)</td>
</tr>
<tr>
<td>Kefali, Ufuk</td>
<td>Development and Performance Evaluation of a SOAP Profile for BEEP (Walke, Jarke)</td>
</tr>
<tr>
<td>Kehren, Peter</td>
<td>Realisierung einer Graphdatenbank auf Basis kommerzieller Datenbanksysteme (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Kensehe, David</td>
<td>Ontology-based monitoring with semantic search engines (Jarke, Lakemeyer)</td>
</tr>
<tr>
<td>Keschenau, Martin</td>
<td>Reverse Engineering of UML-Specifications from Java-Programms (Indermark, Lichter)</td>
</tr>
<tr>
<td>Klinke, Markus</td>
<td>Instanciation of ehome-configurations (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Kölsch, Tobias</td>
<td>Local features for image classification (Ney, Vidal)</td>
</tr>
<tr>
<td>Kosyanskyy, Oleksandr</td>
<td>Parallel block-iterative algorithms for the solution of linear systems (Bücker, Bischof)</td>
</tr>
<tr>
<td>Lang, Eike Michael</td>
<td>Modellierung und Realisierung einer Verfügbarkeitskontrolle für Rollen (Lichter, Giesl)</td>
</tr>
<tr>
<td>Lappe, Christian</td>
<td>Medical Image Retrieval Using Structural Information with a Connectionist Graph-Matching Approach (Spitzer, Seidl)</td>
</tr>
<tr>
<td>Linden, Frank</td>
<td>Development of a form signatur procedure using variable cryptography hardware (Hromkovic, Mathar)</td>
</tr>
<tr>
<td>Lisges, Ralph</td>
<td>Design and analysis of synchronisation methods for interactive, distributed real-time simulation (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Lohmann, Sebastian</td>
<td>Execution of Integration Rules Using a Graph Transformation System (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Lücking, Achim</td>
<td>Automated synthesis of relations for termination proofs (Giesl, Indermark)</td>
</tr>
<tr>
<td>Märlke, Luz Eugen</td>
<td>Entwicklung eines Vorgehensmodells zur Modellierung von Projektmanagementprozessen zur Abbildung in Informationssystemen (Bastian, Lichter)</td>
</tr>
<tr>
<td>Minklai, Markus</td>
<td>Adaptive Modelling of Face Graphs (Kraiss, Kobbelt)</td>
</tr>
<tr>
<td>Mosler, Christof</td>
<td>Description language for EHome configurations (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Musovic, Adisa</td>
<td>Development of a multi-layered Monitor for Controlling the Performance of Distributed Applications (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
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</tr>
<tr>
<td>Ngatchu Tchapchuet,</td>
<td>Application of Requirements Engineering Theories, Concepts and Techniques in a Concrete Project (Jarke, Henning)</td>
</tr>
<tr>
<td>Arnold</td>
<td></td>
</tr>
<tr>
<td>Oellers, Ingo</td>
<td>ATLAS-Flow-Hypermediale Umlaufmappen mit MPE 6-7 (Jarke, Lakemeyer)</td>
</tr>
<tr>
<td>Ottmann, Thorsten</td>
<td>Bestimmung relevanter Datenquellen mittels Ontologien im Semantic Web (Jarke, Lakemeyer)</td>
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<td>Pfeiffer, frank</td>
<td>Process model for collaborative research and development of composite materials applied to textile reinforced concrete (Meskouris, Westfechtel)</td>
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<td>Pelikan, Carsten</td>
<td>Constructive learning in school using multimedia learning environments (Schroeder, Spaniol)</td>
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<tr>
<td>Peters, Markus</td>
<td>Maximal Cliques and Vertical Mining for Clustering Categorical Daten (Seidl, Zaki)</td>
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<td>Plodowski, Bartosz</td>
<td>Modulares Design von webbasierten Benutzerschnittstellen für inhaltsbasierte Bildzugriffe auf medizinische Bilddaten (Spitzer, Seidl)</td>
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<td>Pohl, Johannes</td>
<td>Constrained Surface Modeling with Splings (Kobbelt, Bischof)</td>
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<td>Rattay, Oliver</td>
<td>Security Evaluation of Anonymity Techniques in the World Wide Web (Spaniol, Nagl)</td>
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<tr>
<td>Reichelt, Andreas</td>
<td>Global Model-Checking over Generalized Pushdown Systems (Thomas, Rossmanith)</td>
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<td>Reiff, Andreas</td>
<td>Implementation and Analysis of parallel Algorithms on an FPGA Cluster using the High-Level Language Handel-C (Kurz, Bücker)</td>
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<td>Remke, Anne Katharina</td>
<td>Model, Checking Infinite-State Markov Chains (Haverkort, Seidl)</td>
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<td>Röttches, Dominik</td>
<td>A Computational Model for multimodal Spatial Attention (Lakemeyer, Wagner)</td>
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<td>Rydlikowski, Eva</td>
<td>Design of a planning system with multimodal parameter optimization for the computer aided implantation of total hip revision prostheses (Seidl, Rau)</td>
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<tr>
<td>Schackmann, Holger</td>
<td>Development of a graphical Feature-Editor for the product line toolset RequiLine (Lichter, Schroeder)</td>
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</table>
Schmitz, Andreas: Adaptive Simplification of Triangle Meshes for the Interactive Visualization of Finite Element Computation Results in Virtual Environments (Bischof, Brechner)

Schneider, Jens: Kompressions- und Darstellungsverfahren für hochaufgelöste Volumendaten (Westermann, Bischof)

Schneider, Nicole: Relational Processing of Interval Joins with Temporal and Non-temporal Selections (Seidl, Jarke)

Schnitzler, Michael: Cooperative Ontology-Management in E-Business Negotiations (Jarke, Schoop)

Scholl, Uwe: Methods for Coupling Metal Forming and Crash Simulation Models (Bischof, Lorentz)

Schreiber, Dirk: GSM/GPRS Traffic Engineering under Consideration of Channel Allocation Algorithms for Speech and Multimedia Services (Walke, Spaniol)

Schuphan, Dirk: Potentials and limits of data integration with XML regarding CRM-Data of the automobile sector (Jarke, Lakemeyer)

Simon, Anja: Generierung versionsspezifischer Handbuchvarianten durch ein strukturbezogenes Autorenwerkzeug innerhalb von MS Word (Nagl, Spaniol)

Sluiters, Ralph: Tools for the integration of the technical and the administrative level of development processes (Nagl, Spaniol)

Spernat, Michael: Enhanced Surface-Splatting by Phong-Splat (Kobbelt, Bischof)

Stinauer, Philipp: Dienstekompostion für eHomes (Nagl, Spaniol)

Strack, Andras: Robust Self-Localisation for Mobile Robots in the RoboCup Domain (Lakemeyer, Kraiss)

Sturm, Marc: Werkzeugunterstützung zur Analyse von Telekommunikationssystemen: Flexibles Werkzeug zur Gewinnung und Visualisierung von Software-Architekturen (Nagl, Spaniol)

Vogt, Christian: Design study for migrating the user interface of an application for parametrizing mobile net components (Nagl, Spaniol)

Wegener, Bastian: Personadaptiver Mimic-Analysis in natural Environments (Kraiss, Kobbelt)
Westerburg, Marc-Oliver  
*Interaktive Darstellungsverfahren für hochauflöste Höhenfelder* (Westermann, Bischof)

Westerhoff, Vincent  
*Design and Evaluation of a Parlay-based Management System for personalised Communication Services for Mobile Users* (Spaniol, Nagl)

Willems, Paul Rudolf  
*Symbolic-numeric techniques for the verified solution of nonlinear systems* (Lang, Bischof)

Wolter, Marc  
*Datenmanagement von CFD-Datensätzen für die parallele Berechnung von Strömungsmerkmalen auf Hochleistungsrechnern* (Bischof, Bemmerl)

Wörzberger, Rene  
*Methods and Tools for UML-based Specification of Integration Rules* (Nagl, Spaniol)

Ymga Tembiwe, Nadine  
*Implementation and Performance Evaluation of Frequency based Multi-Protocol and Multi-Hop System in Heterogeneous Network* (Walke, Haverkort)

Yu, Meng, Rong  
*Development and Evaluation of Methods to Support QoS on a Gigabit Physical Layer for Wireless LANs based on 802.11* (Walke, Spaniol)

Zachos, Konstantin  
*Enhanced Multimedia Scenario Walkthroughs in Requirements Engineering* (Jarke, Maiden)

### 4.2 Master Thesis

Al Faroque, Mohammad Abdullah  
*Fine Grained Application Profiling for Guiding ASIP Design* (Leupers, Kowalewski)

Dilbaz, Serife Burcu  
*Investigation of Multimedia Transmission Efficiency over Wireless Networks* (Spaniol, Nagl)

Dilteniz, Abdullah  
*Data Generator Design and Integrating Update Workload for XBench XML Benchmark* (Jarke, Özsu)

Fedosseev, Pavel  
*Provision of Web Services Access and Management in a CORBA-based Service Trading Platform* (Spaniol, Nagl)

Kamalnath, Chandrasekaran  
*Potentials and Limitations of Integrating XP-Oriented Software Development and Helpdesc Processes* (Jarke, Lakemeyer)
Konur, Savas
Applying Decision Tree Learning to the Reactive Component of Robotic Soccer Agents (Lakemeyer, Seidl)

Krishnamoorhie, Vijay Saravanan
Design and implementation of a Graphical Annotation System for electro acoustic music (Jarke, von Blumenröder)

Hanif, Mohammad
Mia Semantic Integration of Asynchronous cooperation tools (Prinz, Jarke)

Mladen, Jovic
Optics-Based Evaluation of the Earth Mover’s Distance for Content-Based Image Retrieval (Seidl, Lakemeyer)

Mozumdar, Mohammad
Architecture exploration and optimization of Phillip’s TruMedia VLIW processor (Leupers, Kowalewski)

Nallanollu Parandhanra, Saresh Kumar
Visualization of past cooperative activities (Prinz, Jarke)

Nopsuwanchai, Anothai
Indexing a Semi-Structured Hierarchical XML Archive (Berlage, Jarke)

Okae, Samuel Smyo
Ontology Search and Reuse in the Context of Electronic Negotiations (Jarke, Schoop)

Özmen, Oguzhan
Behaviour Patterns for a Community Aware Content Adaptation for Mobile End Devices (Jarke, Prinz)

Srirama, Satish Narayana
Concept, implementation and performance testing of a Mobile Web Service Provider for Smart-Phones (Jarke, Prinz)

Subramanian, Kumaran
Development and Evaluation of Radio Link Control (RLC) functions for W-CHAMB (Walke, Spaniol)

Vasques de Ohlms, Isabel
Combining Electronic Negotiations and Electronic Auction Mechanisms (Jarke, Schoop)
## Statistics

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

| Semester | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13* | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| WS00/01 | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| SS01     | 150| 151| 152| 153| 154| 155| 156| 157| 158| 159| 160| 161| 162| 163| 164| 165| 166| 167| 168| 169| 170|
| SS02     | 171| 172| 173| 174| 175| 176| 177| 178| 179| 180| 181| 182| 183| 184| 185| 186| 187| 188| 189| 190| 191|
| SS03     | 192| 193| 194| 195| 196| 197| 198| 199| 200| 201| 202| 203| 204| 205| 206| 207| 208| 209| 210| 211| 212|
| SS04     | 213| 214| 215| 216| 217| 218| 219| 220| 221| 222| 223| 224| 225| 226| 227| 228| 229| 230| 231| 232| 233|
| SS05     | 234| 235| 236| 237| 238| 239| 240| 241| 242| 243| 244| 245| 246| 247| 248| 249| 250| 251| 252| 253| 254|

1 13 or more terms
2 number of PhD students
Enrolled students per semester (1 - 13+)
State: WS 2004/2005
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.

<table>
<thead>
<tr>
<th>Term</th>
<th>male</th>
<th>female</th>
<th>Vordiplom</th>
<th>Diplom</th>
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<tr>
<td>WS72/73</td>
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<tr>
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<td>215</td>
<td>54</td>
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<tr>
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<td>WS81/82</td>
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<td>WS82/83</td>
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<td>WS04/05</td>
<td>1774</td>
<td>277</td>
<td>—</td>
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</tr>
</tbody>
</table>
First-year students and diploma per academic year

Development of the number of students: First-year students and total
Research Reports
Algorithms and Complexity

Staff

- Faculty:

  Univ.-Prof. Dr. Berthold Vöcking  
  (since October 2004)

  Priv. Doz. Dr. Markus Lohrey  
  (temporary professorship, April — September 2004)  
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  Phone: +49 241 8021101  
  Fax: +49 241 8022216  
  e-mail: jussen@cs.rwth-aachen.de

- Researchers:

  Dr. Hans-Joachim Böckenhauer  
  Dipl. Inform. Dirk Bongartz  
  Dipl. Inform. Simon Fischer  
  Dipl. Inform. Thomas Franke  
  Dr. (PhD) Alantha Newman  
  Dipl. Inform. Heiko Röglin  
  Dr. Sebastian Seibert (until March 2004)  
  Priv. Doz. Dr. Walter Unger

- Technical Staff:

  Viktor Keil
Overview

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

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

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

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

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

Besides classes concerning the above mentioned topics, the department regularly offers courses on algorithmic cryptography and parallel algorithms.
Research Projects

vtraffic: Managing Variable Data Streams in Networks
(Management variabler Datenströme in Netzwerken)
S. Fischer, T. Franke, B. Vöcking
(funded by DFG)

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

DELIS: Dynamically Evolving Large Scale Information Systems
S. Fischer, A. Newman, B. Vöcking
(funded by European Union, Integrated Project)

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

Activities within the project can be grouped into two main classes:
Basic Research: basic research to understand the dynamics of the network and the effect of concepts like self-organization, selfishness and bounded rationalism as well as the structure of equilibria (and the form of dynamics) in such systems.

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

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

*W. Unger*

*(funded by European Science Foundation, Cost Action)*

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

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

1. **QoS networks:** Quality of Service (QoS) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on traffic transmission. Elements of network performance within the scope of QoS include availability (uptime), bandwidth (throughput), latency (delay), delay jitter, and error rate.

2. **Optimization in optical networks:** Optical networks using light paths in optical fibers as communication media induce a number of problems that cannot be directly resolved by using standard solutions from electronic networks, but require new approaches and techniques, instead. These problems include routing techniques, wavelength assignment on switches and cross connects, signalling, topologies design, and path recovery (backup) for protection and restoration.

3. **Optimization in wireless networks:** Wireless networks were traditionally related with voice and telephony. Nowadays, packet networks are also supported in mobile, such as in GPRS and UMTS technologies. Trends on wireless networks include QoS for multimedia transmission and backup paths. Therefore, problems for static networks are moving to wireless, such as delay minimization, traffic engineering, frequency assignment and localization. But there are several additional challenges for wireless networks, one is for instance the coordination of the single uncontrolled agents participation in the network.
This project is devoted to the study of algorithmic problems arising in the area of molecular biology. Most of these problems are computationally hard and therefore may be approached by various algorithmic techniques as for instance approximation algorithms. Special focus is given to the design and analysis of algorithms for problems arising in the area of protein folding. One of the basic tasks here, and in bioinformatics in general, is to first model the problem in a mathematically suitable way. Our focus is in particular on modelling protein folding as a special kind of embedding problem.

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

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

**Other Activities**

**Courses**

Our group offered the following lectures and seminars:

**Summer semester 2004**

- Lecture on *Selected Topics from the Theory of Algorithms*
- Seminar on *Algorithmic Cryptography*
- Seminar on *Algorithms from Bioinformatics*
- Seminar on *Circuit Complexity*

**Winter semester 2004/05**

- Lecture on *Algorithmic Cryptography*
- Lecture on *Efficient Algorithms*
Seminar on *Auctions, Games, Algorithms — Algorithmic Game Theory and the Internet*

Proseminar on *Online Algorithms*

**PC Memberships**

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

- 31st International Colloquium on Automata, Languages and Programming (ICALP 2004)
- 16th ACM Symposium on Parallelism in Algorithms and Architectures (SPAA 2004)
- 19th IEEE International Parallel & Distributed Processing Symposium (IPDPS 2004)

**Organization of Workshops and Schools**

- B. Vöcking, together with M. Bläser, P. Krysta, and R. Reischuk, organized a GI research seminar on *Game Theoretic Analysis of the Internet* at Schloss Dagstuhl in August/September 2004.

- D. Bongartz, J. Kupke, and W. Unger were member of the organization committee of *WG 2004*.

- The group organized a *Christmas Symposium on Algorithms* in December 2004.

**Research stays**

H.-J. Böckenhauer and D. Bongartz stayed with Peter Widmayer’s group at ETH Zurich from January 1st through February 28th, 2004.

**Habilitation**

S. Seibert and W. Unger received their habilitations at June 16th, 2004, for their works on

- S. Seibert: Transformation and Approximation: Algorithms and Lower Bounds
- W. Unger: The Complexity of Discrete Optimisation Problems and the Structure of their Hardness Proofs
Publications

Publications in Refereed Journals and Proceedings


Theoretical Computer Science

Staff

- Faculty:
  
  Prof. Dr. Peter Rossmanith

- Secretary:
  
  Valentina Elsner

- Research Assistants:
  
  Dipl.-Inform. Joachim Kneis
  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, often solved by inexact methods that do not give the truly optimal solution. In the case of approximation algorithms, there is at least a guarantee of how close the computed solution is to the exact one. While approximation algorithms are often very useful, they frequently have a very large running time even for rather bad approximation ratios. On the other hand, we sometimes need an exact solution, and we concentrate on such exact algorithms.

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

The picture shows a graph with encircled terminals that have to be connected by a cheapest possible subgraph. This is an instance of the well-known Steiner tree problem. Until recently, the 40 years old Dreyfus–Wagner algorithm was the fastest one to solve this problem — in $O^*(3^k)$ steps.
Research Projects

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

*Daniel Mölle, Stefan Richter, Peter Rossmanith*

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

This leads to the question whether we might be able to identify realistic instances in order to exploit their properties when designing exact algorithms for the respective problem. For instance, consider the problem *3-colorability*: Given an undirected graph, can we assign one of three colors to every vertex such that no two adjacent vertices share the same color? The best known algorithm by 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.

One of the problems investigated in this project is the aforementioned *Steiner tree problem*. We are able to improve the runtime bound from $O^*(3^k)$ to $O^*(c^k)$, where $c$ can be arbitrarily close to 2. In terms of parameterized complexity, this is the first improvement of the famous Dreyfus-Wagner algorithm. Since the bounds we obtain include huge constant factors that increase rapidly as $c$ approaches 2, we started to undertake the effort of implementing our algorithm and test its practicability.
Furthermore, we use the resulting program to find out how certain properties of the input cause the algorithm to be much faster than suggested by the aforementioned explosion of constants. We believe that there are large classes of instances that allow us to skip a lot of steps done in the two outer loops of our algorithm. The number of iterations in these loops is exactly the part of the runtime analysis that contributes the most to these constants.

Another problem that attracted our attention is power dominating set, a variant of the famous dominating set with applications to electric networks. We found that power dominating set can be solved in linear time for fixed treewidth, solving an open question posed in the SIAM Journal on Discrete Mathematics. The problem also turned out to be W[2]-hard when parameterized in the number of nodes required to power-dominate a graph.

This project is funded by the DFG under grant RO 927/6-1 (TAPI).

**Parameterized Complexity of Maximum Exact Satisfiability Problems**

Joachim Kneis, Peter Rossmanith

The Exact Satisfiability Problem (XSAT) is a restriction of the traditional SAT problem. Here we must satisfy exactly one literal in every clause. If we want to satisfy as much clauses as possible (analogous to MAXSAT), we have to distinguish two variants of MAXEXACTSAT as there are different ways to handle clauses with more than one satisfied literal:

If it is allowed to satisfy two literals in a clause \( C \) and count such a clause as unsatisfied, we obtain MAXEXACTSAT. If, otherwise, it is forbidden to satisfy more than one literal per clause, we get RESMAXEXACTSAT. Both versions are consistent with the XSAT problem, where every clause has to be satisfied.

We analyzed the parameterized complexity of both variants in the case of \( q \)-CNF formulæ and unbounded CNF-formulæ. Dealing with \( q \)-bounded CNF formulæ, we found fixed parameter algorithms for MAXEXACTSAT and RESMAXEXACTSAT. Both algorithms use the same technique, only slight adjustments are needed.

In contrary to \( q \)-CNF, MAXEXACTSAT is more difficult than RESMAXEXACTSAT on arbitrary CNF formulæ. We found an algorithm for RESMAXEXACTSAT based on a solution for WEIGHTED SET PACKING with running time \( O(2^{2k} \cdot k^{2k}) \), thereby proving it to be in FPT. But MAXEXACTSAT turned out to be W[1]-complete and equivalent to INDEPENDENT SET.

Finally, we analyzed MAXSAT under the aspect of parameterized complexity. It was previously known that deciding whether \( \frac{m}{2} + k \) clauses out of \( m \) are satisfiable is in FPT. We found a threshold where this problem becomes hard. If we want to decide whether \( \alpha \cdot m + k \) clauses can be satisfied, the problem is fixed-parameter tractable if \( \alpha \cdot m \leq E[\varphi] \cdot (1 - \epsilon) \) where \( E[\varphi] \) is the expected number of clauses satisfied by a random valuation of the variables of \( \varphi \).
If $m \geq E[\varphi] \cdot (1 + \epsilon)$, the problem turns out to be XP-hard. Even for 2-CNF formulae the problem is still W[1]-hard.

Other Activities
Program committee member of IWPEC'2004

Talks and Publications

Talks
Stefan Richter: *Formalizing Integration Theory, with an Application to Probabilistic Algorithms*, TPHOLs 2004, September 15, 2004
Peter Rossmanith: *Ein schnellerer Algorithmus für das Steiner–Baum–Problem*, Informatik-Kolloquium der Universität Stuttgart, November 30, 2004

Publications
Programming Languages and Program Analysis

Staff

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Overview

2004 has been the last entire year in which I was heading Computer Science II. Since my succession was decided earlier than usual—Joost-Pieter Katoen joined us already in December—, we can now work together and easily arrange a smooth transition.

While for many years there was a special focus on sequential and parallel functional languages, activities shifted in recent years towards analysis and efficient implementation of object-oriented programming languages and even more towards modelling, implementation, and verification of distributed systems. This direction was taken in particular by Benedikt Bollig, Martin Leucker, Thomas Noll, and Michael Weber, and matches perfectly with the research interests of my successor.

As research results are reported in the sequel, I take this opportunity to briefly comment on teaching and administrative activities. In both fields our group spent a lot of energy. As an indicator of our success in teaching I mention that in 2004 we had to examine more than 100 students in the Diploma subject of Theoretical Computer Science. Our administrative work included the assignment of undergraduate courses to the teaching personnel, management of statistical tables, student advice, organization of the web site for the technical report series Aachener Informatik–Berichte, and editing the regular Course Guide for students. I gratefully acknowledge the enduring support of all CS II–members.

Finally I wish to say that it has always been a great pleasure for me to work in such a friendly and cooperative environment, and I am convinced that Joost–Pieter Katoen will form again a successful team. Good luck!

Klaus Indermark

Research Projects

**Compiling Recursive Function Definitions**

*K. Indermark, Th. Noll*

A functional program is composed of function definitions, which are operationally interpreted as rewrite rules. These rules can be implemented using several evaluation strategies.

By adding appropriate strictness information to recursive function definitions we have achieved a uniform treatment of lazy and eager evaluation strategies. The restriction to first–order functions over basic types then enabled us to develop a pure stack implementation that avoids a heap even for lazy arguments.

In this context we have elaborated algebraic definitions of the denotational, operational, and stack–machine semantics of annotated function definitions, and have proven their equivalence by means of structural induction.
Integration of Programming Languages by Structural Type Analysis and Partial Evaluation

J. Striegnitz (Forschungszentrum Jülich), K. Indermark

A new technique for embedding a new programming language into an existing one is developed, based on structural type analysis and partial evaluation. In order to demonstrate the practical relevance of this approach, a functional language with lazy evaluation, garbage collection, and algebraic data types has been integrated into C++. Experiments show that with regard to the efficiency of the generated code, this integration is competitive with established compilers for the functional programming language Haskell.

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 the 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.
Verification of Erlang Programs

Th. Noll, L.H. Haß, M. Neuhäußer, C.K. Roy

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:

- To make Erlang systems amenable to automatic model checking techniques, one thread of our research focuses on abstraction techniques which can be employed to reduce the state space of the system under consideration. More concretely we have developed a formal definition of the syntax and semantics of 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.

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

Automata Models for Concurrent Systems

B. Bollig, M. Leucker (TU Munich)

We study the expressiveness and algorithmic properties of automata models that describe the behavior of concurrent systems. To learn more about those models, it has often been useful to characterize them in terms of other formalisms such as monadic second-order logic, rational expressions, and algebraic notions of recognizability. In this regard, we especially focus on communicating finite-state automata and asynchronous cellular automata.
We address the model-checking problem for programs with nondeterministic and randomizing 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.

It is desirable to apply formal methods even in the early stages of system design to avoid extensive reimplementation and redesign. When developing communicating systems, it is a widespread design practice to start with drawing scenarios showing the intended interaction of the system in mind. Message Sequence Charts (MSCs), a modeling language at a high level of abstraction, provide a prominent notion to further this approach. They are widely used in industry, standardized, and similar to UML’s sequence diagrams. An MSC depicts a single partially ordered execution sequence of a system. Moreover, it defines a collection of processes, which, in its visual representation, are drawn as vertical lines and interpreted as time axes. An arrow from one line to a second corresponds to the communication events of sending and receiving a message.

While a high-level MSC specification allows a global view of the system behavior, an implementation thereof will be controlled locally by rather autonomous processes. Due to this inherent discrepancy, it is generally hard to find algorithms for generating adequate distributed systems from an MSC specification. If, for example, the specification admits some global system behavior where, at some point, progress does no longer depend on the decision of only one controller process, but can be triggered by several independent components, inconsistent decisions might lead an implementation into a deadlock. Those phenomena are known as non-local choice. Conversely, a system satisfying the local-choice property can be considered to be realizable. Similar requirements ensuring implementability are global and local cooperativity. Though the latter are less restrictive and extend the notion of what is realizable, however, they are harder to check.

We are currently developing the tool MSCAn, which converts a ITU Z.120 textual description of a high-level MSC specification into a graph structure that naturally reflects choice, concatenation, and iteration. Based on this architecture, MSCAn applies graph algorithms to
explore a specification and to detect global control structures that do not allow an embedding into a locally controlled implementation providing the user with counterexamples, which may be used for debugging and system refinement.

**MSCEEXECUTE: Generation of Typed Process Skeletons**

*V. Stolz, M. Schlüster*

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). Based on our experience with generating an executable Concurrent Haskell skeleton from an MSC, we develop a Java code-generator which captures static properties of the MSC (definition of variables, typed messages) and allows for composition of MSCs with well-defined interfaces (gates). These properties are checked by the target language compiler and reduce the number of additional explicit checks on the specification. The application uses remote method invocation and threads which allows us to execute sample runs on a single host or even on a set of interconnected machines. Apart from being able to generate stand-alone applications from MSCs, possible applications include test-case generation and black-box testing.

Web server access statistics show that our 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/) remains a valuable resource to the community.

**Runtime Verification of Concurrent Haskell programs**

*V. Stolz, F. Huch (CAU Kiel), R. Theisen*

The lazy functional programming language Concurrent 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) formulae are used to express high-level assertions. We implemented an LTL-checker in Haskell which, driven by annotations in the source program, checks those formulae.

For checking dynamic systems, a template mechanism allows to instantiate placeholder variables in parametrised formulae which generate new formulae on the fly.

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.

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**Runtime Verification using Aspect Oriented Programming and Java 5 Metadata**

*V. Stolz, E. Bodden*

Runtime verification relies on overloading or modifying the program under inspection. This can happen either at load-time or by statically modifying the source code or byte-code. Aspect oriented programming in Java through AspectJ eases this task by allowing to execute arbitrary Java code when patterns in the execution (e.g. method invocation or variable access) of a program match.

The temporal properties to verify are extracted via Java 5 Metadata annotations from the source code and stored in a standardised way in the class file. Thus, automatic manipulation of such data no longer depends on pre-processors. We use this scheme to store a combination of LTL formulae and AspectJ expressions. The automaton-based evaluation of those formulae is driven by the aspects. The AspectJ implementation is optimised in such a way that formula evaluation is only triggered at a fine-grained statically approximated set of interesting events at runtime.

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**Reverse Engineering of UML Specifications from Java Programs**

*M. Weber, M. Keschenau*

We present a reverse engineering approach for UML specifications in the form of class diagrams from Java byte-code. While the focus is on “intuitive” results (which can be understood by a programmer when inspecting source code of the class the analysis has been performed on), we developed code-pattern analyses which go beyond mere enumeration of methods and fields. Specifically, we analyse the following notions of UML class diagrams:

- Association multiplicities,
Compositions, which are particular, stronger versions of associations and

Query methods: methods that do not alter the system state.

### DIVSPIN—A SPIN Compatible Distributed Model Checker

*M. Weber, M. Leucker (TU Munich), L. Brim (MU Brno)*

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

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

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

### Distributed Algorithms Test Bench

*M. Weber, M. Rohrbach, E. Bodden*

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

The tool is aimed at researchers who want to experiment with algorithms in their programming language of choice, without the distractions of having to implement a distributed data processing framework, distributed termination checks, instrumentation for profiling, data structures, etc.
We develop formal semantics for a virtual machine which can be used for state space generation.

Common approaches in explicit-state model checking employ modeling languages like CSP, LOTOS or Promela for the description of state spaces. The semantics of these languages are usually non-trivial: besides concepts found in programming languages (scopes, variables, expressions etc.) they often provide features like process abstraction, non-determinism, communication primitives, timers, etc. Implementing the semantics of languages like Promela for use in verification tools is consequently not straight-forward, even more so if the language is described only informally and static and operational semantics are unavailable.

The goal of this on-going work is the definition of formally specified semantics of a small and straight-forwardly implementable byte-code language which incorporates the above mentioned features in a compositional way, so that tool implementors can choose what is needed and leave out the rest.

In a second step, we will define faithful translation functions for modeling languages like Promela, \( \pi \)-calculus, and Dr\lowercase{Vi}\lowercase{NE} language which enables us to compile them into byte-code.
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)
- Administrative tasks:
  - assignment of undergraduate courses to the teaching personnel
  - student statistics
  - head of Committee for Teaching Service

B. Bollig

- Editor of the Course Guide for students (Kommentiertes Veranstaltungsverzeichnis)

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

Th. Noll

- Organizing committee member of the 4th Workshop on Language Descriptions, Tools and Applications (ETAPS/LDTA'04)
- Referee for Netherlands Organization for Scientific Research (NWO)
- 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
- Organization of teaching service of CS Department (http://www-i2.informatik.rwth-aachen.de/Teaching/Service/)

V. Stolz

- Administrator of the web site for Aachener Informatik–Berichte, the technical report series of the Department of Computer Science.
M. Weber

- Visiting Prof. Luboš Brim, ParaDiSe Labs, Masaryk University, Brno, Czech Republic (November 2004).

Talks and Publications

Talks

B. Bollig: Model Checking Probabilistic Infinite-State Systems, Study Group Talk, School of Computer Science, University of Birmingham, February, 2004

B. Bollig: Message-Passing Automata are expressively equivalent to EMSO Logic, The 15th International Conference on Concurrency Theory (CONCUR 2004), London, UK, August 2004

B. Bollig: The Expressiveness of Message-Passing Automata, Séminaire du Laboratoire Spéciication et Vérification, Cachan, France, November 2004


Th. Noll: Gleichungsbasierte Abstraktionen für Erlang–Programme, Kolloquium über Programmiersprachen, Freiburg, March 17th, 2004

Th. Noll: Termmodelle für nebenläuﬁge Systeme, Informatik–Kolloquium, Rostock University, October 29th, 2004

V. Stolz: Runtime Veriﬁcation of Concurrent Haskell programs, 4th Workshop on Runtime Veriﬁcation, Barcelona, Spain, April 3rd, 2004

V. Stolz: Runtime Veriﬁcation of Concurrent Haskell programs, Theoretical Computer Science Group, University of Kent at Canterbury, April 26th, 2004

Publications


Programming Languages and Verification

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  Stephan Swiderski

- Technical Staff:
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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 June 2004, our group hosted and organized the Federated Conference on Rewriting, Deduction, and Programming (RDP 2004) in Aachen, which consisted of the following conferences, workshops, and scientific meetings:

- 15th International Conference on Rewriting Techniques & Applications (RTA ’04)
- International Workshop on Higher-Order Rewriting (HOR ’04)
- 5th International Workshop on Rule-Based Programming (RULE ’04)
- 13th International Workshop on Functional and (Constraint) Logic Programming (WFLP ’04)
- IFIP Working Group 1.6 on Term Rewriting (WG 1.6)
- 4th International Workshop on Reduction Strategies in Rewriting and Programming (WRS ’04)
- 7th International Workshop on Termination (WST ’04)

The conference was funded by the DFG and it was attended by numerous international scientists which led to a very interesting and attractive program. More information on the
conference can be found at

http://www-i2.informatik.rwth-aachen.de/RDP04/

Moreover, in 2004 we held the first-year course on *Computer Science I – Programming Concepts* for more than 600 students and a lecture on *Term Rewriting Systems*. We also offered seminars on *Termination Analysis*, on *Advanced Topics in Term Rewriting*, 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 et al.*

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 and the competition of the existing termination tools at the International Workshop on Termination (WST ’04) show that our system is currently the most powerful termination prover available. The system can be obtained from

http://www-i2.informatik.rwth-aachen.de/AProVE
This project is a cooperation with the TU Eindhoven, The Netherlands, and the KU Leuven, Belgium. Techniques for automated termination analysis have mainly been developed for term rewriting and for logic programming. However, the connection between the respective techniques from these two fields is not clear. Therefore, our aim is to compare the existing approaches for termination analysis from both areas and to develop new techniques which combine their benefits. In particular, we are working on a new approach to transform logic programs into term rewrite systems such that termination of the resulting term rewrite system implies termination of the logic program. Then all existing techniques and systems for termination analysis of term rewriting can also be used to verify termination of logic programs.

**Transformation and Analysis for Different Evaluation Strategies**

Jürgen Giesl, Aart Middeldorp

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.

**Process Verification by Term Rewriting Techniques**

Jürgen Giesl, Hans Zantema, Peter Schneider-Kamp, Christian Hang

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.

**Combining Program Verification and Decision Procedures**

Jürgen Giesl, Deepak Kapur

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

**Program Transformations for Program Verification**

Jürgen Giesl, Armin Kühnemann, Janis Voigtländer, Christian Haselbach

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)

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

- Member of the *IFIP Working Group 1.6 on Term Rewriting*
• Conference Chair of the *Federated Conference on Rewriting, Deduction, and Programming* (RDP '04), Aachen, Germany

• Conference Chair of the *15th International Conference on Rewriting Techniques and Applications* (RTA '04), Aachen, Germany

• PC-member of the *15th International Conference on Rewriting Techniques and Applications* (RTA '04), Aachen, Germany

• PC-member of the *4th International Workshop on Reduction Strategies in Rewriting and Programming* (WRS ’04), Aachen, Germany

• PC-member of the Doctoral Program at the *2nd International Joint Conference on Automated Reasoning* (IJCAR ’04), Cork, Ireland

• Research visits at the Technical University Eindhoven, The Netherlands

• Participant of the International Workshop “Beyond Safety”, Schloss Ringberg, Germany

• Project reviewer for the DFG and the Israel Science Foundation

• Reviewer for many international journals and conferences

P. Schneider-Kamp:

• Friedrich-Wilhelm-Preis of the RWTH Aachen to award his diploma thesis “*Automating Termination Proofs Using Dependency Pairs and Recursive Path Orderings*”

• Participant of the Marktoberdorf Summer School (NATO Advanced Study Institute) on “*Engineering Theories of Software Intensive Systems*”

• Research visits at the Technical University Eindhoven, The Netherlands

• Reviewer for several international journals and conferences

R. Thiemann:

• Research visits at the Technical University Eindhoven, The Netherlands

• Reviewer for several international journals and conferences

**Talks and Publications**

**Talks**

J. Giesl: *Termination and Liveness in Term Rewriting, Beyond Safety International Workshop*, Schloss Ringberg, Germany, April 2004
J. Giesl: *Termination of Term Rewriting Using Dependency Pairs, TeReSe Symposium, Utrecht, The Netherlands, May 2004*

J. Giesl: *Reducing the Constraints of the Dependency Pair Approach, 7th International Workshop on Termination (WST ’04), Aachen, Germany, June 2004*

P. Schneider-Kamp: *Automated Termination Proofs Using Dependency Pairs, Kolloquium Programmiersprachen und Grundlagen der Programmierung, Freiburg, Germany, March 2004*

P. Schneider-Kamp: *Automated Termination Proofs with AProVE, 15th International Conference on Rewriting Techniques and Applications (RTA ’04), Aachen, Germany, June 2004*

P. Schneider-Kamp: *Verwendung von Logik in praktisch nutzbaren Verfahren zur Programmverifikation, Lecture Logik für Informatiker, University Duisburg-Essen, Duisburg, December 2004*

R. Thiemann: *Proving Termination with AProVE, 7th International Workshop on Termination (WST ’04), Aachen, Germany, June 2004*

R. Thiemann: *Improved Modular Termination Proofs Using Dependency Pairs, 2nd International Joint Conference on Automated Reasoning (IJCAR ’04), Cork, Ireland, July 2004*

S. Falke: *Automated Termination Analysis for Equational Rewriting, LuFG Informatik II, RWTH Aachen, April 2004*

A. Lücking: *Automatische Synthese von Relationen für Terminierungsbeweise, LuFG Informatik II, RWTH Aachen, April 2004*

C. Haselbach: *Transformation Techniques to Verify Imperative and Functional Programs, LuFG Informatik II, RWTH Aachen, June 2004*

C. Hang: *Semantic Labelling and String Rewriting Techniques for Automatic Termination and Liveness Proofs, LuFG Informatik II, RWTH Aachen, August 2004*

**Publications**


J. Giesl, R. Thiemann, P. Schneider-Kamp, and S. Falke: *Automated Termination Proofs with AProVE, Proceedings of the 15th International Conference on Rewriting Techniques and Applications (RTA ’04), Aachen, Germany, Lecture Notes in Computer Science 3091, Springer-Verlag, pp. 210-220*

D. Kapur, J. Giesl, and M. Subramaniam: *Induction and Decision Procedures, Revista de la real academia de ciencias (RACSAM), Serie A: Matemáticas, 98(1): 153-180*

J. Giesl: *Terese, Term Rewriting Systems (Review), Bulletin of Symbolic Logic, 10(2): 223-225*

J. Giesl, R. Thiemann, and P. Schneider-Kamp: *Reducing the Constraints of the Dependency Pair Approach*, *Proceedings of the 7th International Workshop on Termination (WST ’04)*, Aachen, Germany

J. Giesl, R. Thiemann, P. Schneider-Kamp, and S. Falke: *Proving Termination with AProVE*, *Proceedings of the 7th International Workshop on Termination (WST ’04)*, Aachen, Germany

J. Giesl, R. Thiemann, and P. Schneider-Kamp: *Automated Termination Proofs Using Dependency Pairs*, *Proceedings Kolloquium Programmiersprachen und Grundlagen der Programmierung*, Freiburg, Germany


J. Giesl: *Termersetzungssysteme*, Course Notes, 2. edition, 139 pages


A. Lücking: *Automatische Synthese von Relationen für Terminierungsbeweise*, Diploma Thesis, LuFG Informatik II, RWTH Aachen, Germany
Staff

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- Research Assistants:
  
  Dipl.-Inform. S. Becker (CRC 476)  
  Dipl.-Inform. B. Böhlen  
  Dipl.-Inform. C. Fuß  
  Dipl.-Inform. F. Gatzemeier (July – October)  
  Dipl.-Inform. S. Giesecke (until June, funded by Graduate College SCS)  
  Dipl.-Inform. T. Haase (CRC 476)  
  Dipl.-Inform. T. Heller (CRC 476)  
  Dipl.-Inform. M. Kirchhof  
  Dipl.-Inform. B. Kraft (funded by DFG)
Research Assistants continued:

Dipl.-Inform. A. Marburger (until April, funded by Ericsson)
Dipl.-Inform. O. Meyer
Dipl.-Inform. C. Mosler (since November, funded by Graduate College SCS)
Dipl.-Inform. U. Norbisrath (funded by Graduate College SCS)
Dipl.-Inf. U. Ranger

Technical Staff:

M. Breuer (part time 50%)
M. Lerch, Trainee, until February
C. Niewerth, part time 50% CRC 476
T. Nguyen, Trainee
Dipl.-Math. (RUS) G. Volkova
S. Wilms (part time 50% CRC 476)

Student Researchers:


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 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 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:

- Visual Programming (L2)
- Software Development Environments (L2)
- Management of (Software) Development Projects (L2)
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 dynamic nature of development processes, which are continuously evolving during enactment. The management model of AHEAD integrates three underlying models for activities, products, and resources. The model is specified based on graph rewriting in PROGRES.

In 2004, we continued our previous work on support for distributed development processes with AHEAD in several ways. First, the AHEAD system has been improved with respect to its delegation-based cooperation model. The extensions mirror more complicated delegation scenarios: (a) a contractor can work with more than one subcontractor at the same time or a subcontractor can play the role of a contractor for another subcontractor. Second, our work focused on the development of a flexible concept supporting a broader spectrum of cooperation scenarios, so that cooperation will not be constrained to a delegation-based scenario in future. Flexible and dynamically changeable contracts will provide a uniform way to couple development processes across enterprises.

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

In cooperation with other projects within the CRC 476 we have investigated several scenarios for supporting a broader spectrum of cooperation scenarios as well as for the use of workflows within development processes in the chemical industry.
The AHEAD system is based on the UPGRADE framework which provides support for the development of graphical user interfaces for graph-based tools. In 2004, work on the UPGRADE framework focused on consolidation and extension. Based on an extension of the UPGRADE framework by web-based views, the AHEAD system now provides developers with a web-based work environment.

### Conceptual Design in Civil Engineering

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

The building construction process is subdivided into several phases. At the beginning, architects analyze the requirements of the new project and develop a first sketch of the future building. During this early phase, called **conceptual design**, the functionality and organization of the whole building are more important than exact dimensions and material definitions. After finishing the conceptual design, the sketch has to be manually transferred into a CAD tool (constructive design information). The semantics, implicitly stored in the sketch, get lost.

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

In the graph-based approach, the visual language has been extended in 2004 by a possibility to define an object-oriented product model. Thereby and by further extensions, the expressiveness of the visual language could be increased. All new concepts have been implemented in PROGRES. A prototype **Knowledge Editor**, used to demonstrate the usability, has been developed based on the UPGRADE framework.

The semantic web approach and corresponding ontology editors have been investigated in 2004 for the tool extension branch of research, in particular with regard to their potentials in knowledge formalization. An ontology for conceptual design rules has been worked out using the ontology editor Protégé. The consistency analysis, integrated in the CAD tool ArchiCAD, has been extended to be able to process RDF-formatted files exported from Protégé.

The project is financed by the German Research Foundation (DFG) within the scope of the priority program “Network-based Co-operation in Structural Engineering” (SPP 1103)
The domain of eHome systems is gaining more importance due to recent developments in hardware technology and the trend towards pervasive and ubiquitous computing. Research in this area is also attractive 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 investigated. 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.

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 under development. The realization of user interfaces 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. Recent research activities covered the extension of the rule-based service development, the process definition and execution support, and the analysis of integrative scenarios and services across different domains (e.g., comfort, infotainment, and security).

For multimedia applications we developed a multimedia mapper based on OSGi which allows 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 storage of knowledge usable in an automatic configuration and deployment process. For extending the features of this ontology we replaced it by an object-oriented model, which has proven to cover all data needed for automating the configuration and deployment process. Furthermore, the model allowed the tight integration and generation of the eHomeConfigurator tool, enabling the creation of data for the model and the generation and execution of a configuration. We have proven the automation of the configuration and deployment process by this tool.

E-CARES (Ericsson Communication Architecture for Embedded Systems)

A. Marburger, C. Mosler, S. Giesecke, M. Nagl, E. Schultchen
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 (see Ph.D. Thesis of A. Marburger), a reverse engineering tool was developed to enable semi-automated program comprehension. The subproject focuses on the detection, extraction, and visualization of information on system structure and behaviour. 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 in 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.

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.

In the second E-CARES subproject (Ph.D. work of C. Mosler), which started in fall 2004, we regard the restructuring of telecommunication systems including their re-design and re-implementation. The aim is to extend the reverse engineering tool to a functional reengineering tool, allowing the engineers to interactively modify and improve the software architecture.
PROGRES: A language for specifying graph transformations

We have started the development of PROGRES in 1989. PROGRES is based on graphs and allows the easy specification of graph rewriting systems. It is on the one hand a language, which is used to define graph grammars in a visual and clear manner. On the other hand, PROGRES is a development environment which consists of a syntax-controlled editor, an interpreter with a corresponding graph browser, and a compiler which translates the specification into efficient C-Code. At our department we are using PROGRES in various domains, for example for the conceptual design in architecture (ConDes), for analysis of communication systems (E-CARES), and for a management system for development processes in engineering disciplines (AHEAD). As each of these projects has its individual requirements to PROGRES, the system still has to be extended and enhanced.

In 2004 the object-orientation in PROGRES was extended by the self expression for identifying the node on which the current transformation is called. This leads to a comfortable handling of object-oriented specifications. Also, the documentation, consisting of a guided tour and a syntax description, was revised and adapted to the language constructs introduced by the object-orientation.

Additionally, we have analyzed the support for handling large specifications and identified problems with the existing package and module concept. Currently we are investigating how these problems can be solved. Furthermore, we have introduced new language constructs for the communication between various PROGRES prototypes. These language extensions enable the specifier to define different message classes. Messages of the defined classes can be sent and received within graph transformations of PROGRES specifications. In this way it is not only possible to exchange information between several prototypes, but a prototype can even react on changes happening locally in another prototype.

UPGRADE: A framework for developing prototypic applications

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

Work in 2004 focused on the consolidation of the framework. Additionally, several significant extensions have been made according to the needs of the projects at our department that
use the UPGRADE framework and the PROGRES system. For example, the UPGRADE framework has been extended with web-based views and with necessary modifications concerning object-oriented concepts of PROGRES.

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

Integrated development environments and visual language editors often use graphs or graph-like structures as data structures for their documents. A natural way to describe the realization of these tools are graph transformation systems as they are realized by PROGRES. The graph-oriented database management system Gras/GXL provides the foundation for storing these graphs persistently, which has many advantages compared to storing them in main memory — data integrity, virtually unlimited graph size, etc. Unlike its predecessors, Gras/GXL offers a rich graph model and an extendable architecture. Thus, Gras/GXL can be utilized by any application which has to store graphs persistently. To hide the complexity of the Gras/GXL graph model, specialized graph models are implemented on top. Features not provided by Gras/GXL itself can be realized by extension modules, e.g. graph versioning, undo/redo etc.

Up to now the specialized graph models — like the PROGRES graph model — had to be realized manually. In 2004 we started the realization of a generator to generate the mapping for specialized graph models from UML diagrams. We use the XMI export offered by most UML case tool vendors as the input for our generator. Because every UML case tool vendor interprets the XMI standard differently and exports only parts of the UML to XMI, we convert the XMI document into our own format to solve this problem. Afterwards the code for mapping the specialized graph model onto the Gras/GXL graph model is generated by XSLT and Java programs. At the moment we are investigating how OCL constraints can be integrated into this process. Unlike its predecessors Gras/GXL can also be used by graph transformation systems other than PROGRES. To prove this, we started the implementation of a plug-in for Fujaba (From UML to Java and back again) which generates code for the Gras/GXL database system. At the end of 2004 we started with the development of a query language for Gras/GXL. Gras/GXL supports only very few databases as a graph storage at the moment. To solve this problem, we started the realization of a storage module using Java Data Objects (JDO) to support a broader range of database systems.

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**Incremental Integration Tools Supporting Development Processes**

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

Development processes in engineering disciplines are inherently complex. Throughout the development process, different kinds of inter-dependent design documents are created which have to be kept consistent with each other. Ensuring consistency is a difficult task, especially if the documents are handled by heterogeneous tools.
This project, which is part of the CRC 476 IMPROVE, deals with the construction of incremental tools for a-posteriori data integration (integrators). Integrators help keeping documents consistent by offering transformation and incremental change propagation between dependent documents. Integration is controlled by rules. Nevertheless, in general, user interaction is required to choose among different possible options. Integration functionality is realized by establishing and maintaining fine-grained inter-document links between related entities of the documents, which mirror the relationships between the documents’ contents.

In 2004, we semi-formally defined the semantics of integration rule execution by specifying the translation of integration rules into graph transformation systems in the PROGRES language. With the UPGRADE framework for rapid prototyping graph-based applications and the PROGRES code generation capabilities, the graph transformation systems can be translated into executable integrator prototypes with GUI. These can be used to further elaborate the integration algorithm as well as to evaluate integration rules.

Besides the PROGRES-based execution, a C++-based framework is constantly developed for evaluation purposes in industry. This framework implements the same semantics as the PROGRES-based machinery, providing an integration rule interpreter. It supports at-hoc learning of new integration rules and offers interfaces to connect a-posteriori to existing applications.

Several integration tools in the area of chemical engineering were implemented in cooperation with other projects of CRC 476 and in cooperation with our industrial partner Innotec GmbH.

This project, which is part of the CRC 476 IMPROVE, coordinates the software development process for an integrated tool environment to support development processes in chemical engineering. Nowadays, single engineering activities are supported by specialized, isolated tools based on heterogeneous system platforms, proprietary document formats, and different conceptual models. Typically, the overall development process, i.e. the dependencies between activities and their resulting products, the consistency between products produced by individual activities etc. are not considered by the supporting tools.

Therefore, existing, heterogeneous 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. This is done on the architectural level by defining the “gluing parts” necessary for performing the integration. The architecture describes for example what kinds of interfaces the tools to be integrated offer or how interfaces are homogenized by special software components called wrappers. To reduce the development
effort for building the required wrappers the project aims to specify them using a visual model. Based on such a model the executable code for the wrapper is generated afterwards. Modeling a wrapper includes several aspects: the syntax and the semantics of the given tool’s interface to be wrapped, the source interface, as well as of the interface required by the client, the target interface, have to be specified. Furthermore, the transformation of the source into the target interface has to be defined. In 2004, a meta-model formally defining the semantics of such models was developed. The meta-model was specified as a graph transformation system using the PROGRES language. With the help of the UPGRADE framework a first prototype for a visual modeling environment was built. Also, the tool for the interactive exploration of applications offering a COM-interface was integrated with this prototype.

Software Architectures for Embedded Systems
C. Fuß, M. Nagl, J. Beckers, T. Nguyen, R. Wittek

The subject of this project is to improve methods and tools for the design of embedded systems. This project focusses on the design of complex, distributed systems in the automotive industry. Without integration of currently used tools the complexity of future vehicle onboard systems will become impossible to handle. Potentials for reuse, portability, extensibility, and scalability cannot be accessed.

In order to yield practical results with industrial relevance a cooperation with the BMW Group’s development center is planned. At the moment possibilities are explored to introduce integrated modelling of functional networks, software architectures, physical network architectures, and application code into the car manufacturer’s development process.

Text structuring
F. Gatzemeier, M. Lerch, O. Meyer

Our efforts in text structuring are twofold: in the CHASID project, on the one hand, we let the author model the semantical structure of his document. The additional structure is used to support an author in document creation. In the aTool project, on the other hand, we semi-automatically derive the structure of a text as it manifests itself in the typographic layout. Both projects reached their homestretch in 2004. You can read about CHASID’s major results in the dissertations section of this report. aTool will be the topic of a dissertation to appear in 2005.

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

In 2004, the focus of the project went to the creation of constructive error messages. If an error in the XML structure is detected, we compare the actual element sequence with all allowed sequences and derive a list of editing steps that will transform the erroneous sequence into a correct one. These editing steps are then condensed, brought into human readable form and presented to the author.

Other Activities

International Workshop on Graph Theoretic Concepts in Computer Science (WG ’04)

WG ’04 was the 30th occurrence of this international workshop series. The workshop was held in Physics Center, Bad Honnef, near Bonn, from June 21–23, 2004. J. Hromković and M. Nagl acted as Program Co-Chairs and Co-organizers.

The workshop unites theory and practice by demonstrating how graph-theoretic concepts can successfully be applied to various fields of computer science and by exposing new theories emerging from applications. In this way, WG provides a common ground for the exchange of information among people dealing with several graph problems and working in various disciplines.

31 selected presentations formed the program of WG ’04. Two invited speakers, Derek Corneil from Toronto and Roger Wattenhofer from Zurich, gave nice overviews on lexicographic BF search and wireless refactoring, respectively. 65 participants took part in this workshop.

The proceedings were published as volume 3353 of Lecture Notes in Computer Science with both Co-Chairs and B. Westfechtel acting as editors.

Thanks go to DFG, proRWTH, the Rectorate of RWTH Aachen University, and to Swiss Federal Institute of Technology for sponsoring this workshop.

Prototype demonstrations


Kraft, B.: Werkzeugunterstützung für den konzeptuellen Gebäudeentwurf, Condes-Workshop, Aachen, Germany, 5.3.2004

Kraft, B.: Konzeptueller Gebäudeentwurf mit ArchiCAD, DFG-SPP 1103 Workgroup-Meeting: Distributed Product-Modeling, Weimar, Germany, 18.3.2004


Conference Activities and Academic Administration

B. Böhlen: Editor of proceedings of the workshop “AGTIVE 2003”.
C. Fuß: Organizer of the workshop “WG ’04”
F. Gatzemeier: Member of the Regina Testing group
B. Kraft: University teaching position at Aachen University of Applied Sciences; Member of examination board at the chamber of industry and commerce at Cologne
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”; Acquisition of industrial stipends for students and organizing the competition; Intl. Workshop WG’04 Bad Honnef on “Graph-Theoretic Concepts in Computer Science” (PC Chair and organisation together with J. Hromkovic); PC-Memberships: Software Engineering 2005 at Essen, Ada 04 Germany, ICGT 04 Rome, Italy.
U. Ranger: Organizer of the workshop “WG ’04”; Faculty representative for the equality commissioner Ms. Athing.
B. Westfechtel: Student advisor in computer science (Graduate studies); Member of PC and editor of proceedings of the workshop “WG ’04”.

Talks and Publications

Talks
Becker, S.: Rule Execution in Graph-Based Incremental Interactive Integration Tools, 2nd International Conference on Graph Transformations, Rome, Italy, 29.09.2004

Giesecke S.: *E-CARES research project: Interactive, stakeholder-tailored reengineering*, 6. Workshop Software-Reengineering, Bad Honnef, Germany, 03.05.2004

Haase, T.: *Die Rolle der Architektur im Kontext der a-posteriori Integration*, 6th Workshop on Software Reengineering (WSR 2004), Bad Honnef, Germany, 05.05.2004

Ranger U.: *Concepts for Specifying Complex Graph Transformation Systems*, 2nd International Conference on Graph Transformations, Rome, Italy, 30.09.2004

Kraft, B.: *Graphbasierte Werkzeuge für den konzeptuellen Gebäudeentwurf*, Condes-Meeting, Aachen, Germany, 05.03.2004

Kraft, B.: *Konzeptueller Gebäudeentwurf: Aktueller Stand des Projekts*, DFG-SPP 1103 Workgroup-Meeting: Distributed Product-Modeling, Weimar, Germany, 18.03.2004

Kraft, B.: *Graphbasierte Werkzeuge für den konzeptuellen Gebäudeentwurf: Aktueller Stand und Ziele*, DFG-SPP 1103 Reviewers-Colloquium, Braunschweig, Germany, 30.04.2004

Kraft, B.: *Interactive Distributed Knowledge Support for Conceptual Building Design*, 10th International Conference on Computing in Civil and Building Engineering, Weimar, Germany, 03.06.2004


Kraft, B.: *Graphbasierte Werkzeuge für den konzeptuellen Gebäudeentwurf: Aktueller Stand und Ziele*, DFG-SPP 1103 Workshop of the Workgroups, Darmstadt, Germany, 16.11.2004

Kirchhof, M.: *Component-based Development of Web-enabled eHome Services*, Ubiquitous Mobile Information and Collaboration Systems Workshop 2004 (UMICS 2004), Riga, Latvia, 08.06.2004


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Publications


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Overview

Research
In 2004 we have carried on our research projects on software product line development. The product line requirements engineering tool (RequiLine), developed in our group, was substantially enhanced by an interactive means to enter and visualize feature models. A series of presentations and talks were given, which show that our tooling approach is promising and fits most requirements. During 2004 a couple of companies as well as research institutions used RequiLine for evaluation purposes. In autumn a diploma theses was started in cooperation with an industrial partner, which aims to asses and evaluate RequiLine in a large industrial product line project.

Within the context of architecture modeling for software product lines we have developed a first prototype of a plugin for the eclipse platform called PLA-Editor which allows to annotate UML class diagrams with variability information. Currently the plugin supports modeling variability which can be resolved at design time of the products derived from the product line platform. Thereby it assists the designer with a consistency checker which checks the designed architecture for inconsistencies regarding the modelled variability.

Based on the conceptual results on modeling architectures for small embedded devices the development of an architecture modeling tool was started, based on the UML2 standard, called ViPER. Although the tool is far from being complete it validates our chosen architectural and tooling approach.

Beside these project activities we have organized a workshop in the context of the GI conference Modellierung 2004 which was dedicated to the use of feature modeling in product development. Furthermore we have hosted some GI requirements engineering working group meetings and organized the D.A.CH workshop in September. Concerning our teaching activities we enhanced the course on Software Quality Assurance and Project Management by integrating a project management simulation tutorial (SESAM). This tutorial was carried out in cooperation with the software engineering chair of the University of Stuttgart.

In July Holger Schackmann joined our group. He is funded by an industrial partner and is doing research in the area of managing the development and evolution of multi-products in a multi-project context. Until now a concept on interleaved processes focusing on requirements management, project planning, and change management was developed.

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 and Project Management*
• Lecture *Component Technology*
• Lecture *Product Line Development*
• Lecture *Object-Oriented Software Construction*
• Seminars on various topics.
• Practical Labs

**Research Projects**

**Requirements Engineering for Software Product Lines**

*T. von der Maßen, H. Lichter*

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

Modeling 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 modeling is one methodology to express these hierarchies through compositional-relationships combined with variability information.

Ensuring the integrity and consistency within and across feature models are of high importance, too. The derivation of products from the product line models can only be done, if the product line models do not show any inconsistencies. Therefore the research group has defined categories of inconsistencies and identified the problems that can appear within the models.

Our research group has developed furthermore 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 it allows to define queries and consistency checks on the model.

RequiLine’s feature editor

As RequiLine currently supports only a very limited way to derive products, a product derivation wizard is currently under development. This wizard should guide the user through the instantiation process to avoid building inconsistent product derivations. In the current release features and natural language requirements are in the focus. The integration of Use Cases is possible indeed 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.

Feature-based Architecture-Modeling for Software Product Lines

T. Weiler, H. Lichter

External cooperation: ABB Corporate Research, Ladenburg

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. In this project we analyze how variability influences software architecture. For that purpose we have developed a metamodel which allows modeling of variability in arbitrary architecture description languages (ADLs) which are based on entities and relations. This metamodel can be extended by the metamodel of concrete ER-based ADLs like for example uml class diagrams.

Based on this approached a first prototype of a plugin for the eclipse platform called PLA-Editor was developed which allows to annotate UML class diagrams with vari-
ability information. Currently the plugin supports Modeling variability which can be resolved at design time of the products derived from the product line platform. Furthermore the plugin assists the designer with a consistency checker which checks the designed architecture for inconsistencies regarding the modelled variability.

![PLA-Editor Plugin for Eclipse](image)

Currently a methodology which allows smooth transition from requirements engineering to architecture Modeling by using feature models as a basis is developed. While the single phases of the software development process are mostly self-contained with continuous methodology, notation and also adequate tool support, the transitions often exhibit a gap. To bridge this gap, transformations between the different methodologies and notations used in the adjacent phases are needed. But the abstraction needed for these transformations results in information loss.

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

Feature Modeling can assist this task by providing an input for the design process to identify components and structures of the PLPA. Because this process will rarely be a one to one mapping between features and architectural components, we are developing guidelines on how to identify architectural components based on feature models and how to structure them. The methodology developed in this step will later also be integrated in the PLA-Editor.
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 coorporation 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).

**Process and Tool Support for the Maintenance of Hierarchical Product Lines**

*H. Schackmann, H. Lichter*

*External cooperation: Kisters AG, Aachen*

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

In our current work we inspect how the structure of the product line can be considered in processes for change request, task management and configuration management. This approach should facilitate the identification of the many dependencies that exist in the maintenance of the product line. An improved transparency of the different activities and their progress will support the product-line wide coordination and planning.

**Other Activities**

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

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

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

Organization of the Beginner’s Course in Computer Science 2004, H. Lichter, T. Weiler

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

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

Research stay at ABB Corporate Research Germany, Ladenburg, June 2004, A. Nyßen

Talks and Publications

Talks

H. Lichter: Die Hochschule als Karriereziel, ABB Corporate Research, Ladenburg

H. Lichter: Software-Prozessmodelle - Chancen und Risiken für KMU, Workshop Entwicklung von Individualsoftware für den Mittelstand, Forschungsinstitut für Rationalisierung, Aachen


T. von der Maßen: Anforderungen an Requirements Engineering Werkzeuge für Produktlinien, Jahrestreffen der GI-Fachgruppe Requirements Engineering, November, Kaiserslautern

T. von der Maßen: Key challenges in Industrial Product Line Engineering, Multikonferenz Wirtschaftsinformatik, März, Essen


**Publications**

T. von der Maßen: *Anforderungen an Requirements Engineering Werkzeuge für Produktlinien*, Software-Technik Trends, Band 24, Heft 4, ISSN 0720-8928, 2004


M. Schnizler: *Rollenbasierter Test objektorientierter Programme*, Dissertation RWTH Aachen, 2004


Communication and Distributed Systems

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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 Interneting, 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', and 'Privacy Enhancing Techniques'). Practicals in 'Agent Technology' and 'Network Programming' as well as a virtual practical 'Computer Science' were also offered.

For further information please see:

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

Artificial Policy Agents Supporting Time Scheduling in Hospitals

Karl-Heinz Krempels

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

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

Stefan Penz

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 device 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 has developed such a middleware system based on the IETF Service Location Protocol (SLP). In a second step, this service management is currently extended with a component that determines relevant quality parameters of communication paths between the service user and possible service providers. This allows the user to select a provider not only by his properties, but also to consider the characteristics of the corresponding communication path. This is especially important for services that require a minimum bandwidth or a stable communication path for a certain period of time, e.g. telephony applications. The quality parameters can be estimated either by direct end-to-end measuring or by calculation from available quality factors, like signal strength or node movement information. The goal of this project is to identify relevant quality parameters and factors, to develop acquisition and calculation methods for those, and to integrate this system as a component for service provider selection into our service management. The project is part of the German Research Foundation’s (DFG) Priority Programme ’Basis Software for Self-Organizing Infrastructures for Networked Mobile Systems’, which currently comprises thirteen research projects at German universities. The main topics of this program include routing, middleware and application support of mobile ad-hoc networks. More information can be found at [http://www.tm.uka.de/forschung/SPP1140/](http://www.tm.uka.de/forschung/SPP1140/).

**An MPLS-based handover solution for cellular networks**

*Rajendra Persaud*

The convergence of wireless networks is mainly visible in the core networks of cellular systems that are going to comprise a variety of different access technologies. In addition to the 3GPP access technologies, these include e.g. IEEE 802.11 Wireless Local Area Networks or IEEE 802.16 Wireless Metropolitan Area Networks. The handover solutions currently deployed in cellular systems will thus have to be extended or adapted in order to allow seamless packet-switched services between the legacy and the new access technologies. The main incentive for the use of an MPLS-based handover solution is that for inter-technology layer-2 handovers no layer-2 solutions (such as those of IEEE 802.11 or IEEE 802.16) can be used since those do not support handovers between points of attachment of different access technologies. Furthermore, the existing layer-3 solutions such as Mobile IP, Fast Handovers for Mobile IP, HAWAII etc. suffer from several disadvantages such as considerable additional overhead through IP tunnelling and long signalling delays, or they cannot be deployed due to inherent scalability issues. The MPLS-based handover solutions that have already been developed mitigate some of these disadvantages, but suffer from the same long signalling delays and cannot be deployed in cellular systems due to the same scalability issues resulting from the deployment of per-user Label Switched Paths. In this
A mobile ad-hoc network (MANET) is a collection of mobile nodes which communicate over radio. These networks have an important advantage; they do not require any existing infrastructure or central administration. Two nodes can communicate together as soon as they are in communication range. Two nodes apart from each other need the help of intermediate nodes relay their data. Mobile ad-hoc networks are suitable for temporary communication links. This flexibility, however, comes at a price. Communication is difficult to organize due to frequent topology changes. In this project, fundamental questions in regard to mobile ad-hoc networks, which are needed to realize and develop such networks, were considered. While the difference between mobile ad-hoc networks and classical networks are minor, ad-hoc networks have inherently some properties, which make them much more difficult to handle. Especially two aspects of ad-hoc networks make more intricate their realization: The first aspect is the used communication medium, which, compared to wired communication, has higher bit error rates. The other aspect is the dynamic network topology, which is caused by node mobility. These two problems of ad-hoc networks have effects on all communication layers. This project dealt with two main issues in ad-hoc networking. Namely routing and automatic configuration. Routing in ad-hoc networks is aggravated by the dynamic network topology. In the worst case the topology is changing continuously. To guarantee efficient data communication, it is necessary to transmit data packets over a shortest path. This requires high adaptability from routing algorithms. At the same time it is important to take into consideration, that the routing must be realized by all nodes in the ad-hoc network. This project developed a new on-demand routing algorithm based on ant algorithms named ‘ant routing algorithm (ARA)’ and evaluates its performance. The second topic of this project was automatic configuration of ad-hoc networks, since zero configuration networking is also associated with ad-hoc networks. Many investigations assume, that each node in an ad-hoc network has an unique IP-address, but it is an open question how this can be performed. This project developed a distributed algorithm for the assignment of IP-addresses in ad-hoc networks and evaluates the protocol.
Ant Routing in mobile multi-hop Ad Hoc Networks

Martin Wenig, Dirk Thißen

A mobile multi-hop ad hoc network is a set of mobile nodes which communicate by radio and do not require any infrastructure. Due to the limited transmission range of wireless interfaces, packets most likely have to be forwarded by intermediate nodes. Therefore, each node has also to provide routing functionality. As link changes occur frequently in such networks, the network topology is highly dynamic - traditional routing algorithms are useless for efficient and reliable data transfer; instead, adaptive routing algorithms are required to cope with the dynamics of the topology. The goal of this project is to develop and implement a new routing algorithm based on a swarm intelligence concept. The basic idea of the ant algorithm is taken from the behavior of real ants. When ants search for food, they start from their nest and walk towards the food. When an ant reaches an intersection, it has to decide which branch to take. While walking, ants deposit pheromones which mark the selected route. The concentration of pheromones on a certain path is an indication of its usage. This ant behavior is transferred to find the shortest path in a network. The implemented algorithm consists of three phases. In the route discovery phase, a host sends a packet called Forward Ant which discovers the shortest path to the destination node. The destination node responds with a Backward Ant packet. Both are modifying the routing tables of the intermediate nodes by leaving a pheromone value. After route establishment, the route maintenance phase starts. For each passing data packet a node increases its corresponding pheromone value. To model the real world scenario, the pheromone value decreases over time with an exponential function. The third phase is failure handling, dealing with broken paths. When a node detects a link loss, it starts establishment of a new path by sending new ant packets and informing the neighbor hosts which maybe have alternative path information in the routing tables, respectively. The algorithm is implemented as an overlay socket for small handheld devices; a chat application is implemented to demonstrate and observe the routing algorithm.

PRIME - Privacy and Identity Management for Europe

Dogan Kesdogan, Lexi Pimenidis, Tobias Kölsch

PRIME is the name of a 4-year project, conducted within the EU’s 6th Framework Programme. The project was launched March 1, 2004. Its objective is the research into, and development of solutions to empower individuals to manage their privacy in cyberspace. In the online world, every person has to handle numerous accounts and data-sets. These so-called “digital identities” will increasingly play a key role in future electronic services as well as in public security (e.g. border controls). They may very well convey sensitive personal data, such as patient health data, employee data, credit card data, etc. Surveys have shown
that people now feel their privacy is at risk from identity theft and erosion of individual rights. In the Information Society, people want to interact securely and safely while maintaining control of their personal data. PRIME focuses on solutions for privacy enhancing identity management that supports end-users’ sovereignty over their privacy sphere and enterprises’ privacy-compliant data processing. We investigate the means of secure and privacy-friendly communication providing data confidentiality and hiding sender/recipient relationships. To this end we develop and analyse means of encryption and hiding network addresses by means of anonymous communication network layers. However, it is well known that secure communication does not exist without context: it is always as strong as its weakest link. We therefore do some research in general security issues as well, i.e. teaching security in user education, security awareness in risk management, measuring security and applied IT security.

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**Service Management and Trading for Design Tools**

*Yuri Babich, Dirk Thißen*

The Co-operative Research Centre IMPROVE (SFB 476) aims to support and accelerate design processes in chemical and plastic engineering through computer science concepts. It is comprised of several subprojects carried out by computer science institutes working on such concepts for direct and indirect process support as well as subprojects led by engineering institutes that bring in their domain-specific knowledge and ergonomics experts. The subproject *Service Management and Trading for Design Tools* provides the other project partners with a service layer that separates the tools used in the design process from the different underlying platforms. This allows an abstraction from the details of systems, networks and applications. In order to account for the heterogeneity of systems and tools and their physical distribution, the service management is based on the Common Object Request Broker Architecture (CORBA).

The service layer has to guarantee high availability and fault tolerance of the 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 to migrate to a target system from the viewpoint of a maximum efficiency, thus realising a scalable management approach. Likewise, the trading process and service management must ensure a good execution performance of all tools. For this purpose load balancing is performed for distribution of tasks to run. 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. External services that are implemented in the Web Services technology are loosely integrated by means of a gateway. They reside in foreign administrative domains and are subject to heuristic trading decisions and limited management in the service layer.

### Universal Mobility Management for Nomadic Users

*Stefan Diepolder*

Next generation heterogeneous networks with wireless access will integrate today’s telecommunication services with data and value added services. The discussion around contention or co-existence of different broadband access schemes like UMTS, WLAN, and even ADSL will disappear in the near future. It is safe to assume that users are expecting integrated services which combine the advantages of the different technologies. This leads to the need to support not only Terminal Mobility but also an enhanced Session Mobility and Service Portability. That is, networks will have to support Personal Mobility to nomadic users who are crossing network boundaries and service provider domains. Especially the mechanisms necessary for the provision of Service Mobility are only covered insufficiently by today’s management and service provisioning platforms. Therefore, the main purpose of this project is to define a universal management that can cope with the four different types of mobility, and which exploits the dependencies between each of them and the involved objects to support efficient services for nomadic users. During the last years the Parlay/OSA-Framework was defined as a descendant of the TINA initiative, and was adopted by ETSI. Parlay’s interfaces allows an object-oriented view of the resources of a telecommunication network. Moreover, middleware components are being introduced in Signalling and Data Networks. With the proposed management which fits seamlessly into the Parlay Framework it is possible to use object oriented techniques to abstract from users, services, and resources of hard- and software. With the help of the developed simulation tools the different strategies can be tested and evaluated in real world scenarios.

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

*Ralf Wienzek*

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

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

*Carsten Pils, Tim Seipold, Thitinan Tantidham*

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

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

Our solution is to deploy an intermediate hub between the terminals and the service providers. This splits the communication into one half dependant on the access network and terminal, and a middleware dependent server side half, each of which may be implemented and optimized individually.

**URMEL (Ubiquitous RWTH for Mobile E-Learning)**

*Michael Wallbaum*

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

MoPS (MOBILE PROFESSORS AND STUDENTS)- 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 offers RWTH students and employees a high bandwidth, however it also exhibits some drawbacks:

- no or bad connectivity in lecture halls, seminar rooms and public places;
- wired network usage is necessarily stationary;
- the deployment of a wired infrastructure is generally more costly and in some cases not possible at all.
In contrast to that, a Wireless LAN comes at a lower cost, involves less installation effort, and offers its users far greater flexibility. The MoPS-network currently comprises of more than 250 access points spread across some 45 buildings. Many central areas of Aachen University - such as the library, the main mensa, and the Karman-Auditorium are already covered by MoPS and the network is still expanding. In addition, WLAN-coverage also extends to areas where the university is not present, such as train stations, pubs and the main market square. To date, the networks serves several thousand users – during the peak hours of the day nearly 1000 users are seen by the network. MoPS is based on the IEEE 802.11 a/b/g standards and thus offers a bandwidth of up to 54 Mbps per cell. In comparison to mobile communication networks the cell radii are significantly smaller, and hence the available bandwidth usually has to be shared among 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. Examples include the localisation of mobile stations as well as location-based and wireless multimedia services and applications for mobile e-learning. The expansion of the network continues the ultimate aim is to provide city-wide coverage offering RWTH staff and students ubiquitous access to information and communication resources. For more information see http://www.mops.rwth-aachen.de

Transport protocol with tuneable reliability for streaming (TPTR)
Jan Kritzner

Multimedia streaming applications which transport data streams through a mixed wired-/wireless network need a transport-protocol with special 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 wit Tunable Reliability is being developed and refined. In 2004 the work focused on the development further evaluation of developed scheduling techniques, the calculation of priority values, stream switching techniques, and effects of congestion control. The characteristics of the transmission system like 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. Currently, some diploma theses regarding proxy techniques and improved integration of the concepts are under way.

**Access Control in Wireless Sensor Networks**

*Zinaida Benenson*

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

**Ant Algorithm Approach on Routing Protocols for Sensor Networks**

*Kittisak Ormsup*
Existing routing protocols for wireless sensor networks do not perform very well in real sensor applications. The reasons for this include:

1. Gradient Technique (Directed Diffusion, GRAB, GEAR):
   - Gradient setup phase is expensive.
   - It is not energy aware, as the best paths might be used too often.
   - Interest retransmission and alternate path maintenance is needed.

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

3. Clustering Technique (LEACH, TTDD, GEAR, GAF):
   - Failure of cluster heads due to excessive use.
   - Cluster head selection is to be optimized.
   - All nodes assumed to be capable of long range communication.

4. Geographic Technique (GPSR, GAF GEAR):
   - Not energy aware.

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

**NO-REST - Networked Organisations - REsearch into Standards and Standardisation**

*Kai Jakobs*

The NO-REST project aims to investigate the applicability and dynamics of standards in the e-business and e-government sectors, and to develop guidelines for tools for the assessment of their performance, and of the impact they have on networked organisations. To this
end, NO-REST evaluates the various standards development platforms, examines how implementations affect standards and interoperability, and does a pro-active integrated impact assessment. NO-REST looks at the application of standards, and analyses how standards, and their implementations, are subject to change incurred by the environment within which they are implemented. The project will then devise an analytical framework for a causal model of such changes. This, in turn, will help understand the nature of these changes and will allow for the formulation of adequate counter-measures or - even better - for the derivation of conclusions for developing standards in the future, and possible mechanisms to feed back these changes continuously into dynamic standards building. The project also analyses the various standards setting organisations, with a focus on how they react to - and influence - the dynamics of the environment within which they work. This also includes an analysis to which extent the origin of a standard influences its viability in the market place. The project will then establish if, and how, a standard’s origin affects its performance, and will set up guidelines helping those who wish to create a standard decide which standards setting organisation to select. Finally, based on the above, NO-REST is developing, and applying, a methodology to help assess, a-posteriori, the performance of a standard. This will ultimately contribute to guidelines and tools to evaluate - a-priori - the impact a standard will have on the market. The project is co-funded by the European Commission under their Framework Programme 6. Further information may be found at http://www.no-rest.org.

INTEREST - INTEgrating REsearch and STandardisation

Kai Jakobs

Standards are a proven mechanism for technology transfer, fostering the diffusion and utilisation of technology. Thus, standards may be considered as an important aspect of various fields of policy, like innovation, trade and environmental policies. INTEREST aims to support Community policies by improving the interface between research and standardisation. Work started with a literature survey on the types of research and standard products, to be followed by a survey of the different interfaces that exist between research and standardisation. Subsequently, the rationales and incentives schemes that exist within the research communities, and their contacts to standardisation bodies and industry will be collected through a survey-based study. This will also reveal any co-operation patterns (or the lack thereof). Following an indicator based approach, INTEREST will develop a matrix linking the science and technology base of companies (e.g. their patent portfolios) and their standardisation activities. Through case studies the project will analyse the internal organisational structure of the interface between research and the standards department within companies. Thus, solutions and organisational models can be identified suitable to support the transfer of research results into standards and to appropriate results from research institutions in order to transpose them into standards. In addition, the project will analyse the pros and cons of patent pools as a means to transfer complex research
results produced by various partners to standardisation processes and to reduce complex IPR-related problems within standardisation processes. Based on these new insights, and on the taxonomies of standards and research outputs, respectively, a taxonomy will be developed to characterise the typical relationships of the two dimensions. This taxonomy will be the basis to identify relevant combinations between R&D, but also innovation and standardisation and to develop specific policies, since standardisation does not only benefit from R&D, but has also positive impacts on innovation. The project is co-funded by the European Commission under their Framework Programme 6. Further information may be found at http://www.interest-fp6.org

## Talks and Publications

### Talks

### Publications


Laboratory for Dependable Distributed Systems

Staff

- Faculty:
  Prof. Dr. Felix Christoph Freiling geb. Gartner
  http://www-i4.informatik.rwth-aachen.de/lufg/

- Research Assistants:
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  Dipl.-Jur. Maximillian Dornseif
  Dipl.-Inform. Martin Mink

- Student Researcher:
  Michael Becher
  Thorsten Holz
  Andreas Sensen
Overview

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

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 learned and applied most effectively. The aim is to combine these teaching concepts with more “organized” forms of university teaching to give students an idea of a scientifically sound engineering methodology to design, deploy and operate modern information systems in a dependable way.
Safe and Secure Distributed Algorithms

Lucia Draque-Penso Rautenbach, Felix Gärtnert

In this research project we investigate problems that make use of fault-tolerant distributed ideas to solve open issues in the security area, especially in mobile communication systems. Our aim is to give efficient and practical solutions to (mobile) problems, while bridging the gap between fault-tolerant distributed algorithms, which assume random but rather benign faults (such as crashes and message losses), and security protocols, which consider malicious and worst-case types of faults (such as bad intentioned network sniffers).

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

Measuring Security Threats in Communication Networks

Thorsten Holz, Maximillian Dornseif

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

This research project aims at learning more about the tools, tactics, and motives involved in computer and network attacks. We are currently running a Honeynet with several Honeypots that permanently collect data about security threats. In addition, we participate in a research project called Leurre.com that aims at developing a distributed approach to Honeypot-based research. Furthermore, we were able to show limitations of current logging-mechanisms used in Honeypots during a project called NoSEBrEaK.
Forensic science faces great challenges by the fact that information technology now is present in every aspect of our lives. Information technology from PDAs to digital telephone systems, from email to car navigation systems can provide the forensic analyst with a wealth of data to be used. But this data is often hard to access since on one hand the interfaces intended by the designers of the systems were not designed with forensic requirements in mind, on the other hand the internal workings of most of these systems are undocumented or even considered a trade secret. Extracting possible evidence effectively from multitude of sources and aiding the forensic analyst in filtering out the relevant information is still a great challenge.

This project aims at establishing computer forensics as a scientific discipline instead an handicraft. Recognizing the demand not only on tools tactics and techniques to make forensic discovery as effective as possible but also for trained forensic experts by public administration and industry we incorporate the New Teaching Concepts for Applied Computer Security project looking at different didactic concepts for teaching computer forensics to students. One of the main challenges is the need for data which can be used for forensic analysis in a research or in a teaching context. Most data connected to real world incidents is associated with serious privacy and incorporate issues. There the Measuring Security Threats in Communication Networks project allowed us access to a wealth of data related to incidents but uncontaminated with personal or otherwise to be kept secret data.
and try to get a detailed understanding on the workings of attack techniques. Building on this knowledge not only more secure systems can be developed but also testing of existing and future systems can be greatly improved.

**Other Activities**

Prof. Freiling served as a member of the program committee of DISC, the 18th Annual Conference on Distributed Computing, which was held between October 4 and October 7 in Amsterdam, the Netherlands.

Dr. Neeraj Mittal, Assistant Professor at the University of Texas at Dallas, was a guest researcher at the Laboratory in June and July. The topics of collaboration were termination detection algorithms, fault tolerance and failure detectors.

*NoSEBrEaK - Attacking Honeynets*, a paper published by members of the lab won the Best Paper Award at the *5th Annual IEEE Information Assurance Workshop* in Westpoint, June 10 and 11.

The lab organized the *Aachen Summer School Applied IT Security* for three weeks in late September and early October. The summer school was attended by 16 researchers from Great Britain, the Netherlands, Turkey and different parts of Germany. Goal of the summer school was to get a better understanding on how security systems fail in the real world and to foster networking between interested researchers. A detailed review can be found in RWTH Technical report AIB-2005-02.

Maximillian Dornseif visited the *TÜV Secure IT GmbH* for one week of internship in September to foster the exchange between industry and academic research on common security failures.

On February 18, Lars Brückner gave a talk on *The Hacker Contest at TU Darmstadt*, presenting experiences with the *Hacker Contest* at the Darmstadt University of Technology. In this practical security course for CS students, offered since 1999, teams of students have to install and administer “real-life” systems while attacking the systems of the other teams.

In June, members of the group organized a small workshop on Trusted Computing (TC). TC provides a computing platform on which you can’t tamper with the application software, and where these applications can communicate securely with their authors and with each other. TC opens many new possibilities and problems in IT security. This workshop was intended to bring (mostly German-speaking) researchers together and discuss further research directions in the area of TC.

At this year’s UCSB *Capture The Flag* (CTF) contest – a distributed, wide-area security exercise, whose goal is to test the security skills of students from both the attack and defense viewpoints – a team from RWTH Aachen University participated. This team consisted of students which had previously attended lectures or labs offered by the Laboratory for Dependable Distributed Systems. The team reached second place in overall standings and first place in the category “attacks”.

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Since November 2004, the Laboratory for Dependable Distributed Systems is the official German Honeynet Project and member of the Research Alliance of the Honeynet Project. The Honeynet Research Alliance is a trusted forum of Honeynet research organizations worldwide and aims at developing and deploying Honeynets. Furthermore, ideas for further research topics are discussed and the lessons learned with the help of Honeypots are shared.

**Talks and Publications**

**Talks**

Felix C. Gartner: *Sichere Hardware*, FIfF-Stammtisch Aachen, January 26

Maximillian Dornseif: *Open Source: Sicherheit und Vertrauenswürdigkeit*, Regina e.V. Open Source Software-Workshop, Aachen, March


Felix C. Gartner: *Trusted Computing: Vom Fluch und Segen sicherer Hardware*, Forum Informatik, Aachen, April 26

Felix C. Gartner: *Secure multiparty computation with security modules*, Yearly meeting of the “GI-Fachgruppe M-Sec and NETSEC”, Saarbrücken, May 5


Maximillian Dornseif: *Costs and Benefits of Honeynets*, Third Annual Workshop on Economics and Information Security (WEIS04), Minneapolis, May

Maximillian Dornseif, Thorsten Holz: *NoSEBrEaK – Attacking Honeynets*, 5th Annual IEEE Information Assurance Workshop, Westpoint, June

Felix C. Gartner: *Secure Multi-Party Computation with Security Modules*, University of Lübeck, June 14

Thorsten Holz: *FoMSESS-relevante Forschungen an der RWTH Aachen*, Yearly meeting of the “GI-Fachgruppe FoMSESS”, Darmstadt, June 25

Maximillian Dornseif, Thorsten Holz: *NoSEBrEaK – Defeating Honeynets*, Black Hat Briefings USA, Las Vegas, July


Felix C. Gartner: *IT-Sicherheit zwischen Lehre und Praxis*, REGINA Management Treff, RWTH Aachen, July 7

Felix C. Gartner: *Secure Multi-Party Computation with Security Modules*, FernUniversität Hagen, September 29

Thorsten Holz: (Anti-)Anti-Sebek and Distributed honeynets in Europe, Annual Honeynet GetTogether, Chicago, September

Thorsten Holz: Defeating Honeypots, IT Underground Warsaw 2004, October 13

Lucia Draque Penso: How Failure Detectors from Related Problems Relate to Each Other?, Diskussionskreis Fehlertoleranz, Humboldt University, Berlin, November 12

Felix C. Gärtner: Sicherheitsprotokolle mittels fehlertoleranter Protokolle, Diskussionskreis Fehlertoleranz, Humboldt University, Berlin, November 12

Maximillian Dornseif: Owned by an iPod – Hacking by FireWire, PacSec.jp/Core04 conference, November 12

Martin Mink: Das Hacker-Praktikum: IT-Sicherheit zwischen Lehre und Praxis, Tag der Informatik, RWTH Aachen, December 3

Maximillian Dornseif: Hidden Data in Internet Published Documents, 21st Chaos Communication Congress, Berlin, December 27


Maximillian Dornseif: The Art of Fingerprinting, 21st Chaos Communication Congress, Berlin, December 29


Publications

Gildas Avoine, Felix C. Gärtner, Rachid Guerraoui, Marko Vukolic: Gracefully Degrading Fair Exchange with Security Modules, Swiss Federal Institute of Technology (EPFL), School of Computer and Communication Sciences


Gildas Avoine, Felix C. Gärtner, Rachid Guerraoui, Klaus Kursawe, Serge Vaudenay, Marko Vukolic: Reducing Fair Exchange to Atomic Commit, Swiss Federal Institute of Technology (EPFL), School of Computer and Communication Sciences


Alejandro Buchmann, Christof Bornhövd, Mariano Cilia, Ludger Fiege, Felix Gärtner, Christoph Liebig, Matthias Meixner, Gero Mühl: DREAM: Distributed Reliable Event-Based Application Management, Web Dynamics. Adapting to Change in Content, Size,


Maximillian Dornseif, Felix C. Gärtner, Thorsten Holz: *Vulnerability Assessment using Honeypots*, Praxis der Informationsverarbeitung und Kommunikation (PIK), Number 27, Volume 4, pages 195–201


Felix C. Gärtner, Rachid Guerraoui, Petr Kouznetsov: *The CHT play*, Swiss Federal Institute of Technology (EPFL), School of Computer and Communication Sciences
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Tatiana Liberzon
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Overview

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

Informatik V cooperates closely with the Fraunhofer Institute for Applied Information Technology (FIT) of which Prof. Jarke is Executive Director. Two FIT area managers, Professors Wolfgang Prinz and Thomas Berlage, hold cross appointments as Associate Professors in Informatik V; in 2004 Thomas Rose, leader of the business process management group at FIT, received a joint appointment as Associate Professor of Media Processes in the context of the Bonn-Aachen International Center for Information Technology (B-IT) in which Prof. Jarke is one of the Founding Directors. Major B-IT activities in 2004 were the move into the freshly renovated B-IT Building in Bonn, a successful accreditation audit, and the start of a joint European Master with the Universities of Edinburgh and Trento within the prestigious Erasmus Mundus Programme. Other joint activities with FIT include Semantic Web EU project SEWASIE and the European Network of Excellence in Technology-Assisted Learning (PROLEARN). Together with Fraunhofer FIT and with the FIR Institute at RWTH Aachen University, Informatik V won a IBM Shared University Grant in the field of Coopetition in Life Science and Automotive Engineering against strong international competition.

The Aachen-Bonn-Cologne joint Research College ‘Media and Cultural Communications’ (SFB 427), one of the largest DFG-funded projects in the cultural sciences in Germany, was successfully reviewed for the third time in the summer of 2004 and will be funded for the last four years with an again increased budget, quite an unusual achievement in the economically not so easy times. Building on selected results of our work in the recently completed DFG PRIME project and in the Collaborative Research Center on Computer-Assisted Chemical Engineering (SFB 476, IMPROVE), a new BMBF-funded joint project with industry started in the field of experience-based process management in plastics engineering.

After four years as Vice President and Treasurer of GI, the German Informatics Society, Prof. Jarke was elected as GI President for the 2004-2005 election period. Among other activities, he organized a Dagstuhl Perspective Seminar on the Future of Software Engineering Research together with Professors Broy (Munich) and Rombach (Kaiserslautern). Prof. Jarke was also re-elected for another four years as Senior DFG Reviewer for Practical Computer Science.

Several Informatik V researchers took new positions. After completing her habilitation, Priv.-Doz. Mareike Schoop received three offers for Full (C4) Professorships from the universities of Hohenheim, Koblenz, and Vienna, and joined the University of Hohenheim together with three Ph.D. students from Informatik V in the Fall of
2004; she was also recipient of the 2004 Friedrich-Wilhelm Habilitation Prize at RWTH Aachen University. B-IT Assistant Director Dr. Hans Nissen was appointed Professor of Software Engineering at FH Köln, and former Informatik V Graduate Dr. Stephan Jacobs (Ericsson EuroLabs) was appointed Professor of Business Informatics at FH Aachen. Dr. Ralf Klamma served as Substitute Professor at the Universities of Chemnitz and Passau. Thomas List completed his dissertation at RWTH Aachen University and took a position with the NRW Statistics office. Dr. Christoph Quix and Dr. Lemonia Ragia participated in research visits to Microsoft Research in Redmond, Wash. Despite the six employees that left in this way, the net size of the group grew through the addition of eight new researchers and Ph.D. students.

Research Projects

Internet-based community support

M. Jarke, R. Klamma, R. Linde, S. Srirama, C. Valle, J. Mathieu

Since 1995, Informatik V is active in the field of internet-based community support, both in terms of research on community and web service tools and in terms of providing infrastructure for scientific communities worldwide. For example, Informatik V hosted the first website for the city of Aachen in 1995 and, since the same year, manages one of the most successful public-domain internet servers in the German science net, SunSITE Central Europe (http://sunsite.informatik.rwth-aachen.de). Supported by Sun Microsystems with powerful hardware and base software, SunSITE Central Europe focuses on scientific community support, including mirrors of some of the most important research literature indexes, workspaces for internet cooperation, and about 1 TB of open source software. Typically, the SunSITE enjoys several million accesses per month. As one special activity, in 2004 the NRW-funded project WWBIT was completed in which - jointly with the University of Bonn - an internet portal for continuing education by NRW universities was developed together with several concepts of how to improve these offerings and their marketing.

In terms of research, several dissertation projects are ongoing in this field. After completing a highly successful master thesis on the topic of mobile web service provisioning in cooperation with Ericsson EuroLabs, Satish Srirama was accepted into the Ph.D. College “Software for Mobile Communications” where he further refines and evaluates one of the first approaches worldwide to operate a web service provider on smart phones.
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. In December 2004, ConceptBase version 6.1 has been released, which has been registered by more than 100 users within a month. Furthermore, Christoph Quix was invited for a visit of Microsoft Research for three months, working on new techniques for model management and schema matching.

Screenshot of the GUI of CB 6.1
Knowledge discovery, knowledge management and mobile access in combination with trusted security play a crucial role in the business processes of the future. Flexible information and knowledge networks with several partners provide the basis for success in the information society. The “Living Coopetition” initiative of Informatik V, FIT, and FIR aims to enable such networks by powerful concepts and information architectures like services-on-demand. Two case studies will demonstrate the performance of these concepts. While the first case will be elaborated within a knowledge network of automotive suppliers, the second case will be situated within the life science area. The “Living Coopetition” initiative requires a powerful information system infrastructure to achieve its objectives. This includes first of all sufficient computing performance for data management, digital image analysis and processing as well as information retrieval in complex information structures. In particular, we will demonstrate Itanium-based enterprise servers and Opteron-based cluster systems with Thinkpad clients as attractive computing platforms and a software infrastructure centered around WebSphere and DB2.

The main event of the cultural science research center (SFB 427) in 2004 was the successful review of the whole center leading to four further years of funding and especially our subproject ‘Agency in digital social networks by visualization of multidimensional patterns of disturbance’. The subproject ‘Impact of multimedia information systems on communication and knowledge organisation in cultural science projects’ was finished in 2004. We cooperated with RWTH Klinikum and German philology to support a community of aphasics with a specially designed Chat/Talk tool (SOCRATES). Together with colleagues from University of Bochum we developed a technology enhanced course “Pathos and Passion” for students in the cinematics sciences (MECCA-Learn). In the context of this research field, Dominik Lübbers investigates in his ongoing Ph.D. thesis user-adaptive retrieval strategies for music.
databases. Besides preparing the new proposal and consolidating ongoing cooperation and implementation work we presented our results to the scientific audience. In 2004 we co-organized the three day symposium ‘The Ruses of Evidenz’ where we demonstrated our reflective measurement and analysis environment MAVIS. The ongoing cooperation with the research group ‘Narratology’ at the University of Hamburg (Jörg Schöner) was strengthened and extended by a joint workshop in Hamburg together with our colleagues from FIT. We presented MECCA and BSCW as tools for collaborative research and teaching in the humanities. Marc Spaniol participated in a MIT European Media Lab’s workshop on ‘ICT and Education: Incremental Progress or Fundamental Change?’ in Dublin. Additionally, we presented our research results at major events such as I-Know, ICALT, ICCHP, ICWL, PAKM and the Learntec in Karlsruhe.

ATLAS system architecture as a basis for self reflective information systems in the cultural sciences

PROLEARN: Network of Excellence on Professional Learning

M. Jarke, R. Klamma, A. Chatti, S. Steinfels, M. Pienkos, D. Senk, H. W. Gudenhau, K. Mavromatis, A. Babich (and more than 200 other researchers)

Networks of Excellence (NoE) are a new research tool in the 6th framework programme. PROLEARN, started January 1, 2004, is dedicated to join research in the area of professional learning and training focusing on small and medium enterprises (SME). The NoE advances the state of the art in the key areas personalized adaptive learning and interactive media, with learning resources connected to real-world settings and reusable in different contexts. It investigates and advances issues especially relevant for professional training in SME’s and larger companies, including brokerage platforms and services, business models for specific markets, and advanced eLearning and knowledge work management arrangements. To accomplish these goals, the NoE brings together the most important research groups in the aforementioned areas, as
well as other key organisations and industrial partners, thus bridging the currently exist- 
ing gap between research and education at universities and similar organisations and training and continuous education that is provided for and within companies. The NoE focuses on large scale research cooperation and coordination of degree programs in the context of the PROLEARN Academy, setting up a virtual research centre comprising all consortium members, as well as on exchange and transfer activities especially with industrial partners in the context of the PROLEARN Virtual Competence Centre. It integrate existing and future activities of the 19 NoE core partners and more than 200 associated partners, and ensure the critical mass necessary for mutual complementary exchange of technologies, tools, experiences, and scenarios.

SFB 476 IMPROVE

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

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

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

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

In the project “experience-based support for cooperative engineering processes” (B1), work has focussed on the simplification of our underlying PRIME architecture, taking into account the recent contributions made by the field of service-oriented architectures. Some practical experiments were made mostly in the context of plastics engineering applications to try out the practicality of ideas. Current work also focusses on the interaction between the designer and the management layer of engineering work, and on extensions of our decision support facilities.

In the project “goal-oriented management of information flows in engineering design processes” (C1), a process data warehouse is offered as an ontology-oriented infrastructure for semantic access to product and process experience data. Work in 2004 concentrated on including semantic access to documents stored in document management systems, whereas present work focusses on the added problems encountered in the case of inter-organizational cooperation.
MErKoFer
M. Schlüter, M. Jarke, B. Quade, M. Sedlmayr

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

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

After determining the most influential process parameters and applying explorative data mining methods to identify interrelations and temporal dependencies, we correlate product flaws and the according process states. By recording the operator’s actions and evaluating their efficiency, we are able to construct an experience knowledge base. When another problem occurs, we can supply an operator with a number of actions previously accomplished in a similar context. Based on this additional information he has a much better chance to quickly compensate the interference.

TROPOS – Agent-Oriented Requirements Engineering in Strategic Networks
M. Jarke, G. Lakemeyer, G. Gans, D. Schmitz

Inter-organizational networks of people, information and communication systems are often described by the interplay between individual goals and actions and the strategic dependencies among individuals and subgroups. The TROPOS project started in the context of the DFG Focussed Research Programme on Socionics, jointly conducted with the KBS group of Prof. Lakemeyer and the network sociology group of Dr. Funken, and is now expanded in the context of the DFG-funded Graduate School 643 “Software for mobile communication systems”. It aims at improving requirements engineering for such networks by not just representing their goals and dependencies statically, but also by studying the dynamic interactions between both via agent-based simulation through our SNet prototype environment. Key features of SNet are the automatic translation of extended i* models into the process modeling environment ConGolog (via ConceptBase) and to use sophisticated deliberative representatives.
within the simulations. This year’s work concerned extending the modeling facilities by a role concept to allow for higher level modeling (to enable coping with more complex scenarios), introducing inter-agent monitoring, suggestions for specifying the evolution of agents, and import facilities for BPEL process descriptions in order to ease the modeling work.

**BMBF/DFG Information System in Earth Management: From Geodata to Geoservices**

*M. Jarke, L. Ragia, R. Klamma, K. Schetelig (LIH), C. Kiehle (LIH), H. G. Meiners (ahu AG), F. Wendland (FZJ)*

The goal of the project is the development of an information infrastructure for the preparation of heterogeneous geodata according to datadriven rules and independent of scales. To demonstrate the use of the infrastructure an example application - the development of an ground water protection function - is deployed. The role of our chair in the project is to share our expertise in data mining, databases, web services and information systems architectures.

**SEWASIE: Semantic Webs and AgentS in Integrated Economies**

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

SEWASIE is a European project with partners from Germany (RWTH Aachen, Informatik V; Fraunhofer Institute for Applied Information Technology (FIT); Thinking Networks AG) and Italy (Università di Modena; Università di Roma “La Sapienza”; Università 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. Work in 2004 con-
centrated on the implementation of an integrated software prototype that shows the
overall methodology of the SEWASIE project, and the evaluation of the system within
end-users of the textile domain.

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

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

The research group (DFG-Nachwuchsgruppe) is funded by the German Research Founda-
tion (Deutsche Forschungsgemeinschaft, DFG) in their “Aktionsplan Informatik”. The
group is led by Prof. 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 negotia-
tions 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 2004, a
student experiments were conducted in cooperation with the University of Münster and
the University of Hohenheim in order to assess and evaluate our approach implemented
in our negotiation support system Negoisst. Features of the Negoisst system, including
decision and communication support, have been evaluated and their contribution to
performance and effort expectancy have been assessed. It is concluded, that both
types of support are valuable and that a more integrated approach to the design of
Negotiation Support Systems is needed. Negoisst has also successfully taken part in
the annual negotiation tournament. Several 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 buyer and a supplier of pharmaceutical
products) 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 so that different approaches can be compared.
Other Activities

Service
Prof. Jarke’s major administrative and service activities in 2004 included:

- Executive Director, Fraunhofer FIT, Birlinghoven
- Founding Director, Bonn-Aachen International Center for Information Technology (B-IT)
- President, GI German Informatics Society
- member, extended management board of FIR Forschungsinstitut für Rationalisierung an der RWTH Aachen
- Supervisory, Curatory and International Scientific Advisory Board, IBFI, Schloss Dagstuhl
- DFG elected reviewer for practical computer science
- BMBF steering committee for research program IT-2006
- chaired one faculty search committee at RWTH Aachen

Dr. Klamma held stand-in professorships at the Technical University of Chemnitz (summer term 2004) and at the University of Passau (winter term 2004). He is a substitute member of the PROLEARN executive board. Dr. Klamma served as study advisor of the master program Software Systems Engineering.

Prof. Schoop was elected as the chair of the GI Special Interest Group on Electronic Commerce.

Editorial Boards
After more than ten years M. Jarke ended his tenure as 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 a Dagstuhl Perspective Seminar on Challenges for Software Engineering Research in Germany, Oct. 11-12, 2004, together with M. Broy (TU Munich) and D. Rombach (TU Kaiserslautern). In addition, he was a member of the following


C. Quix was member of the programme committee of the 11th International Conference on Artificial Intelligence: Methodology, Systems, Applications (AIMSA 2004), Varna, Bulgaria, September, 2004.

M. Spaniol was member of the programm committee of the symposium “The Ruses of Evidenz”, Cologne, Germany, February 4-5, 2004.

**Software Demonstrations**

Talks and Publications

Talks


M. Jarke: *B-IT: Bonn-Aachen International Center for Information Technology*, Presentations during visit of NRW Research Minister H. Kraft to China, Beijing; Chengdu, Sichuan; Nanjing, Jiangsu; Shanghai, February, 21-28, 2004.


M. Jarke: *A view in the future: how can we exploit information technology to improve our life?*, Invited Talk, Indo-German Young Leaders Forum, Delhi, India, March 20, 2004.

M. Jarke: *Bonn-Aachen International Center for Information Technology (B-IT)*, Presentation, visit of Jiangsu delegation to NRW, Bonn, April 20, 2004.


D. Lübbers: Logic-based Integration of Multi-Feature Music Information Retrieval, ISMIR Graduate School, Barcelona, October 8, 2004.


**Publications**

**Journal Articles**

T. Berlage: *IT-Unterstützung bei bildbasierten Experimenten*, LITUS 2/2004


Conference and Book Contributions


Knowledge-Based Systems & Cognitive Robotics Group

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Overview

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

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

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

In collaboration with Hector Levesque at the University of Toronto, we have been investigating basic issues in knowledge representation regarding the logic of knowledge bases and tractable forms of inference. This work has led, among other things, to a book recently published by MIT Press. Gerhard Lakemeyer is also the co-editor of the book “Exploring AI in the Next Millennium,” published by Morgan Kaufmann, which features a collection of “best” papers in a wide range of areas in Artificial Intelligence.


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 of 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 Networks.

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

*Gero Iwan, Gerhard Lakemeyer*

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

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

**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.
Sound Source Localization for a Mobile Robot

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

The aim of this work is to equip a mobile robot with a method of sound source localization by using biologically inspired algorithms. The Jeffress model has been a fruitful scheme for understanding the representation of 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 workshops.

Membership in Editorial Boards

G. Lakemeyer is an Associate Editor of the Journal of Artificial Intelligence Research.

Research stays

G. Lakemeyer visited the University of Toronto in March 2004.
Publications


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  St. Petersburg State University, Russia
  since Nov. 2004
  Prof. Dr. Srinivasan Umesh
  Indian Institute of Technology – Kanpur, India
  since Jul. 2004
Overview

The Lehrstuhl für Informatik VI is concerned with research on advanced methods for statistical pattern recognition. The main application of these methods is in the field of automatic processing of human language, i.e. the recognition of speech, the translation of spoken and written language, the understanding of natural language and spoken dialogue systems.

The general framework for the research activities is based on statistical decision theory and problem specific modelling. The prototypical area where this approach has been pushed forward is speech recognition. Here, the approach is expressed by the equation:

\[
\text{Speech Recognition} = \text{Acoustic–Linguistic Modelling} + \text{Statistical Decision Theory}
\]

The characteristic advantages of the probabilistic framework and statistical decision theory are:

- The approach is able to model weak dependencies and vague knowledge at all levels of the system.
- The free parameters of the models can be automatically learned from training data (or examples), and there exist powerful algorithms for this purpose.
- Using the Bayes decision rule (as derived from statistical decision theory), the final decision is made by taking all available context into account. For example, in large vocabulary speech recognition, a sound is always recognized as a part of a word, which itself is part of a sentence. This allows the optimal feedback from the syntactic–semantic constraints of the language down to the level of sound recognition.

From speech recognition, we have extended and are still extending this approach to other areas, in particular the translation of spoken and written language and other tasks in natural language processing.

For language translation, the approach is expressed by the equation:

\[
\text{Language Translation} = \text{Linguistic Modelling} + \text{Statistical Decision Theory}
\]

This approach has been started in projects like VERBMOBIL (German project) and EUTRANS (European project). The experimental comparisons with traditional rule–based and other competing approaches show that the statistical approach is at least competitive in terms of performance, if not superior. In addition, it offers a couple of advantages like increased robustness and easy adaptation to a new task. In the final large–scale end–to–end evaluation of the VERBMOBIL translation project, the RWTH Aachen translation approach achieved a sentence error rate which was lower by a factor of two in comparison with three competing translation approaches.
In summary, the research activities of the Lehrstuhl für Informatik VI cover the following applications:

- speech recognition
  - large vocabulary recognition
  - multi-lingual speech recognition
  - speaker independent and adaptive speech recognition
  - robust speech recognition
- machine translation of spoken and written language
- natural language processing
  - document classification
  - language understanding
  - spoken dialogue systems
  - part-of-speech tagging and text annotation
- image recognition

Most of these research activities have been or are carried out in the framework of European projects (see below). In addition, there are bilateral research projects with companies.

**Selected Research Projects**

**EU Project TC-STAR**  
(Technology and Corpora for Speech-to-Speech Translation)

TC-STAR is a concentrated three year effort for advanced research in all core technologies for speech-to-speech translation: speech recognition, translation, and synthesis. This EU integrated project targets at selection of unconstrained conversational speech domains i.e. broadcast news and speeches in a few languages relevant for Europe's economy and society: Chinese, European English and European Spanish. The technical challenges and objectives of the project focus on the development of new algorithms and methods, integrating relevant human knowledge which is available at translation time into a data-driven framework. Examples of such new approaches are the integration of linguistic knowledge in the statistical approach of spoken language translation, the statistical modelling of pronunciation of unconstrained conversational speech in automatic speech recognition, and new acoustic and prosodic models for generating expressive speech in speech synthesis. This work is supported by the collection of language resources and the setup of an evaluation infrastructure.

The Lehrstuhl für Informatik VI is involved in several work packages of this project. We are building the European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation. The EPPS corpus consists of acoustic data, corresponding transcriptions, and
parallel texts/translations of plenary sessions of the European parliament in the languages English and Spanish. We develop translation systems for Chinese-English, Spanish-English, and English-Spanish as well as automatic speech recognition systems for English and Spanish in the EPPS domain. In the area of machine translation, we are involved in research on innovative translation methods, use of human-supplied knowledge, and on the integration of machine translation and speech recognition. In the area of speech recognition we work on lightly supervised transcription, new optimization criteria, and open vocabulary methods.

EU Project TT2 (TransType2)
The aim of TransType2 is to develop a computer-assisted translation 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 computer-assisted translation paradigm, in which the human translator ensures high-quality output; and the machine translation paradigm, in which the machine ensures significant productivity gains. Another innovative feature of the system is that it has two input modalities: text and speech. Six different versions of the system are developed for English, French, Spanish and German which are evaluated by two professional translation agencies. Lehrstuhl für Informatik VI contributes to improving the translation technology; and systems are set up for all six language pairs. Additionally, we extend the system by a speech interface for German to make the system more convenient for human translators.

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 at the creation of 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.

Our group is involved in the comparative evaluation of baseline systems and in the integration of statistical machine translation with speech recognition. In particular, a benchmark for speech translation is developed to work under well-defined and shared experimental
conditions. Research activities focus on speech translation, minimum error training, improved translation models, as well as the integration of linguistic knowledge into the statistical machine translation framework.

**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 Modelling for Image Object Recognition**

The aim of the project is to investigate suitable statistical models for image object recognition on three levels: modelling of object appearance using maximum entropy models; modelling of the variability of image objects using hidden Markov models; modelling of complex scenes 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.

At Lehrstuhl für Informatik VI, emphasis is put on the research in the domain of automatic image categorization and the evaluation of different features for medical image retrieval.

![Figure 1: Examples from the IRMA Database](image-url)
National and International Evaluation Campaigns

- **NIST 2004 Chinese–English Machine Translation Evaluation**
  In 2004, we took part in the NIST machine translation evaluation for translation of Chinese news text into English. Among leading research groups from all over the world, our system was ranked among the best systems in this evaluation.

- **IWSLT 2004 (International Workshop on Spoken Language Translation)**
  In 2004, the C-STAR consortium organized the first evaluation campaign for speech translation. The task was the travelling domain, the translation directions were Japanese to English and Chinese to English. The Lehrstuhl für Informatik VI took part in this evaluation and achieved first or second positions (depending on conditions and evaluation criterion) among 13 research groups.

- **CLEF/ImageCLEF Image Retrieval Evaluation 2004**
  In 2004, we took part in the ImageCLEF content-based image retrieval evaluation for medical images. Among leading research groups from all over the world, our system was ranked first when only visual information was used, and it was ranked among the best systems when allowed to use additional text and user feedback.

- **Data Mining Cup 2004**
  In 2004, a team of three students from Lehrstuhl für Informatik VI took part in the Data Mining Cup organized by the Chemnitz University of Technology, prudsys AG, and Quelle AG. They achieved the 1st, 3rd, and 5th place out of 97 participants from national and international universities.

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**Speech Recognition**

Today, state-of-the-art systems for automatic speech recognition are based on the statistical approach of Bayes decision rule. The implementation of Bayes decision rule for automatic speech recognition is based on two kinds of stochastic models: the acoustic model and the language model which together are the basis for the decision process itself, i.e. the search for the most probable sentence. These modules of an automatic speech recognition system (cf. Figure 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 in a context dependent way.

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. Statistical methods provide a general framework to model such redundancies robustly. Therefore state-of-the-art language models usually are based on statistical concepts.

- The 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, which is done efficiently using dynamic programming. The efficiency of the search process is increased by pruning unlikely hypotheses as early as possible during dynamic programming without affecting the recognition performance.

At Lehrstuhl für Informatik VI, the following research directions related to all main areas of automatic speech recognition were pursued in 2004:
The European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation between English and Spanish was built. This corpus consists of transcribed speech and parallel texts in the languages English and Spanish and is based on corresponding TV broadcasts and internet publications.

Extraction methods for novel acoustic features were developed to capture relevant articulatory information not extracted by former extraction methods used in automatic speech recognition. Also, investigations on different acoustic feature combination methods were carried out.

Research on speaker normalization and adaptation and their relation was done, from which restricted speaker adaptation methods were derived.

In pronunciation modelling, methods for automatic phonetic transcription were developed and applied to the detection of out-of-vocabulary words.

Discriminative model combination using a variety of discriminative optimization criteria was developed.

Methods for discriminative training were enhanced and a variety of discriminative training criteria were compared.

Transducer-based search architectures were implemented efficiently and tested.

A transducer-based approach for the integration of speech recognition and machine translation search for speech-to-speech translation was developed.
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.

Figure 4: Architecture of a Statistical Machine Translation System
At Lehrstuhl für Informatik VI, the following research directions related to the main topics of machine translation were pursued in 2004:

- A *computer-aided translation system* that aims at supporting human translators by an interactive machine translation environment was implemented. This system was enhanced with a speech interface and with methods that try to detect errors in automatically generated translations. This system was successfully tested in translation agencies in several evaluation rounds. It was shown that productivity of human translators increases through the use of this system.

- The translation from Chinese into English was improved by handling phenomena like Chinese word segmentation, sentence segmentation, categorization of named entities, and pre- and post-processing.

- A new translation system was developed at Lehrstuhl für Informatik VI which is based on *finite state transducers*. This allows for a tighter integration between speech recognition and translation in speech translation systems.

- Furthermore, the integration of different types of language resources into a statistical machine translation was investigated. The focus was on translation from an inflected language – like Spanish or German – into English. Knowledge about morpho-syntax (such as part-of-speech tags and baseforms of words) was exploited to improve translation quality.

- Several methods that improve the quality of statistical *word alignment* were investigated in 2004, such as a symmetric lexicon model, incorporation of language resources like baseforms and part-of-speech tags, and new algorithms.

- Since suitable training data is crucial for the statistical approach to machine translation, *corpus processing* tasks like pre- and post-processing, automatic sentence alignment, and corpus filtering were studied.

- We investigated several ways of modelling *word reorderings* between languages with different structures.

- In the area of language modelling, we developed clustered language models for different classes of sentences. This accounts for the fact that word order e.g. in questions is different from that in exclamations.

- A new research area is the automatic translation between German written text and *German Sign Language*. Parallel corpora were assembled in order to set up a statistical machine translation system. The translation system itself is optimized for scarce resources, a major problem in Sign Language research. Combined with speech input and a graphical output, the system aims at the support for deaf people.

- Since the output of machine translation systems often contain erroneous words, we investigated so-called *confidence measures* that automatically detect mistakes made by the system.

- We developed refined lexicon models for statistical machine translation that make use of maximum entropy modelling.
Optimization strategies for statistical machine translation systems were implemented and compared.

**Natural Language Processing**

The goal of *natural language processing* is to design and build computer systems that are able to analyze natural languages like German or English, and that generate their outputs in a natural language, too. Typical applications of natural language processing are language understanding, dialogue systems and text annotation.

The development of statistical approaches for these applications is one of the research activities at the Lehrstuhl für Informatik VI.

In *natural language understanding*, the objective is to extract the meaning of an input sentence or an input text. Usually, the meaning is represented in a suitable formal representation language so that it can be processed by a computer.

We developed a spoken dialogue system for the domain of a telephone directory assistance. A large vocabulary continuous real-time speech recognition component as well as a natural language understanding unit and a dialogue manager are integral parts of the system. The implementation of the dialogue system is independent from the application’s domain.

In part-of-speech tagging, each word is labeled with its word class (noun, verb, adjective, etc.). More generally, *tagging* is the task of labeling each word in a sentence with its appropriate tag; "appropriate“ being defined by the task. We developed a tagger using the maximum entropy framework which has been successfully evaluated on different tasks, like named entity recognition, part-of-speech tagging, shallow parsing, true casing and natural language understanding. The obtained results show a state-of-the-art performance.

**Image Recognition and Retrieval**

The experiences gained in human language technology and statistical pattern recognition are applied to the recognition of objects in images. So far, the main emphasis has been put on recognition of single objects using appearance-based methods (examples are shown in Figures 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 2004, the experiences gained in image processing and recognition were applied to content-based image retrieval tasks, and a quantitative evaluation of different aspects of image retrieval was performed. Classification of image objects using local patches in connection with statistical learning methods is another promising research topic.
Experiments in the domain of gesture and sign language recognition showed that the appearance-based approach is very competitive with other existing methods.

![Figure 5: Examples of single objects to be recognized (Caltech database)](image)

![Figure 6: Examples from the USPS database](image)

**Other Activities**

In the projects, various operational prototype systems have been set up, such as:

- Computer aided translation system TRANSTYPE2
- Speech-to-speech-translation system LC-STAR
- Dialogue system for telephone directory assistance
- Image Retrieval Engine FIRE (Flexible Image Retrieval Engine)
  
  http://www-i6.informatik.rwth-aachen.de/~deselaers/cgi_bin/fire.cgi

Among other demonstrations, the TransType2 prototype was shown at the IST Event 2004 in The Hague, and the FIRE engine was demonstrated at DAGM 2004 (Tübingen), ICPR 2004 (Cambridge, UK), and CLEF Workshop 2004 (Bath, UK).

**Publications**

O. Bender, R. Zens, E. Matusov, H. Ney, “Alignment Templates: the RWTH SMT System”, *Int. Workshop on Spoken Language Translation (IWSLT)*, Kyoto, Japan, pp. 79-84, Sep. 2004


E. Matusov, M. Popovic, R. Zens, H. Ney, “Statistical Machine Translation of Spontaneous Speech with Scarce Resources”, *Int. Workshop on Spoken Language Translation (IWSLT)*, Kyoto, Japan, pp. 139-146, Sep. 2004


H. Ney, M. Popović, D. Sündermann, “Error Measures and Bayes Decision Rules Revisited with Applications to POS Tagging”, *Conf. on Empirical Methods in Natural Language Processing (EMNLP)*, Barcelona, Spain, pp. 270-276, July 2004


**Dissertations**

F. Hilger: *Quantile Based Histogram Equalization for Noise Robust Speech Recognition*

Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr. Harald Höge
December 2004
Logic & Theory of Discrete Systems

Staff

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

- Secretary:
  Marianne Kuckertz

- Research Assistants:
  Dipl.-Inform. Jan Altenbernd
  Dr. Mikhail Kats
  Dr. Christof L"oding
  Dr. Volker Penner
  Dipl.-Math. Philipp Rohde
  Dipl.-Inform. Nico Wallmeier
  Dipl.-Math. Stefan W"ohrle

- 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).

Research Projects

Algorithmic Model Theory

Ch. Löding, W. Thomas, S. Wörle
together with Th. Colcombet (Rennes)

One of the main challenges in model-checking is to extend the methodology to finitely presented infinite graphs. In this area, we focussed on properties which are expressible in monadic second-order logic (MSO) and developed new methods for the transformation of structures (MSO-transductions). In [3], a model of deterministic tree transducer was introduced and connected with conditions on MSO-definability. This model can be used in the study of unravellings of transition graphs.

In the dissertation project of S. Wörle weaker logics were investigated, however powerful enough to express reachability conditions (as needed e.g. in verification). It was investigated how given structures can be composed by various product operations (with synchronization constraints) without spoiling the decidability of the model-checking problem. We obtained corresponding "composition theorems" and showed tight bounds which exist when one tries extensions. The results were presented at LICS 2004 (see [10]).

Automata and Languages

M. Kats, Ch. Löding, W. Thomas, v.d. Bussche

In this research we study the connection between language theory and logical formalisms used e.g. in data base theory.
In the paper [1], a problem of special data base theory was solved by reducing it to a language theoretical question (on the power of first-order logic over strings). This research was done in cooperation with M. Benedikt, J.v.d. Bussche (University of Limburg) and Th. Wilke (Kiel). Further research dealt with acceptors with dynamically changing transition functions, and with a corresponding generalized theory of recognizability (cf. [5]).

Infinite Games

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.

Algorithmic solution of games

Ch. Löding, W. Thomas
funded by EU

Two-player games were analysed on different classes of infinite graphs. These “game arenas” may be transition graphs of pushdown automata and the (more general) graphs of the “Caucal hierarchy” (transition graphs of higher-order pushdown automata), or may be derived from specifications of high-level languages like Life Sequence Charts. Concerning the first domain, we studied in a cooperation with P. Madhusudan (Chicago) and O. Serre (Paris) the new class of ”Visibly pushdown games”, a class where winning conditions of level 3 of the Borel hierarchy occur naturally and where an algorithmic synthesis of winning strategies was developed (see [6]).
In a second cooperation (with Y. Bontemps, P.Y. Schobbens, Namur) we developed a game-based analysis algorithm for Life Sequence Charts, introducing a new kind of “merciful” winning strategies. This work was published in [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 (and even of local) saboteur moves is PSPACE-hard. For the second aspect, a modal logic was developed including an edge deletion modality, and it was shown that this new logic resembles first-order logic in many ways.

The results obtained in 2004 are presented in [8]. Current work is concerned with model-checking games for sabotage logics with fixed points.

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).
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.

**Other Activities**

W. Thomas

- Dean of the Faculty of Mathematics, Computer Science, and Natural Sciences of RWTH Aachen, since October 2004 (Vice-Dean until October 2004)

- Chairman of the Board of Referees in Computer Science of the German Science Foundation (DFG), until April 2004

- Member of the steering committee of the International Conference on Developments in Language Theory (DLT)

- Program Committee Member of the following conferences:
  - 11th Conference on Logic for Programming, Artificial Intelligence and Applications Reasoning (LPAR 2004, Montevideo)
  - Foundations of Software Science and Computation Structures (FOSSACS), Lisbon, March 2005

- Member of the Editorial Board of the following journals:
  - ACM Transactions on Computational Logic
  - RAIRO Theoretical Computer Science and Applications
  - Discrete Mathematics and Theoretical Computer Science

- Chairman of the German Section of the European Educational Forum (EEF)

- Member of 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
W. Oberschelp

- Member of the interdisciplinary working group “Karolingisches Aachen” at the RWTH Aachen
- Member of the preparing committee for the “Odysseum Cologne”, guided by FAW Ulm (F. J. Radermacher). Responsible for the topic “Computers” together with C. Drösser (Die Zeit)

Talks and Publications

Talks

C. Löding: Deterministic Transducers over Infinite Terms, Final Meeting of the ADVANCE Project. LIAFA, Université Paris 7, January 2004

C. Löding: Sabotage Modal Logic, Séminaire Vérification. LIAFA, Université Paris 7, February 2004

C. Löding: Computing Obliging Winning Strategies for Games on Finitely Colored Graphs, Séminaire du LSV. Cachan, France, May 2004

C. Löding: Visibly Pushdown $\omega$-Languages: Determinization and Topological Complexity, Séminaire automates. LIAFA, Université Paris 7, June 2004

C. Löding: Visibly Pushdown Games, Annual Meeting of the RTN “Games and Automata for Synthesis and Validation”. Bordeaux, France, September 2004

C. Löding: Ground Term Rewriting Graphs, Workshop on Automata, Structures, and Logic. Auckland, New Zealand, December 2004

W. Oberschelp: A collection of mathematical problems from Carolingian Times: Alcuins Propositions (in German), Aachen, Karolingisches Aachen, May 13, 2004

W. Oberschelp: The Venus transit 2004 (in German), Students excursion to the observatory Hoher List (Eifel) with observation of transit, June 8, 2004

W. Oberschelp: Farewell addresses for the Diploma Graduates in Informatics, Sommerfest June 9, Tag der Informatik December 3, 2004

W. Oberschelp: Perspectives in Computer Architecture (in German), Workshop for Teachers, Dagstuhl, Dezember 10, 2004

Ph. Rohde: Network Ressource Allocation, Arbeitsgemeinschaft Logik und Automaten, RWTH Aachen, October 14, 2004, Aachen, Germany


Ph. Rohde: Network Ressource Allocation, GI-Dagstuhl-Seminar “Game-Theoretic Analyses of the Internet”, August 30 - September 3, 2004, Schloss Dagstuhl, Germany
W. Thomas: *The algorithmic theory of infinite games*, Université Rennes, March 18, 2004

W. Thomas: *Finite Automata and Algorithmics over Infinite Graphs*, Invited address, Colloquium in honour of Arto Salomaa, Turku, July 11, 2004

W. Thomas: *Das Rechnen mit Wissen: eine historische Perspektive*, ETH Zürich, November 25, 2004

N. Wallmeier: *Game-theoretic Analysis of Life Sequence Charts*, Graduiertenkolleg “Software für mobile Kommunikationssysteme”, February 2004


S. Wöhrle: *Model Checking Synchronized Products of Infinite Transition Systems*, Annual Symposium on Logic in Computer Science (LICS), Turku, July 2004

**Publications**


Mathematical Foundations of Computer Science

Staff

- Faculty:
  
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  Vince Barany
  Dietmar Berwanger
  Lukasz Kaiser
  Antje Nowack
Overview

The research group on Mathematical Foundations of Computer Science is part of the Department of Mathematics, but there is a very intensive collaboration, both in research and teaching, with the Department of Computer Science, most notably with the research group Computer Science VII (Prof. Wolfgang Thomas).

The main research areas of the group are logic, the theory of infinite games, and complexity, with particular emphasis on logic for computer science, algorithmic issues in logical systems, computational model theory, and descriptive complexity. On the methodological side, fixed point logics, games, and automata play a central role in our research.

Research Projects

Games and Automata for Synthesis and Validation (GAMES)

www.games.rwth-aachen.de

E. Grädel, D. Berwanger, L. Kaiser, J. Obdrzalek
(and Research Group Computer Science VII of Prof. W. Thomas)

GAMES is an EU Research Training Network (RTN), co-ordinated by E. Grädel, which includes seven European sites (Aachen, Bordeaux, Edinburgh, Paris, Uppsala, Vienna, Warsaw) and one site from the USA (Rice). The Aachen node of the network includes our research group and the one led by Prof. W. Thomas.

The goal of the network is the development of specification and validation methodologies that are based on games and automata, for guaranteeing the reliability, correctness, and efficiency of large computing systems. More specifically, the research objectives are the following.

A. Foundations: Games, automata, and logic. The combination of automata, game theory, and applied logic constitutes a powerful theory with important practical applications. However, the present state of the theory still has essential gaps in central issues. Challenging problems concerning the mathematical foundations of infinite games and the interplay between automata, games, and logics have to be solved and a deeper integration of concepts from automata, games, and logics is needed for obtaining wider applications.

B. Reactive computation. We want to make progress in a so-far unexploited potential of infinite games, namely to develop them as a model of reactive computation. Our aim is to devise game-based methods for the automatic synthesis and testing of reactive controllers.

C. Verification: New Frontiers. Model checking techniques have been applied with great success to the verification of hardware. One of the big challenges for this network is to
extend the verification methodology so as to deal with broader classes of systems, including important classes of software systems.

D. Web Technologies: Queries and Protocols. Mobile Computing, e-Business, and the World Wide Web have dramatically changed the way in which data are stored and manipulated. New technologies have emerged, with a strong demand for better foundations and efficient algorithmic strategies, and with new validation and security problems. We will exploit the methodological proximity between databases and verification to develop game and automata based techniques for query evaluation and for the new validation tasks in this area.

Algorithms and Complexity for Logic Problems
E. Grädel, D. Berwanger

The goal of this research is the design and analysis of decision algorithms and complexity issues for logic problems that are relevant for computer science. Application areas where these problems arise include, for instance, the specification and verification of hardware and software, databases, and knowledge representation. 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.

Computational Model Theory and Descriptive Complexity
E. Grädel, D. Berwanger, V. Barany

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.

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**Abstract State Machines**

*E. Grädel, A. Nowack*

Abstract State Machines (ASM) are a successful formalism for the specification of large discrete systems. The success of ASM is based on several properties. ASM bridge the gap between formal models of computation and practical specification methods, they can model any algorithm at its natural abstraction level, and they provide executable specifications. (For background on ASM, see www.eecs.umich.edu/gasm.)

The goals of our project are on the one hand a systematic study of the applicability of model checking methods for ASM. We want to identify classes of ASM and specification logic for which automatic verification algorithms are possible. On the other hand, we want to provide model-theoretic and complexity-theoretic foundations of the ASM methodology. In particular we aim at

- The classification of the fundamental algorithmic problems related to ASM according to their complexity.
- The systematic development of a complexity theory for ASM,
- Definability issues for ASM in suitable specification logics,
- The development of model-theoretic tools for ASM, in particular a composition theory.
Other Activities
Erich Grädel

- Co-ordinator of the European Research Training Network *Games and Automata for Synthesis and Validation* (GAMES).

- Member of the Editorial Board of The Bulletin of Symbolic Logic, (Reviews Editor for Logic in Computer Science).

- Member of the Editorial Board of *Logical Methods in Computer Science*

- Member of the Programme Committee of the Annual EACSL Conference on Computer Science Logic, CSL 2004, Karpacz, Poland.

- Member of the Programme Committee of the 11th International Conference on Logic for Programming, Artificial Intelligence and Reasoning LPAR 2004, Montevideo.

Talks and Publications

Talks
D. Berwanger: *Automata for Guarded Logics*, ESSLLI Workshop on Guarded Logics, Nancy, August 2004

D. Berwanger: *Combinatorial Auctions. Truthfulness at the Approximability Frontier*, GI-Seminar on Game-Theoretic Analyses of the Internet, Dagstuhl, August 2004

D. Berwanger: *The Variable Hierarchy of the Mu-Calculus is Strict*, GAMES Annual Meeting, Bordeaux, September 2004

D. Berwanger: *Hope and Trust in Infinite Games*, Logics and Semantics Seminar, University of Cambridge, October 2004


E. Grädel: *Jeux de Muller avec un nombre de priorités infini*, Workshop Complexité, Modèles Finis et Bases de Données, Lausanne, May 2004.


L. Kaiser: *Network Design Games with Selfish Agents*, GI-Dagstuhl-Seminar Game-Theoretic Analyses of the Internet, September 2004

L. Kaiser: *Game Reductions and Finite Appearance Records for Infinite Games*, GAMES Annual Meeting, Bordeaux, September 2004


A. Nowack: *A Guarded Fragment for Abstract State Machines*, ESSLLI 2004, Nancy, August 2004

**Publications**


A. Nowack: *A guarded fragment for abstract state machines*, Proceedings of the ESSLLI 2004 Workshop on Guarded Fragments


A. Nowack: *A Guarded Fragment for Abstract State Machines*, Accepted for the JoLLLI special issue on guarded fragments
Computer Graphics and Multimedia

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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 (which combine surface and volume representations) have attracted our interest since they allow for more robust and more efficient algorithms for various geometry processing tasks.

The processing of 3D geometry data is becoming more and more important in industrial product design and development. Typical applications go way beyond classical CAD/CAM tasks. Through the availability of high performance computer hardware and highly efficient numerical algorithms, various phases of the industrial development process are being based on computer simulations today. In order to guarantee the reliability of these simulations one needs very detailed 3D models. Well known examples for this scenario are the flow or crash simulation in the early stages of automotive and airplane development. Further applications are reaching from bio-medical engineering to rapid prototyping and to multimedia data archives. Especially in 3D medical image processing, geometric algorithms gain increasing relevance. In all these applications the cost efficient generation and modification of complex 3D models is essential for the successful use of computers.

To promote this fresh and highly relevant research area we have started an international symposium series on Geometry Processing which after its successful start in Aachen in 2003 is now establishing as the major international forum specialized to this field. On the national level, we founded a “Geometry Processing” section as a sub-organization of the national Gesellschaft für Informatik. As the speaker of this section, Leif Kobbelt’s goal is to join the forces of the various research groups in industry and academia.
This year, the head of the Computer Graphics Group took a sabbatical leave during the summer term. Between May and September, he spend research stays at various internationally renowned institutions including Microsoft Research in Redmond and the ETH in Zürich. As a personal highlight, Leif Kobbelt received the Outstanding Technical Contributions Award 2004 from the Eurographics Association for his research work in the field of Geometry Processing during the last decade. This mid-career award is considered the most prestigious European award in Computer Graphics.

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). In addition to the courses, we offer a practical exercise project on Special Effects. Our goal in this project is to develop a software system that processes video streams from 20 digital cameras filming the same scene from different 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 fourth 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 and journals in Computer Graphics. At Eurographics 2004, the leading conference in Europe, Jianhua Wu received one of the best paper awards in the category “paper, first-authored by a student”.

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Research Projects

**CAD model repair**

*Stephan Bischoff, Leif Kobbelt*

A common dilemma in today's CAM production environments are the different geometry representations that are employed by CAD systems on the one hand and downstream applications on the other hand. While CAD systems usually represent a model by a set of trimmed NURBS patches, downstream applications like computational fluid- or structure simulation, rapid prototyping, and numerically controlled machining rely on closed and consistent manifold triangle meshes as input. The conversion from one representation into the other is not only a major bottleneck in terms of time, but also with respect to the accuracy and quality of the output and thus directly impacts all subsequent production stages.

Common tessellation algorithms are able to efficiently and accurately convert *single* patches into triangle meshes, but usually cannot handle continuity constraints between different patches or detect and resolve intersecting geometry. This leads to artifacts like gaps, overlaps, intersections, or inconsistent orientations between the tessellated patches, which often have to be repaired in a manual and tedious postprocessing step. For this reason, quite some effort has been put into algorithms that are able to automatically repair such models.

*Surface oriented algorithms* fix the inconsistencies by perturbing the input only slightly, but they cannot handle special cases. *Volumetric algorithms* produce guaranteed manifold meshes but destroy the structure of the input tessellation due to global resampling. In this project we combine the advantages of both approaches: We exploit the topological simplicity of a voxel grid to reconstruct a cleaned up surface in the vicinity of intersections and cracks, but keep the input tessellation in regions that are away from these inconsistencies. We are thus able to preserve the characteristic structure of the input tessellation, close gaps up to a user-defined maximum diameter, resolve intersections, handle incompatible patch orientations and produce a feature-sensitive, manifold output that stays within a prescribed error-tolerance to the input model.

![input model](image1)
![volumetric reconstruction](image2)
![hybrid reconstruction](image3)
Generalized Active Contour Models

Stephan Bischoff, Leif Kobbelt

Active contour models (snakes) have been used in a wide variety of applications in computer vision and image analysis ranging from motion capturing to image segmentation. Traditionally snakes are only applied in Eulerian setups, i.e. curves embedded in \( \mathbb{R}^2 \) for segmenting images and surfaces in \( \mathbb{R}^3 \) for segmenting volume data. However, there are many applications that would benefit from more general settings. In this project we consider in particular the case of curves that are embedded on arbitrary surfaces.

As an example consider the problem of accurately locating and measuring (e.g. vascular) constrictions. In this case, the embedding surface is just the surface of the vessel. Initially, the user places a curve on this surface which runs around the vessel. If we let evolve this curve according to its curvature it will become a locally shortest curve (geodesic) and its length will be a measure for the vessel’s circumference. Other application scenarios include automatic mesh partitioning and interactive mesh editing.

Early attempts for modeling embedded snakes were limited to particular applications, suffered from low accuracy, supported only expanding fronts or relied on an elaborate piecewise parameterization of the underlying meshes. In this project we are exploring a new representation for snakes that avoids these artifacts:

**Adaptivity:** The sampling of the snake automatically adapts to the resolution of the triangle mesh. There is no need for elaborate resampling strategies based on intrinsic properties of the snake or of the surface like curvatures which are susceptible to parameterization artifacts.

**Topology control:** The topological behavior of the snakes can be adjusted to fit the requirements of the application. In addition to a fixed connectivity, our model also supports merging or splitting of snakes.

**Robustness:** Our model avoids any numerically unstable (back-) projections of snaxels onto the mesh. In particular, the snake is guaranteed to always lie exactly on the mesh.
Point-based rendering, in particular surface splatting, has developed into a valuable alternative to triangle meshes when it comes to rendering of highly detailed massive datasets. However, even highly accurate approximations of given geometry by means of elliptical planar splats may not provide a sufficient rendering quality, since surface lighting mostly depends on normal vectors, whose deviation is not bounded by the Hausdorff approximation error. Moreover, current point-based rendering systems usually associate a constant normal vector with each splat, leading to rendering results which are comparable to flat or Gouraud shading for polygon meshes.

In contrast, we propose to base the lighting of a splat on a linearly varying normal field associated with it, and we show that the resulting Phong Splat provide a visual quality which is far superior to existing approaches. Moreover, the rendering quality degrades very slowly with decreasing geometric complexity, resulting in high quality visualizations even for rather coarse approximations. A Phong splat representation can simply and efficiently be constructed by a straightforward least-squares fitting to both the underlying surface geometry and its normal field.

Our surface splatting system is implemented completely based on vertex and pixel shaders of current graphics cards and achieves a rendering performance of up to 5M Phong shaded, filtered, and blended splats per second. In contrast to previous point-based rendering approaches, our scan conversion furthermore is projectively correct per pixel, leading to more accurate visualizations.
In an increasing number of applications triangle meshes provide a flexible and efficient alternative to traditional NURBS-based surface representations. Especially in engineering applications it is crucial to guarantee that a prescribed approximation tolerance to a given reference geometry is respected for any accumulation of geometric operators that are applied when processing a triangle mesh.

The distance to a given reference surface \( S \) can be computed most efficiently based on its implicit signed distance field \( d : \mathbb{R}^3 \rightarrow \mathbb{R} \), which maps each point to its distance to \( S \), such that consequently \( S = \{ x \in \mathbb{R}^3 | d(x) = 0 \} \). We therefore propose a simple and generic method for computing the distance of a whole triangle mesh to a given reference surface \( S \) based on a pre-computed piecewise trilinear approximation of its signed distance field \( d(\cdot) \).

Exploiting the hardware acceleration of modern graphics hardware allows us to perform up to 3M triangle distance checks per second, thus enabling real-time distance evaluations even for complex geometries. An additional feature of our approach is the accurate high-quality distance visualization of dynamically changing meshes at a rate of 15M triangles per second.

Due to its generality, the presented approach can be used to enhance any mesh processing method by global error control, guaranteeing the resulting mesh to stay within a prescribed error tolerance. The examples at the bottom show the precise error visualization for mesh decimation and mesh smoothing.
Isotropic Remeshing
Mario Botsch, Leif Kobbelt

Due to their conceptual simplicity, triangle meshes are the de-facto standard surface representation employed for numerical simulations. Moreover, because of their flexibility and efficiency, triangle meshes are also used in many other areas of geometry processing, like for instance de-noising, shape optimization, surface modeling, and morphing.

Most of these methods involve to solve PDEs on the two-manifold surface represented by the triangle mesh, which requires the triangle elements to be well-shaped to guarantee numerical stability. While the required derivative information cannot be derived from long and skinny triangles in a robust manner, equilateral triangles allow for numerically stable computations. The process of isotropic remeshing optimizes the surface tessellation in order to achieve a highly regular triangulation with uniform vertex distribution and close-to-equilateral triangles.

In contrast to other remeshing techniques, our approach does not require global surface parameterizations, but is based on local topological and geometric operators only. As a consequence, our method is considerably more efficient compared to other techniques and processes meshes of about 100k triangles in about 5s. Since the local remeshing operators can easily be adjusted to detect and preserve sharp features, the remeshing of complex technical datasets is possible without introducing geometric sampling artifacts, thus providing both a high quality tessellation and a geometrically faithful approximation.
The basis of many Computer Vision applications is the so-called *camera calibration* which requires the reconstruction of the position of a camera in space, its viewing direction and several intrinsic parameters influencing the imaging process. Applications like stereo or multi-image 3D reconstruction, object and terrain measurement from images or perspectively correct interpolation of unknown views of a scene all rely on precisely calibrated cameras. Besides traditional calibration methods based on specially crafted calibration objects with known spatial features, a different class of algorithms, known as *Structure from Motion* (SFM), exists. If the input is a continuous stream of images showing a scene or an object from different viewing positions and directions, these algorithms are capable of directly computing the desired calibration from the input images. Furthermore a set of 3D points lying on the object surface is reconstructed.

The algorithms implemented and evaluated in the course of this project belong to the class of *feature-based* Structure from Motion: Point features are detected in the first image and tracked as long as possible over the image stream. From these *point correspondences* the desired camera calibration is computed either sequentially, i.e. image by image, or – if the constraint of every point feature being visible in every image is met – in a global fashion simultaneously for all images.

A major problem of this approach is the instability of today's feature tracking algorithms. Incorrectly tracked feature points distort the SFM process, rendering the result useless. Therefore, the main emphasis of this project lay on the stabilization of the feature tracking and Structure from Motion processes: A multi-pass approach has been implemented which, in each iteration, first tracks features and then performs a robust SFM computation (based on RANSAC). The resulting (approximate) camera calibration is used in subsequent tracking passes to predict feature positions (thereby guiding the feature tracker) and to filter out bad correspondences. After a few iterations the process results in stably tracked features and correctly recovered camera parameters.

Sample input image and camera positions of a turntable sequence.
3D reconstruction, i.e. the transformation of real-world objects into polygon meshes, is a core part of many applications. Examples include the design of new cars in the automotive industry, multimedia applications like online catalogs or the generation of special effects in today’s movies and video games. A well-established method for object digitization is laser scanning. It has, however, several drawbacks: the scanning devices are expensive and inflexible, it does not scale well with respect to object size and it has problems scanning specular or transparent objects.

A different method for 3D reconstruction originates from the field of Computer Vision: 3D reconstruction of objects or scenes from two or more digital images is one of its most active research areas.

The reconstruction method developed in this project is strongly inspired by laser scanning and traditional stereo reconstruction techniques. A depth value is computed for every pixel of a reference image, resulting in depth maps similar to those produced by a laser scanner. The depth for one specific pixel is estimated by constructing a viewing-ray through that pixel, constructing a small square patch on that ray and finding the optimal depth by projecting the patch into several comparison images.

Similarly to laser scanning, this reconstruction method is patch based. That is, several reference images have to be chosen such that the resulting set of patches covers the objects’ surface completely. The main advantage of this approach is that the existing processing pipeline developed for laser scanning (volumetric fusion of patches, mesh decimation, smoothing, optimization, etc.) can be applied without any changes.
The faithful digitization of three dimensional real world objects remains a great challenge in computer graphics and computer vision. Although established technologies such as laser scanning are able to produce high quality 3D reconstructions, they still lack flexibility with respect to material and lighting conditions and are relatively expensive. Hence the idea of reconstructing 3D objects from video is not only of scientific importance but would also be an economically relevant alternative to specialized 3D scanning devices.

Unfortunately current video based reconstruction approaches do not provide comparable accuracy and quality of the reconstructed object surface. Many stereo reconstruction techniques are solely based on local feature matching between different images, such that the noisy nature of digital image data makes it difficult to extract a continuous, smooth surface, which can be used, e.g., as an input for further mesh processing such as modeling.

We present a new, efficient algorithm to reconstruct the 3D shape of an arbitrary object which is captured on video from different viewpoints (1). After a structure from motion calibration of the raw input, we perform a hierarchical procedure which generates adaptively refined voxel grids (2). On each hierarchy level we first assign image consistency values in a crust around the surface similar to known reconstruction methods such as voxel coloring (3). However, to reach a globally optimal solution for the reconstructed surface, we generate a weighted graph structure (4) and extract the surface by computing the minimum cut which separates the exterior from the interior (5). Our graph structure is able to handle surfaces with arbitrary genus and leads to minimum graph-cuts which optimize the global image consistency while at the same time preferring locally smooth surfaces. Moreover, the geometric embedding of the graph implies a simple algorithm which extracts a guaranteed manifold triangle mesh from the voxel grid.
Capturing the motion of a person or other articulated bodies plays an important role in Virtual Reality applications and computer animation as well as in motion analysis, e.g., for medicine or sport science. In the context of virtual environments motion capturing is especially interesting as it has the potential to create a very “natural” and therefore intuitive interface to the Virtual Reality application. However, established motion capturing techniques for articulated bodies are still very inflexible because of their reliance on pre-specified models and their computational complexity. This normally prohibits their usage in highly dynamic virtual environments, since they fail to meet the demanding requirements such as real-time response, immersion, and ad hoc configurability.

The goal of this project is to support the use of motion capture as a general input device for Virtual Reality applications. We present a self-calibrating framework for optical motion capture, enabling the reconstruction and tracking of arbitrary articulated objects in real-time. Our method automatically estimates all relevant model parameters on-the-fly without any information on the initial tracking setup or the distribution of optical markers, and computes the geometry and topology of multiple tracked skeletons, such that a high level of flexibility is reached even in highly dynamic setups.

Moreover we provide solutions to make the actual motion capture phase more robust against the problem of optical marker occlusions by exploiting the redundancy in the skeleton model and by reconstructing missing inner limbs and joints of the tracked subject from partial information. Meeting the above requirements our system is well applicable to a wide range of Virtual Reality based applications, where unconstrained tracking and flexible retargeting of motion data is desirable.
Due to the availability of reasonably priced 3D scanning equipment the need for shape modeling techniques which enable the flexible modification of (unstructured) high resolution 3D models becomes more and more evident. Ideally such techniques should be independent from the actual tessellation of the mesh and they should provide handles through which the user can control the shape in a flexible and intuitive way. Due to the high complexity of the scanned meshes, necessary for representing the edited model with a certain precision, multiresolution modeling techniques resort to a coarse, low frequency representation (base domain) of the input geometry, so that the designer can efficiently describe the editing operations. Such an approach imposes a restriction on the used base-domain: it has to represent the structure of the model as close as possible, so that a modification expressed with respect to it propagates in an intuitive fashion to the edited mesh.

Our contribution is a new simplification scheme for polygonal meshes which generates a progressive sequence of coarser versions of the input mesh $M$ adjusted and aligned to the major geometric features. The algorithm is specifically designed to overcome difficulties arising when $M$ is decimated to extremely coarse resolutions and provides valid, non-folding, two-manifold polygonal meshes approximating the structure of the model. The scheme is guided by two major principles: minimizing a combined integral zero/first order error for all faces (this provides the relation to the input surface) and guaranteeing that each face is injectively projectable to a plane (this weakly controls the quality of individual faces).

*From left to right:* a) The fan model at full resolution. The model simplified to b) 50, c) 17, d) 5 faces by our algorithm.
We propose an elegant two-scale framework which allows for modeling of an arbitrary input mesh $M$ by simply transforming control points. The low-frequency, base domain for performing the modification is a smooth (almost everywhere) $C^2$ subdivision surface $S$. We take advantage of several properties of our simplification scheme, which is used to produce the control mesh of the subdivision surface: Since the user is able to browse the sequence of fine-to-coarse representations of $M$, a desired domain surface $S$ is available on any level of detail. The control vertices are placed at intuitive locations and the mesh faces are aligned with the anisotropy of the input surface, hence the support of the modification corresponding to one control point movement is naturally defined and adjusted with the structure of the model. Also, refining of the control mesh is not constrained to an uniform refinement of a fixed base domain, but is completely irregular and new degrees of freedom are placed adaptively in accordance to the employed approximation metric. Since our simplification algorithm operates natively with general polygonal faces, both Catmull-Clark and Loop surfaces are supported. Therefore both triangular and quad control lattices are available. This property is especially important in practice, since quad lattices are preferred in CAD applications. Hence our framework can be useful for CAD systems with emphasis on applications such as rapid prototyping and reverse engineering for conceptual design.

*From left to right:* a) A tessellated CAD model as input, b) The model simplified to 24 faces, c) A corresponding Catmull-Clark subdivision surface with 44 control vertices. d) Using that surface as a base domain of our multiresolution representation allows us to perform several large-scale modifications on the original mesh (represented as a normal displacement field). Notice that moving a control vertex corresponds to a “meaningful” deformation because the coarse control mesh captures the global structure of the model.
One of the central problems in image processing is the problem of image segmentation, where one is interested in separation between regions of interest and the rest. This separation is mainly based on one of the two criterions: discontinuity and similarity. Using discontinuity, images are separated along high-frequency boundaries like edges. Similarity leads to segmentation according to a set of predefined criteria like similar color.

There is a wide field of applications which make use of image segmentation techniques: pattern recognition, motion tracking, feature detection, etc. In medicine image segmentation is needed for information retrieval out of CT- or MR-scans, e.g. during image-guided surgery. Often we simply refer to the regions of interest as foreground and to the rest as background and the problem of image segmentation becomes the problem of foreground extraction. Generally for a given input image the problem is to find an alpha-channel image, the so-called matte, which gives the confidence for each pixel to be a part of the foreground. Based on the term matte, foreground extraction is also called pulling-of-matte-problem or simply matting.

Using recent achievements in the area of matting we are developing algorithms which are able to extract mattes out of images, where the transition between foreground and background is very complex. By proper definition of the matting problem we are able to use direct solvers in order to improve the time complexity of the whole process. User interaction during the process is minimized to the drawing of a simple approximate contour of the boundary region for foreground and background.
Video processing has its main applications in the film and entertainment industry. The film industry makes use of different video processing techniques in order to generate very impressive special effects. In video games or in cartoon animation one is interested in surrealistically rendered sequences which often are created directly from real videos by using different tooning techniques.

A video is simply a sequence of images, however, processing of such a sequence differs strongly from processing single images. The most frequent problem one has to deal with when using single image processing for each frame are the flickering artifacts which resulting from not regarded temporal coherence of the video. That is the reason why we have to interpret a video as spatio-temporal volume of image data. Using this approach video processing becomes 3D-volume-processing.

Using the interpretation of spatio-temporal volume we are developing techniques for video processing, which include video segmentation, deletion and insertion of different objects in video and so creating a very powerfull application for video manipulation. We extend the established image-based approaches to 3D in order to add temporal coherence as additional constraint. E.g. in image processing different texture synthesis techniques can be used for filling in missing regions in images by comparison of neighborhoods across the image. We have extended these techniques to 3D and are able to remove objects and fill in the missing parts in the video volume by appropriate adjustment of the neighborhood term.
Automatic Surface Structure Recovery

Jianhua Wu, Leif Kobbelt

Finding the optimal structure and a faithful approximation of a given surface’s geometry is always a challenging task in graphics research. Due to the steadily increasing availability and complexity of geometric models, better understanding of the underlying surface structures and characteristic geometric features becomes more critical nowadays. Accurately recovered surface structures will provide best blueprints for most geometry processing tasks which require optimal surface approximations, like multiresolution modeling, remeshing, high quality LODs, progressive compression and hybrid shape representations etc. Moreover, traditional CAD applications including reverse engineering and rapid prototyping will also benefit from such representations.

We present an automatic surface structure recovery algorithm by extending the powerful optimization technique of variational surface approximation. In addition to standard planes, we allow for higher order surface elements like spheres, cylinders and more complex rolling-ball blend patches to embrace a new hybrid variational framework. By this, surface structures can be recovered more elegantly and automatically than typical reverse engineering processes due to the robust segmentation and global optimization properties of the variational scheme. Moreover, as a side product of the improved structure recovery, our hybrid approximation method typically provides a higher approximation quality compared to the standard variational approximation in particular when a very coarse segmentation is used.

The following figures show how well the surface structures can be recovered with only 50 hybrid surface elements: the original mesh (top left), recovered partitioning (top right) and its approximation via vertex projection (bottom left) and via remeshing (bottom right).
3D geometry data is establishing as a new digital multimedia data type after text and sound in the 80’s, image and video in the 90’s, since it enables the user to actually interact with the displayed contents, thus more and better interactive multimedia applications can be promoted, e.g. immersion, virtual reality, Avartars and 3D TV etc. On the other hand, the rapid evolution of the network technology brings new potentials for communication between people and computers in heterogeneous environments, which has led to numerous geometry-based networking and mobile applications nowadays.

Within such distributed network-computing environment, in this project, we develop a mobile geometry processing prototype module working on the Pocket PCs. Limited by low performance mobile clients, geometric models should be transmitted in a progressive fashion that users can see/process the important data in the very beginning: Once having the requests from clients through the wireless connection (WLAN) based on TCP/IP protocol, the server sends the base geometry model first followed by lengthy detail information. Clients can decide with themselves when to stop the transmission to make possible interaction and processing on the mobile devices. The rendering on Pocket PCs are achieved with a compliant implementation of the OpenGL Embedded System 1.0 API.
Other Activities

Committees and Organization:

- Member of the internat. Program Committee of the ACM SIGGRAPH and Eurographics Symposium on Geometry Processing 2004, Nice, France
- Member of the internat. Program Committee of the Second International Symposium on 3D Data Processing, Visualization and Transmission, 3DPVT 2004, Thessaloniki, Greece
- Member of the internat. Program Committee of the Pacific Graphics Conference 2004, Seoul, Korea
- Member of the internat. Program Committee of the WSCG Conference 2004, Pilzn, Tschechien
- Member of the internat. Program Committee of the Symposium on Point-based Graphics 2004, Zürich
- Member of the internat. Program Committee of the Shape Modeling International Conference 2004, Genova, Italy
- Topic chair of the internat. Program Committee of the Eurographics 2004 Conference, Grenoble, France
- Member of the internat. Program Committee of the Graphics Interface Conference 2004, London, Canada
- Member of the internat. Program Committee of the Biennial Geometric Modeling and Processing Conference 2004, Beijing, China
- Member of the internat. Program Committee of the Vision, Modeling, and Visualization Conference VMV2004, Stanford, USA
- Speaker of the “GI Fachgruppe Geometrieverarbeitung”
- Member of the “VRCA-Beirat”

Offices:

- Head of the Examination Commission
- Speaker of the GI section “Geometry Processing”
- Member of the scientific board Virtual-Reality (VRCA)
- Director of the Steinbeis Transfer Center “Geometry Processing”
- Reviewer:
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  - Humboldt-Stiftung
  - German-Israelian Foundation
  - Studienstiftung des Deutschen Volkes
  - Deutscher akademischer Austauschdienst
  - Norwegian Research Council
- Stephan Bischoff: Student Advisor, main study period computer science
Talks and Publications

Talks

Invited talks

- “Subdivision Scheme Tuning Around Extraordinary Vertices”, IMS-IDR-CWAIP Joint Workshop on Data Representation
- “Point-Sampled Shape Representations”, Symposium on Point-Based Graphics, Zürich
- “Automatic Restoration of Polygon Meshes”, Mathematical Methods for Curves and Surfaces, Tromso, Norwegen
- “Automatic Mesh Restoration”, Workshop on Digital Geometry Processing, Peking University \ Tsinghua University, Beijing
- “Freeform Shape Representations for Efficient Geometry Processing”, State Key Lab of CAD & CG \ Zhejiang University, Hangzhou

Conference presentations

Stephan Bischoff: *Automatic Mesh Repair*, Chemnitz, Germany, September 2004
Stephan Bischoff: *Topologically Correct Extraction of the Cortical Surface of a Brain Using Level-Set Methods*, Berlin, Germany, March 2004
Mario Botsch: *Phong Splatting*, Symposium on Point-Based Graphics, Zürich, Juni 2004
Mario Botsch: *A Remeshing Approach to Multiresolution Modeling*, Symposium on Geometry Processing, Nice, July 2004
Mario Botsch: *An Intuitive Framework for Real-Time Freeform Modeling*, ACM SIGGRAPH, Los Angeles, August 2004
Darko Pavic: *Automatic Mesh Restoration*, GIF Project Symposium, Bonn, Germany, July 2004
Dakro Pavic: *Open mesh - a generic and efficient polygon mesh data structure*, VRCA workshop, Aachen, Germany, July 2004
Jianhua Wu: Out-of-core Mesh Processing, GIF Project Symposium, Bonn, Germany, July 2004

Jianhua Wu: Optimized Sub-Sampling of Point Sets for Surface Splatting, Eurographics 2004, France, September 2004

Publications

N. Linnenbrügger, R. Webber, L. Kobbelt, T. Lehmann: Automated hybrid TACT volume reconstruction, Methods for Information in Medicine, 43:315-319

L. Barthe, L. Kobbelt: Subdivision Scheme Tuning Around Extraordinary Vertices, Computer Aided Geometric Design, Vol 21 Iss 6, pp. 561-583


S. Bischoff, L. Kobbelt: Teaching meshes, subdivision and multiresolution techniques, Computer-Aided Design, 36 (14), 1483-1500

L. Barthe, C. Gerot, M.A. Sabin, L. Kobbelt: Simple computation of the eigencomponents of a subdivision matrix in the Fourier domain, Advances in Multiresolution for Geometric Modeling, N.A. Dodgson, M.S. Floater and M.A. Sabin (ed.), Springer Verlag, to appear


M. Pauly, L. Kobbelt, M. Gross: Point-based multi-scale surface representation, submitted to transactions on Graphics

M. Marinov, N. Dyn, D. Levin: Geometrically Controlled 4-Point Interpolatory Schemes, “Advances in Multiresolution for Geometric Modelling”, N. A. Dodgson, M. S. Floater, M. A. Sabin (eds.), Springer Verlag, pp. 301-315

M. Marinov, L. Kobbelt: Optimization Techniques for Approximation with Subdivision Surfaces, ACM Symposium on Solid Modeling and Applications, pp. 113-122


L. De Floriani, L. Kobbelt, E. Puppo: A Survey on Data Structures for Level-Of-Detail Models, “Advances in Multiresolution for Geometric Modelling”, N. A. Dodgson, M. S. Floater, M. A. Sabin (eds.), Springer Verlag


M. Botsch, L. Kobbelt: An Intuitive Framework for Real-Time Freeform Modeling, ACM Transactions on Graphics (TOG), 23(3), 630-634


J. Wu, L. Kobbelt: Optimized Sub-Sampling of Point Sets for Surface Splatting, Computer Graphics Forum, 23(3), 643-652, Best student Paper Award

A. Hornung, S. Sar-Dessai, L. Kobbelt: Robust and Automatic Optical Motion Tracking, submitted: IEEE Virtual Reality Conference

M. Botsch, L. Kobbelt: A Remeshing Approach to Multiresolution Modeling, Symposium on Geometry Processing, pp. 189-196


M. Marinov, L. Kobbelt: Direct Anisotropic Quad-Dominant Remeshing, Proceedings Pacific Graphics, pp. 207-216

S. Bischoff, L. Kobbelt: Netzbasiertes Geometrisches Modellieren, Informatik Spektrum, Sonderheft Graphische Datenverarbeitung, Springer Verlag, pp. 516-522

M. Marinov, L. Kobbelt: Optimization Methods for Scattered Data Approximation with Subdivision Surfaces, to appear in GMOD; special issue on SM 2004

A. Hornung, L. Kobbelt: Robust and Automatic Optical Motion Tracking, to appear in Virtuelle und erweiterte Realität, Workshop der GI Fachgruppe VR/AR, Chemnitz


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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. Our research in this direction focuses on Relational Indexing where built-in index structures of Relational Database Management Systems are exploited for efficient and robust data management.

A central question our research group is interested in is how to find and extract the hidden knowledge from large databases. At this point we encounter the problem of Data Mining or Knowledge Discovery in Databases. To establish content based retrieval and similarity search, appropriate data structures are needed to represent the complex objects. Depending on the chosen data model it is possible to develop effective data management techniques while simultaneously achieving interactive response times for queries.

In addition to completely automatic methods, it is necessary to support data mining by interactive techniques. Interactive data mining methods help to improve the results by using visual representations and taking relevance feedback into account in order to include the cognitive abilities of human experts.

A few contacts to local and international operating companies could be established since the chair had the opportunity to organize the day of computer science last year. The management of that day’s software price sponsored by Sun Microsystems and organization of the day implied a lot of work but we were rewarded by a lot of fun. We hope that all guests enjoyed the day of computer science 2004 as much as we did.

The activities on the field of scientific research had also been reinforced which yielded various new diploma theses concerning relational indexing, multimedia retrieval and clustering. Various projects and cooperative work with industrial partners including CIM, Daimler Chrysler and IBM were also stated and deepened.

Besides that, the chair further extended the offered lecture courses concerning the topics Data Mining Algorithms, Models for Data Exploration and Index Structures for Databases. In our seminars offered last year we especially focused on Subspace Clustering, a very active field of research, and on other current hot topics of Data Management and Data Mining. The related lab course on Data Mining Algorithms offered an opportunity to interested students to implement some Subspace Clustering Algorithms and to gain experience in handling various data mining tools and database systems.
Research Projects

Data Exploration

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 need to turn such massive 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 analyze the similarity between objects is too high to apply them to huge amounts of objects. To obtain acceptable response times for similarity queries many different techniques must be combined. For example, 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).

![Figure 7: Computation of a 3D shape histogram for a molecule as an example of high dimensional feature extraction](image)

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.

As a particular aspect for content-based retrieval, structured and semi-structured object representations are getting more and more important for modern database applications. Examples for such data are hierarchical structures including chemical compounds, XML data or image data. As a key feature, database systems have to support the search for similar objects where it is important to take into account both the structure and the content features of the objects. A successful approach is to use the edit distance for tree structured data. As the computation of this measure is NP-complete, constrained edit distances have been successfully applied to trees. While yielding good results, they are still computationally complex and, therefore, of limited benefit for searching in large databases. We propose a filter and refinement architecture to overcome this problem. We investigate a set of new filter methods for structural
and for content-based information in tree-structured data as well as ways to flexibly combine different filter criteria. The efficiency of our methods, resulting from the good selectivity of the filters, is demonstrated in extensive experiments with real-world applications.

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.

Data Management: Complex Objects in Relational Databases

There is a growing demand for database applications to handle complex objects including time spans for the validity of stored facts, tolerance ranges for imprecisely measured values in scientific databases, or approximate values in local caches of distributed databases. Furthermore, many topics of data mining have to solve the problem of querying high dimensional data or of effectively executing range queries. In order to obtain industrial strength, query processing has to be integrated into existing robust database systems.

![Query using a relational interval tree](image.png)

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.

Figure 9: Online demo for the relational interval tree

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.

In order to integrate the RI-tree in present-day object-relational database systems, we use their extensible indexing frameworks that enable developers to extend the set of built-in index structures by custom access methods. Although these frameworks permit a seam-less integration of user-defined indexing techniques into query processing they do not facilitate the actual implementation of the access method itself. In order to leverage the applicability of indexing frameworks, relational access methods such as the Relational Interval Tree (RI-tree), an efficient index structure to process interval intersection queries, mainly rely on the functionality, robustness and performance of built-in indexes, thus simplifying the index implementation significantly. To investigate the behavior and performance of the recently released IBM DB2 indexing framework we use this interface to integrate the RI-tree into the DB2 server. The standard implementation of the RI-tree, however, does not fit to the narrow corset of the DB2 framework which is restricted to the use of a single index only. We therefore adapt the originally two-tree technique to the single index constraint. As experimental results with interval intersection queries show, the plugged-in access method delivers excellent performance compared to other techniques.

Other Activities

Courses

Lectures:

- Data Mining Algorithms (winter 03/04)
- Index Structures for Databases (summer 04)
- Models for Data Exploration (winter 04/05)
- Algorithms and Datastructures (summer 04, undergraduate)
- Interdisciplinary team-taught lecture series for Bionic I: Basics and Methods for Bio-
  logic and Technology (with Priv.-Doz. Dr.rer.nat. Harald Luksch et al., winter 03/04 and winter 04/05)
- Interdisciplinary team-taught lecture series for Medical Image Processing (with Priv.-Doz. Dr.rer.nat. Thomas Lehmann, et al., winter 03/04 and winter 04/05)

Seminars:

- Medical Image Processing (with Priv.-Doz. Dr.rer.nat. Thomas Lehmann et al., summer 04)
- Algorithms for Data Mining (summer 04 and winter 04/05)
- Methods and Tools (winter 04/05, undergraduate)

Lab Courses:

- Data Structures (summer 04, undergraduate)
- Data Mining Algorithms (winter 03/04 and winter 04/05)
Reviewing

Membership in program committee:

- ACM International Conference on Knowledge Discovery and Data Mining (SIGKDD-04)
- ACM International Conference on Management of Data (SIGMOD-04)
- IEEE International Conference on Data Engineering - Demo program (ICDE-DEMO-04)

Journals:

- International Journal of Computers and Applications (IJCA)
- Journal of Systems and Software (JSS)
- IEEE Transactions on Visualization and Computer Graphics (TVCG)
- Information Processing Letters (IPL)
- Knowledge and Information Systems (KAIS)
- IEEE Transactions on Knowledge and Data Engineering (TKDE)
- ACM Transactions on Database Systems (TODS)

Ph.D. Committee

- Reviewer and Member of the Ph.D. committee for Stefan Schönauer at the Faculty for Mathematics, Computer Science, and Statistics of the University of Munich.

Diploma theses:

- Eric Camen: Concepts for Region-Based Similarity Search in Image Databases by Using the Earth Mover’s Distance
- Alfa Debus: Extensions of the Relational Interval Tree to Floating Point Intervals
- Boris Glavic: Subspace Clustering for Sequences of Ordered Categorical Data
- Mladen Jovic: Optics-Based Evaluation of the Earth Mover’s Distance for Content-based Image Retrieval
- Boris Kaiser: A Mapping and Validation Concept for Data Exchange in E-Business Applications
- Markus Peters: Maximal Cliques and Vertical Mining for Clustering Categorical Data
- Achim Schlosser: Single index based interval management in relational databases
- Jochen Schlosser: Stream-Based Processing of Interval Joins
- Nicole Schneider: Relational Processing of Interval Joins with Temporal and Non-temporal selections
- Gunter Ohrner: Database-supported consistency checks for electronic communication systems
- Andrea Wenning: Approximation and Indexing of the Earth Movers Distance for Efficient Contentbased Search in Multimedia-Databases
- Marc Wichterich: Approximation of Voronoi Cells for Nearest Neighbor Search

**Industrial and Academic Collaboration:**

- CIM-Aachen GmbH: A Mapping and Validation Concept for Data Exchange in E-Business Applications
- Daimler Chrysler AG: Database-supported consistency checks for electronic communication systems
- IBM Germany: Single index based interval management in relational databases
- RWTH Faculty of Medicine, Department of Medical Informatics: Medical Image Processing (Spitzer/Lehmann)
- RWTH Faculty of Civil Engineering, Section of Engineering Hydrology: Subspace Clustering for Sequences of Ordered Categorical Data (Nacken)
- RWTH Faculty of Medicine, Institute for Biomedical Engineering - Cell Biology: Data Mining in Gene Expression Databases
- LMU München: Similarity Search in graph databases
- Roland Berger Strategy Consultants: Talk on „Zukunft Telekommunikation“ by Dr. Gustav Adolf Oertzen (23.06.2004)
Publications

Enderle J., Hampel M., Seidl T.: Joining Interval Data in Relational Databases, Proc. ACM SIGMOD Int. Conf. on Management of Data, Paris, France, 2004


Kailing K., Kriegel H.-P., Schönauer S., Seidl T.: Efficient Similarity Search in Large Databases of Tree Structured Objects, (Poster) Proc. IEEE Int. Conf. on Data Engineering (ICDE), 2004

Kailing K., Kriegel H.-P., Schönauer S., Seidl T.: Efficient Similarity Search for Hierarchical Data in Large Databases, Proc. 9th Int. Conf. on Extending Data Base Technology (EDBT), Heraklion - Crete, Greece. Springer LNCS 2992., 2004

Jovic M., Seidl T., Stejic Z., Assent I.: Image Clustering and Retrieval Combining fixed/adaptive-binned Histograms and various Distance Functions, IEEE Conference on Cybernetics and Intelligent Systems, 2004

Seidl T.: Nearest Neighbor Search on Multimedia Indexing Structures, Tutorial on 1st Int. Workshop on Computer Vision meets Databases (CVDB) in cooperation with ACM SIGMOD, 2004


Brochhaus C., Enderle J., Schlosser A., Seidl T., Stolze K.: Integrating the Relational Interval Tree into IBMs DB2 Universal Database Server, accepted for publication in the 11th GI Conference on Database Systems for Business, Technology, and the Web (BTW’05), Karlsruhe, Germany. GI-Edition Lecture Notes in Informatics, 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 instructional scenarios,
- frameworks for the implementation of innovative instructional theories and development of sophisticated learning and authoring tools,
- didactics of computer science, and
- the role of IT and media competencies in teachers’ education.

This year’s activities were dominated by the development of strategies and concepts for the sustainable introduction of eLearning into all educational programmes of RWTH Aachen University. As a result of the activities of the eLearning working group the Center for integrative eTeaching and eLearning concepts (CiL) was founded in October (http://www.cil.rwth-aachen.de/). This eLearning competence center will develop supporting structures and activities for the university.

In teaching, the course “Fachdidaktik Informatik I” was newly developed and held for the first time. The undergraduate course “Introduction to Computer Science” (Java Programming for non-computer scientists with more than 550 students) was supported by self-directed learning sequences implemented with the learning environment jBat. Its weekly programming assignments were partly automated and enriched with automatic tests and feedback by Praktomat. One eLearning module with animations, audio annotated animated slides, and integrated self-assessments replaced a regular lecture and assignment of one week in November.

Kerstin Kohl concluded her dissertation supervised by Prof. Schroeder at Ludwigsburg University of Education. The dissertation deals with the systematic development of a strategy for a sustainable introduction of eLearning at universities with the help of suitable supportive tools. The subject comprises expertise in different fields, including aspects from computer science necessary for evaluating feasibility and limits of innovation by means of computer systems, and including in particular didactical basics. Especially the interplay of pedagogy, instructional design and computer science creates the new interdisciplinary field of eDidactics. Moreover, the dissertation deals with aspects of organisational development and knowledge management and project management in eLearning projects.
Research Projects

**jACK - Assessment Center Framework**

Eva Giani, Ulrik Schroeder

The jACK project aims at the development of a distributed framework architecture for an assessment system, which allows for the automated evaluation of student tasks such as mathematical problems, answers to questions, UML specifications, 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 courses.

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.

**jBat - Situated Learning Environment**

Eva Giani, Ulrik Schroeder

The jBat project aims at developing 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.

**Clever - Capture, Log, Edit, Visualize, Evaluate, and Replay Interaction with programs in order to foster action-oriented learning**

Ulrik Schroeder, Christian Spannagel
The Clever application with the underlying Jacareto framework is a flexible tool for capturing user interaction on graphical user interfaces written in Java. In contrast to other capture&replay tools, Jacareto replays recorded interactions on new instances of the observed software itself. This form of replaying has many advantages. In this project the tool has been used for the implementation of various action-oriented learning scenarios, such as the cognitive apprenticeship model for programming classes.

**eSWES (eLearning Systems for Water and Environmental Studies)**

*Ulrik Schroeder - with Heribert Nacken (RWTH Aachen university), Laura Farinetti (Politecnico di Torino), Kamal Ewida (Zagazig University)*

Egypt is facing many challenges due to its increasing population, limited water resources and serious environmental problems. Therefore, among the Egyptian universities, water and environmental studies are becoming a vital issue. The need for highly qualified graduates and improving the education methods in Egypt has forced the Egyptian ministry of higher education and universities to look for new educational solutions in these areas. The three year EU TEMPUS project has the intention to improve the teaching and learning processes by introducing eLearning at both the department of water & water structures and the department of environmental engineering, faculty of Engineering, Zagazig University (Egypt). The project will result in the first eLearning model to the whole Zagazig university to ensure its advanced position among Egyptian universities. The success of this model will encourage other departments to move towards eLearning to enhance the quality of education and in turn the qualification of graduates.

**FiLM - Fachintegratives Lernen mit digitalen Medien**

*(Integrated Learning with digital media)*

*Ulrik Schroeder, Christian Spannagel - Graduiertenkolleg with Raimund Girwidz, Franz-Xaver Bogner, Joachim Engel, Herbert Löthe*

The project FiLM develops concepts and implementations for integrated cross-domain instructions in mathematics, natural & computer sciences. Natural phenomena and environmental processes, daily life, and technology are specified by domain-specific methods from biology, physics, mathematics and computer science. Therefore, a concrete example of each field is illustrated from diverse perspectives by means of new media and worked out by students in cross-domain projects. New information and communication technologies thus serve as facilitators for cross-domain learning based on new findings in learning psychology.
The purpose of this pilot project is to objectify some subjects beyond the boundaries of individual classes and to create transparency for teachers, pupils and their parents. Currently, the pilot project is implemented at the Inda Gymnasium at grades 5 and 6 for English and mathematics. On a weekly basis, additional exercises are developed in cooperation with the responsible teacher and corrected manually. This training system supports pupils in the preparation for exams. The results show that all learners could significantly increase their performance.

For the future, the plan is to transform the exercises gradually into eLearning units with a complete exercise and practice set, and to automatise the time-consuming manual corrections with the help of eLearning systems to a large extent, such that these exercises can be easily created and used by teachers for the corresponding grades.

Other Activities

U. Schroeder:

- Scientific leader of the newly founded eLearning Center of RWTH Aachen university: Center for integrative eTeaching and eLearning Concepts (CiL) (see http://www.cil.rwth-aachen.de)
- Head of the eLearning working group of RWTH Aachen University, which has been defining a strategy for the sustainable integration of eLearning into RWTH curricula by developing an eLearning portal for RWTH Aachen University, 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://www.eLearning.rwth-aachen.de)
- Chair of the second “RWTH eLearning Day in Aachen”, which brought together experts in eLearning from various projects.
• Head of the committee for the evaluation of studies in secondary school teachers’ education for Computer Science at RWTH, which prepared a detailed report on the situation and possible improvement of the 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 Computer Science faculties of the 9 leading universities of Technology in the TU-9 working group for the discussion of Bachelor/Master concepts in engineering education.

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

Eva Giani:

• Member of the eLearning working group of RWTH Aachen.

• Co-organizer of the second “RWTH eLearning Day in Aachen”.

• Co-organizer of the “Girls Day” for Computer Science.

Talks and Publications

Talks


U. Schroeder: Strategien zur Einführung von eLearning an Hochschulen, 2nd eLearning Day of the RWTH Aachen University, 2004


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E. Giani: Situated Learning with the Learning Environment jBat, Int. Conference on Web-Based Education, WBE, IASTED, Innsbruck, 2004


Publications


K. Kohl and U. Schroeder: Nachhaltige Integration digitaler Medien in die Hochschullehre, Franzbecker, to appear


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  Dipl.-Ing. (FH) Nils Beck
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.

During the last year, the Media Space has been used for regular group meetings, presentations, video conferences and student projects. During this time, new devices such as small microphones and Bluetooth headsets have been introduced into the Media Space environment.
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 (TUls). 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. Using the rapid configuration capabilities of the Patch Panel, the concept of focus can be modeled for multiple users in post-desktop environments. We are using the Patch Panel to examine how well users cope and perform with different post-desktop focus mechanisms.
Phonecam-based interactions with Large Public Displays

Rafael Ballagas, Jan Borchers

Interaction with large public displays presents unique challenges, particularly with physical interaction. Using personal devices as tools for interaction satisfies the major design considerations for this domain. We have developed a set of direct manipulation interfaces based on camera-enabled mobile phones that use both visual codes and optical-flow processing to support serendipitous interaction with large public displays. The “Point & Shoot” technique allows users to select objects on a large display by aiming through the camera viewfinder. This technique uses visual codes to set up an absolute coordinate system on the display surface instead of tagging individual objects on the screen. The “Sweep” technique enables users to wave the phone in the air to control a large display application with three degrees of freedom using optical-flow processing.

Our research goals are to create intuitive and fluid interaction techniques that allow people to serendipitously interact with the resources in their immediate environment. These techniques help enable new classes of large public applications including interactive art, games, bulletin boards, and advertising.

Personal Orchestra: A Family of Interactive Conducting Systems

Eric Lee, Jan Borchers

Our work in interactive conducting attempts to break the mold of current multimedia interfaces which are largely limited to the decades-old metaphors of play, stop and rewind. Embedded in multimedia is a rich set of semantics; for example, music is vertically composed of
chords, voices and instruments and horizontally composed of notes, beats and bars. However, multimedia continues to be treated as “black boxes” of data in most systems available today. We have further developed our interactive conducting systems in this past year by building a “hybrid” system which combines the best of the original Personal Orchestra and You’re the Conductor (Personal Orchestra 2). We have also been working on an improving various aspects of the conducting system, discussed below.

One of the challenges of designing an interactive conducting system is how to properly map the user’s conducting gestures with a baton to the music beat. We studied this mapping in more detail through a series of user studies comparing the temporal characteristics of conducting gestures amongst conductors and non-conductors. Our aim was twofold: to determine a method of systematically distinguishing conductors from non-conductors, and to better understand the various mental models of conducting. Our results confirmed that conductors, unsurprisingly, place their beats ahead of the music beat, and with little variance. Non-conductors, however, also place their beats slightly ahead of the beat on average, but vary them significantly more. By analyzing only beat placement, however, we were able to uncover a variety of differing conceptual models of conducting. Some users, for example, unconsciously conduct to the rhythm of the music rather than the beat. Others synchronize their beats to the upwards turning point of a simple up-down gesture, rather than the downwards turning point.

**Left:** Comparison between a conductor’s and a non-conductor’s conducting.

**Right:** Our multiresolution peak picking algorithm.

Time-stretching digitally sampled audio without changing the pitch remains an active area of research. The rigid phase-locked phase vocoder algorithm used in Personal Orchestra 2, for example, exhibits musical overtones and a shallow bass when compared to the original signal. We have been working on these reducing these artifacts and have developed a multiresolution peak picking algorithm to be used in conjunction with the rigid phase-locked phase vocoder. This multiresolution peak picking algorithm takes into account the non-linear frequency response of the human ear to produce audibly better results.
The above research work is currently being incorporated in our latest iteration of conducting systems (Personal Orchestra 3), which will be installed in the Betty Brinn Museum in Milwaukee, USA.

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**coJIVE: COllaborative Jazz ImproVisation Environment**

*Eric Lee, Jan Borchers*

Improvisation in music is a complex creative process and the most native way of musical performance. A musician playing an improvised solo has to constantly create melodies that fit the harmonic context of a tune. Playing freely under such constraints demands a great deal of technical ability and experience from the performer, especially in settings with more than one instrumentalist. Even advanced musicians with a classical education often refrain from improvising, out of fear of making mistakes.

coJIVE offers various mechanisms to facilitate improvisation, making this type of performance accessible to anyone. The system is being developed in two parts. The analytical framework is responsible for identifying patterns in Jazz and establishing a consistent (textual) notation to describe them; it is also responsible for modeling musical rules, and fitting users’ input to these rules.

The frontend application is responsible for correcting users’ performance based on data from the analytical framework, finding ways to enrich users’ input for a satisfying experience, adjusting the degree of assistance based on users’ level of expertise and coordinating collaborative performances featuring several players.

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**The Regensburg Experience**

*Rafael Ballagas, Eric Lee, Daniel Spelmezan, Nils Beck, Jan Borchers*

The Regensburg Experience (REX) is a project with the goal of providing visitors with an enriching experience. The role of the Media Computing Group in this project is to design and develop a series of interactive exhibits that enable visitors to actively and interactively partake in the city’s rich culture and history. Each system is distinct with its own set of research questions and goals; these exhibits include:

**Minnesang:** This exhibit tries to convey the curiousness of Old German by providing a customized translation service that can convert the spoken language of the visitor using voice conversion. The objective of voice conversion is to convert a speaker’s voice to exhibit desired characteristics, while preserving the original content (meaning), e.g., the speech of one speaker is perceived as if it was spoken by another speaker. The research goals of this
is to understand how personalization can improve the educational experience by making the exhibit more engaging.

**Interactive Scavenger Hunt:** The scavenger hunt is designed to lure visitors out of the museum setting to see the medieval treasures of this well-preserved city with their own eyes. Visitors will receive missions or stunts on their mobile phone that will lead them to certain locations that have historical or scenic significance. Interactions will consist of missions that require users to record video, audio, take pictures, interact with large public displays, or answer questions. Progress of each contestant can be monitored in “real-time” through a mobile media blog that displays the contestant’s media content along with an automatically generated textual description of each mission (optionally customized with personal notes). A graphic overview of the progress of each contestant over a city map will also be included in the blog. These blogs will also serve as a souvenir journal of the visitors experience in Regensburg after the trip that can be shared with their family and friends. This project is designed to combine the topics of public games, mobile blogs, and large public displays to inform research from all three areas. By implementing the game, we are developing a platform from which all three areas can be studied from a user-centered and technological perspective.

**Time Window:** Visitors to Regensburg will have the opportunity to glimpse into Regensburg’s past. The system is inspired by the historical viewpoints found in many European cities. These viewpoints typically have a static artist rendering of the city at a certain point in history. Our vision is to have a time window that shows the progression of Regensburg’s history through audio clips, video clips, photos, and artist renderings. Users can move through periods of Regensburg’s past through novel input devices and metaphors. The primary research goals are creating novel visualization metaphors and mappings to help guide users through the large amounts of information.

**Medieval Band:** Museum visitors directly interact with mock instruments on the floor to collaboratively create music that is acoustically adjusted by a computer for harmonization. This exhibit is designed to teach visitors about medieval music and common instruments of the time. Users experience the sense of being in a medieval band by playing along with other museum visitors. The exhibit consists of three mock instruments that people can walk up and start to “play”. The research questions consist of how to assist collaborative content creation such that all of the individual players notes are slightly transformed to “sound good” while still maintaining the feeling of control for each musician. This assistance must not only happen on the harmonic (pitch) scale, but also on the temporal scale.

**Audiospace: A Universal Audio Service for Interactive Rooms**  
*Stefan Werner, Walter Kriha, Jan Borchers*
Audiospace is a middleware for real-time transport of audio over high-speed LANs. It is designed as an integral part of the Aachen Media Space, which made high reliability, multiple audio channels, low latency, ease of use and good integration into the host environment key requirements.

The Aachen Media Space contains several Apple PowerMac G5 workstations running 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 over the MediaSpace’s GBit Ethernet or 802.11g wireless networking. The server uses several of CoreAudio’s AudioUnits: The HALOutput unit provides access to the audio hardware, the MatrixMixer unit is responsible for mixing several streams, and each incoming stream gets its own Converter unit, allowing clients to choose their audio format independently. In addition, the Varispeed AudioUnit is being used for clock skew compensation.

The software is available for download from our web site.
HCI Design Patterns: Capturing User Interface Design Guidelines for Interactive Multimedia Systems and Environments

Jan Borchers

HCI Design Patterns are a format to capture golden rules, design guidelines, and design rationale when building interactive systems. Building on our past work in this area, we have established a collaborative web site for the growing international community of researchers working on this topic (http://www.hcipatterns.org/) which we host as heads of the IFIP task group on this topic.

In 2003, we worked with international partners both at the CHI 2003 Patterns Workshop and online, to create a structural specification for HCI Design Patterns. The result, PLML (the Pattern Language Markup Language, pronounced pell-mell), is expressed as a Document Type Definition (DTD) in XML, and can be found on our web site.

Several pattern languages, including our own HCI Design Patterns for Interactive Exhibits, have been converted by their authors into PLML and been made available online for general use.

Together with partners in the RUFAE network, we are currently working on a new pattern language for interactive environments such as the Aachen Media Space. It will capture the lessons we learned by designing this and other similar spaces (at Stanford and elsewhere), and should be of help to others planning to create similar environments.

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We explore new ways to interact with speech in the Aachen Media Space.

Our Speech Server middleware allows users to control room devices and applications by speech, independent of their location in the room and independent of the machines that run these applications. Possible scenarios include setting up the hardware when people enter the room, such as controlling window blinds and room lights, or turning on displays and computers for a meeting. Furthermore, users are able to control any application by speech with minimal programming effort. Simple scripts that map the recognized speech commands to the applications’ input keystrokes are one possible solution to achieve this.

The Speech Server utilizes the Mac OS X built-in speech recognition libraries to recognize speech, and the ubicomp infrastructure Event Heap to communicate with client applications over the network. Client applications define a grammar consisting of speech commands they want to respond to, such as words or short sentences, and send this grammar to the Speech Server, which then listens for these commands. Upon successful recognition of a command, the server sends the recognized utterance back to the client.

Several issues need to be considered when developing speech interfaces for interactive rooms. Some of these issues include background noise from nearby users or system generated sounds, user privacy, and the overall design of the speech interface. Background noise makes the process of speech recognition a demanding task, since it worsens the recognition accuracy. Wireless headsets allow to speak commands from every location within the room and provide private system feedback, but they imply that users permanently wear these
Another question includes the tradeoff between continuous listening to speech or explicitly triggering the recognition process, e.g., by pressing a dedicated button.

**Other Activities**

The Media Computing Group at RWTH Aachen University was established in October 2003. Our infrastructure that is currently being installed consists of 3 XServe G5 servers with a 1TB XServe RAID, around 15 Dual-2GHz G5 desktop machines with 23” Cinema Displays and iSight cameras for the student Laboratory, and several G4 PowerBooks with similar periphery for our staff. The Media Space (in its final setup) will contain eight 40” mobile interactive LCD screens, a large rear projection screen, an eight-channel networked surround audio setup with four discrete amplifiers and dedicated Firewire audio interface, high-fidelity videoconferencing and a variety of non-standard input and output technologies (infrared batons, various sensors, Bluetooth devices, etc.) We create this environment to facilitate experimentation with time-based multimedia for our students and staff.

In 2004, 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 5th HCI Patterns workshop at CHI 2004. We worked as reviewers for CHI 2004, WWW 2004, and the MIT Press, and host the hcipatterns.org home page as heads of the IFIP task group on this topic. We also worked as co-chairs for the Interactivity Venue at CHI 2005 and as Posters co-chair for UIST 2005.

**Talks and Publications**

**Talks**


**Publications**

Rafael Ballagas, Michael Rohs, Jennifer Sheridan, and Jan Borchers: *BYOD: Bring Your Own Device*, Ubicomp Workshop on Ubiquitous Display Environments, Nottingham, UK, September 2004.
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Overview

Informatik XI began operation in November 2003. So, 2004 was our first full year at RWTH. It was characterized mostly by starting-up activities like hiring staff, creating lectures, learning how to deal with the administration, organizing the day-to-day routine paperwork, but also initiating research projects. We supervised the renovation of our new rooms to which we moved in June. Since most of them are merely an interim solution, we look forward to organizing the next move in 2005.

Research at Informatik XI is 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 today’s 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 organization by agile methods, quality evaluation of architectures, and the application of formal methods to safety-critical systems.

With respect to teaching, we finished the first cycle of lectures for the specialization area Embedded Software, but did not reach an equilibrium, yet. The lectures were Introduction to Embedded Systems, Design of Embedded Software and Automotive Software Engineering. In all three lectures I tried to create a sensitivity to real-world requirements in the embedded systems industries. The introductory lecture included a crash course in continuous and logic control which shall enable computer science students to communicate properly with control engineers and which was well received by the students. The same spirit of interdisciplinarity is driving the preparation of a new Masters program in Automation and Control. It will be offered by four faculties – computer science, mechanical engineering, materials engineering, and electrical and computer engineering – and be open to graduates from all these disciplines.

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. Todays cars host nearly 1 GByte of code distributed over up to 70 electronic control units interconnected with up to five different buses. We believe that the key to meeting the challenges posed by this rising system complexity can be found in a sound design and analysis of the system’s architectures. Therefore we are interested in design and analysis methods for system and software archi-
tecture, which support the achievement of predefined quality goals and, in particular, meet current requirements like composability and exchangeability of software components from different sources and over the complete vehicle network.

One way to analyze software architectures is the examination of scenarios that focus on a product’s requirements. In requirements engineering we distinguish between functional and non-functional (also qualitative) requirements of a product. Qualities are desired features which exceed correct functionality, e.g. reliability, changeability or testability.

The non-functional requirements are frequently given less attention than the functional ones. They are often harder to analyze but crucial for the success of software intensive systems. Whether a product achieves its quality requirements is strongly affected by its software and system architecture. A careful requirements analysis therefore enables the designer to choose an architecture for the system by balancing opposing requirements. One way to achieve the detected quality goals is to construct the system from architectural patterns.

For analyzing existing systems’ architectures we are working on description languages that are constructed for the automotive domain. We hope to be able to detect architectural decisions that compromise and decisions that assist in reaching a product’s business goals by giving the system designer the possibility to simulate his architecture early in the development cycle.

\[\text{Safety Critical Embedded Systems}\]
\[Falk Salewski, Stefan Kowalewski\]

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.

One of our interests in this field is the influence of hardware decisions on the safety and reliability of the according software. We see a chance to improve safety and reliability of a system by finding the optimal hardware-software combination. On the one hand this could be an appropriate microcontroller (MCU) with the according software or a programmable logic circuit (PLD) like a FPGA or a CPLD designed in a suitable hardware description language. In this context, we prepared an empirical study, which will take place in a graduate lab exercise (Hauptstudiumspraktikum) ‘Programming Embedded Hardware’ in summer 2005, in order to get the necessary basic data to work with. Examples for different hardware structures to analyse the influence on the according software are given in Figure 10.

On the other hand, the optimal hardware-software combination could be a partition of the systems functionality on a suitable microcontroller/microprocessor with the corresponding
software and an appropriate programmable logic circuit. One of the major problems when dealing with software safety is complexity. However, the safety critical functions are in some cases of a simpler nature. Thus, the idea is to implement the safety critical part in a very simple way on the programmable logic circuit and leave the complex higher level functionality for the microcontroller. The advantage of this approach is that the basic safety critical functions on the programmable logic circuit are independent of the CPU, they can be implemented in redundant hardware modules and they are easier to verify (e.g., timing analysis of programmable circuits is usually easier than the one of software running on a CPU). It has to be analysed which functionalities are suitable for this partition and how it should be realised in the design flow. In order to provide our results for other designers of safety critical systems we plan to allocate them in a pattern catalogue with the according building codes.

Another topic is the model based specification and analysis of safety requirements. There is a close connection to the research field of model checking.

**Model checking and static analysis of C source code for embedded systems**

* Bastian Schlich, Stefan Kowalewski
In the automotive area many embedded systems are microcontrollers which are programmed in the C programming language. Nowadays, the programs on this microcontrollers become bigger and more complex. They have many interactions with their environment. Thereby they are difficult to test. In this situation model checking and static analysis in combination can help developers to debug their applications. Actual model checking tools for C source code and actual frameworks for static analysis of C source code are not able to handle all constructs found in the ANSI C standard. Additionally, there are constructs in the C source code found in embedded systems that are not part of the ANSI C standard. There are for instance embedded assembler commands, direct hardware accesses, special registers. These constructs are not handled by these tools either. So at present there is no possibility to use these tools for C source code for embedded systems.

We are developing a tool that can handle these constructs and does model checking and static analysis of C source code for embedded systems. Our approach is depicted in figure 11. The circles represent artifacts given by the user. The rectangles represent fixed elements that cannot be changed easily. The ellipses represent the parts of our tool. The tool first transforms the C source code in an abstract syntax tree (AST). This AST is then annotated with additional informations gained from the compiler and the hardware description. From this AST our tool creates a control flow graph (CFG) and a data flow graph (DFG). The CFG is used in the model checking process and the DFG is used for the static analysis. The specification that is used in the model checking process is given by the user. We plan to use timing information in this process. The static analysis should for instance find errors in the use of the special registers.

Figure 11: Procedure for Model Checking and Static Analysis of C Source Code for Embedded Systems
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.

The first empirical study concerning agile methods has been finished with the lab course „Hardware Programming of an Embedded Assistance System“. During this course, the students were divided into two groups: a planning group and an ’agile’ group. This was done in order to evaluate whether there is an influence of the design and planning horizon on embedded systems or not. Data acquisition was done in the form of a biweekly status-survey and a log book, which had to be filled out by the students. The validity of the study is strongly threatened by the fact that the knowledge of system development was rather weak among students. In addition and even worse, four of the seven planning groups quit the course, while the ’agile’ groups finished. Though the analysis of the data still has to be done, first results indicate that the core functionality was implemented slower by the planning group, while their system had more features in the end.

Other Activities
Stefan Kowalewski:
Editing:

- Associate Editor of the IEEE Transactions on Control Systems Technology
- Member of the Editorial Board (Herausgeberbeirat) of at-Automatisierungstechnik, Oldenbourg-Verlag, Munich

Program committees:

- IEEE Conference on Computer-aided Control Systems Design, Taipei, Taiwan, 2004
Talks and Publications

Papers
Georg Frey, Stefan Kowalewski: *Einordnung und Bewertung von Beschreibungsmitteln aus der Automatisierungstechnik*, Jahrg. 49, Heft 9, pp. 73-79, at-Automatisierungstechnik, Oldenbourg-Verlag, Munich, 2004

Stefan Kowalewski: *Discrete control systems in cars - quality is more than correct function (Plenary)*, Proc. IFAC Workshop on Discrete Event Systems, Reims, September 2004

Talks

Stefan Kowalewski: *Über Kulturunterschiede – was Regelungstechnik und Informatik voneinander lernen können*, Kolloquium „Rückblicke, Einblicke, Ausblicke“, Universität Dortmund, 27 February 2004

Stefan Kowalewski: *Anwendung und Potenzial formaler Methoden in der Automatisierungstechnik*, Kolloquium „Beiträge zur Regelungstechnik“, Institut für Regelungstechnik, RWTH Aachen, 5 May 2004


Stefan Kowalewski: *Eingebettete Software und die Schnittstelle zu den Ingenieurwissenschaften*, Workshop „Herausforderungen an die Software-Engineering-Forschung in Deutschland“, Schloss Dagstuhl, 11-12 October 2004
Scientific Computing

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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. Bucker

This project deals with the numerical simulation of reactive transport in porous media using the simulation package SHEMAT (Simulator for HEat and MAss Transport). SHEMAT is an easy-to-use, general-purpose reactive transport simulation code for a wide variety of thermal and hydrogeological problems in two or three dimensions. The goal of this project is to develop a parallelization of SHEMAT based on the OpenMP standard for shared memory computers as well as to establish a methodology to reliably estimate model parameters using automatic differentiation. This project is funded by GEOPHYSICA Beratungs-gesellschaft mbH and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Second Order Derivatives in Process Engineering
M. Petera, C. Bischof, M. Bucker

Dynamic optimization is becoming increasingly important in process engineering. Quasi-Newton methods approximating second order derivatives are currently in frequent use and it is not clear whether or not exact second order derivatives would increase the rate of convergence in actual industrial engineering problems. The goal of this project is to develop an automatic differentiation system specifically designed to evaluate second order derivatives for modeling languages that are typical in process 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:

- Lars Kübler, University Erlangen-Nuremberg (May 24–26, 2004),
- Uwe Scholl, Fraunhofer-Institute for Algorithms and Scientific Computing (June 2, 2004),
- Paul Willems, BGH Wuppertal (June 2, 2004),
- Jean Utke, Argonne National Laboratory, USA (September 6–17, 2004),
- Hans-Jörg Kull, Theoretical Physics, RWTH (September 10, 2004),
- Tatjana Eitrich, Research Center Jülich (November 12, 2004)
- Heike Emmerich, Process and Material Simulation, RWTH (November 18, 2004)

Christian Bischof is speaker of the Working Group “Parallelism” within the Forum Informatik and organizes — jointly with F. Hoßfeld (Forschungszentrum Jülich GmbH), E. Speckennmeyer (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. Our institute organized a round of this symposium on October 11, 2004, highlighting various aspects of Computational Engineering Science, from teaching to challenging applications in a variety of areas.

Christian Bischof served on the program committee for the Fourth International Conference on Automatic Differentiation, July 19–23, 2004, Chicago, USA.

Martin Bücker co-organized the Fourth International Conference on Automatic Differentiation, July 19–23, 2004, Chicago, USA. In addition, he served on the program committee for:

- Second International Symposium on Parallel and Distributed Processing and Applications, Hong-Kong, China, December 13–15, 2004,
• Workshop on High Performance Scientific and Engineering Computing with Applications (HPSECA–04) held in conjunction with the 33rd International Conference on Parallel Processing 2004 (ICPP–2004), Montreal, Canada, August 15–18, 2004,

• International Conference on Computational Science and its Applications, Assisi, Italy, May 14–17, 2004,

• Workshop on Parallel and Distributed Scientific and Engineering Computing with Applications (PDSECA–04) held in conjunction with the 18th International Parallel and Distributed Processing Symposium (IPDPS–2004), Santa Fe, USA, April 26–30, 2004.

Talks and Publications

Talks

C. H. Bischof: *Automatisches Differenzieren und ausgewählte Anwendungen*, THESIS Kick-off Meeting, Bayrischzell, Germany, October 30, 2004

H. M. Bücker: *From Simulation to Optimization in Computational Engineering*, Colloquium “High Performance Computing on Sun – Today and Tomorrow”, Aachen, Germany, October 6, 2004


E. Slusanschi: *Automatic Differentiation in Scientific Computing*, Politehnica University Bucharest - PUB, Bucharest, Romania, October 1, 2004


A. Rasch: *Rechnergestütztes Differenzieren in der numerischen Strömungsanalyse*, Doktorandenkolloquium, TU Dresden, Germany, September 15, 2004


A. Rasch: *Automatic Differentiation and Hybrid Parallelization*, Fourth International Conference on Automatic Differentiation, Chicago, USA, July 23, 2004

A. Vehreschild: *A System For Differentiating MATLAB Built-in Functions*, Fourth International Conference on Automatic Differentiation, Chicago, USA, July 20, 2004
C. H. Bischof: *What can go wrong and what to do about it*, Fourth International Conference on Automatic Differentiation, Chicago, USA, July 19, 2004


H. M. Bücker: *Threads in an Undergraduate Course: A Java Example Illuminating Different Multithreading Approaches*, International Conference on Computational Science and its Applications, Assisi, Italy, May 15, 2004

E. Slusanschi: *Parametterschätzung und Informationsmatrizen*, SFB 540, RWTH Aachen, Germany, May 11, 2004


H. M. Bücker: *Toward Calibrating Turbulence Model Parameters for a Wavy Falling Film*, Minisymposium “Optimum Experimental Design”, European Conference on Computational Optimization, Dresden, Germany, March 29, 2004


**Publications**


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LuFG Software and Tools for Computational Engineering

Staff

- Faculty:
  Uwe Naumann
- Secretary:
  Renate Didolf
- Research Assistants:
  Ebadollah Varnik
- Student Researcher:
  Liliya Sadikova
- Technical Staff:
  Dmitrij Gendler
Overview
Our research activities aim to provide algorithms and software tools to support the use of modern methods from applied mathematics and computer science in computational science and engineering. More specifically, we are interested in the source transformation of numerical simulation programs with the objective to modify the semantics based on well-defined mathematical rules. Ongoing projects are dedicated to the corresponding analytic and compiler issues as well as to the investigation of related graph-theoretical and combinatorial problems.

Research Projects

**Adjoint Compiler Technology and Standards**
*Naumann*

The ,,Adjoint Compiler Technology and Standards” (ACTS) project is a collaborative research and development effort in automatic differentiation (AD) focusing on its application and next-generation tool development. The project also involves oceanographers and chemical engineers at MIT and computer scientists at Argonne National Laboratory/University of Chicago and Rice University. Its main outcome is a platform for the development and implementation of programming language independent AD algorithms. The software is known as OpenAD. Its main application within the ACTS project is the generation of tangent-linear and adjoint codes for the MIT General Circulation Model ([http://mitgcm.org](http://mitgcm.org)). Refer to

[http://www.mcs.anl.gov/OpenAD](http://www.mcs.anl.gov/OpenAD)

for further information.

**Combinatorial Problems in AD**
*Varnik, Naumann*

The ability to generate efficient derivative code for numerical programs requires the solution of various graph-theoretical and combinatorial problems. We have been focusing on the efficient accumulation of derivative information by elimination techniques on the linearized (dual) computational graph. Furthermore, we are interested in the efficient reversal of numerical programs in the context of automatic generation of efficient adjoint codes.
AD-enabled Compiler Technology

Naumann

With $\sin$ or $\exp$ being intrinsics in virtually all high-level programming languages could $\text{jacobian}$ or $\text{hessian}$ not be intrinsics as well? The integration of features that are of interest to numerical simulation into widely used compilers is an important goal of our work. We have been collaborating with the Numerical Algorithms Group (NAG) in Oxford, the University of Hertfordshire, Hatfield, UK, and Humboldt University Berlin in a project that aims to put automatic differentiation capabilities into NAG’s Fortran 95 compiler. Refer to

http://www.nag.co.uk/nagware/research/ad_overview.asp

for further information on the CompAD project.

Automatic Differentiation of Assembler Code (ADAC)

Gendler, Naumann

We are working on the automatic generation of tangent-linear and adjoint models for assembler code resulting from the application of the GNU Compiler Collection (gcc) to numerical programs written in a variety of high-level programming languages. An integration of this effort into the CompAD project is planned.

Teaching Automatic Differentiation by Source Transformation

Sadikova, Naumann

Teaching automatic differentiation by source transformation must be accompanied by practical exercises in the context of a functional software tool. We aim to develop a source transformation tool for AD of a subset of C++ that implements both tangent-linear and adjoint modes together with the relevant program analyses and code optimization techniques. The TASTe tool is intended for use in upcoming lectures / labs at the LuFG.
Other Activities

Prof. Naumann is a co-organizer of the 4th International Conference on Automatic Differentiation held in Chicago, USA, in Juli 2004. He is also a co-editor of the post-conference special collection of papers to be published by Springer in 2005.

Talks and Publications

Talks

Naumann:  *OpenAD*, 4th International Conference on Automatic Differentiation, Chicago, USA, Juli 2004

Naumann:  *Complete and partial Jacobian accumulation by vertex, edge, or face elimination*, Algebraic Complexity Theory meets Algorithmic Differentiation, Berlin, December 2004

Publications

U. Naumann and J. Riehme:  *A Differentiation-Enabled Fortran 95 Compiler*, To appear in ACM Transactions on Mathematical Software


Video delivery is anticipated to become among the most popular services over the Internet. 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 delivery services can suffer severely from variations and deterioration of the video quality. In the absence of QoS-aware networks, applications cannot control the service parameters offered by the underlying protocol layers. By consequence, the applications may experience late packet arrivals and packet loss. This results in severe degradation in the video quality as perceived by the user.

A framework to implement prioritized video delivery is presented. The inherent difference in importance of video packets for the video quality is first identified. Thereupon, a model for the estimation of distortion resulting from loss of video packets is introduced. Based on this distortion model, new robustness techniques are designed to achieve near-to-optimal video quality.

Given the trend towards wireless and mobile access to video content, the deployment of such robustness techniques within proxy caches is advocated. The improvements in video quality, that proxy caching in video delivery sessions can achieve, are emphasized.

**Evaluator:** Prof. Dr. O. Spaniol  
**External Evaluator:** Prof. Dr. J.-R. Ohm  
**Date of oral exam:** September 7, 2004
CHASID: A semantics-oriented authoring environment

Felix H. Gatzemeier

In writing an informational document (such as a scientific article or a textbook), an author faces a number of complicated problems: not just creating the actual media (text, images, and so forth) with its intricacies of formulation, but also selecting the content to be presented and structuring it so that the document in its entirety is consistent and readable. The latter is complicated by re-iterations over the document, where the author reviews and edits it from different perspectives.

CHASID, the project described in this book, addresses these tasks of the author: (a) Planning a document, (b) Upholding plans, and (c) Avoiding common structural problems. To do so, it blends itself into the existing conventional authoring environment and maintains a semantical model of the document, which is connected to its hierarchical structure of chapters, sections etc. The functionality is organized according to a cognitive model of the authoring process.

The semantical model contains the topics of the document, together with their relations. It is thus also called the topic map here. 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.

The additional functionality requires additional information which is not usually captured during authoring, namely the topic map and its connection. The author generally cannot be assumed to be willing to invest the effort of providing this information without seeing some direct benefit. So, the relationship between additional effort and kinds of possible functionality has also been considered.

Beginning with the least additional effort, requiring no additional information to be supplied by the author, tree transformations have been defined to support modifying the document hierarchy. For example, a division may be dissolved, promoting all of its children one level. This functionality requires the author only to find and understand the respective commands.

Addressing the overall planning problem, patterns have been introduced as a structured description of text types. A pattern has a name and consists of the problem to be solved (audience and content), a solution as a set of instructions, and a discussion pointing to alternatives and giving further advice. All these components are given in natural language. As a passive means of support (supplying documentation rather than functionality), they also do not require information from the author.

On the next level, schemata are provided, proven building blocks of documents spanning both the conventional document and the topic map. A schema has a name and consists of a short and a longer description and a part of a document with weighted components. When the author chooses to use a schema, the document part is merged into the existing document. The new and the existing components participating in the schema instance are grouped in the document, and their weights in this context are recorded for later checks. These schema-based checks produce warnings if important or crucial schema components have been
removed. To fix this, the author may connect another component from the document, or dissolves the schema instance. A third weight is used for optional components that may be removed without consequences.

This structure is still simple enough for interested casual users to understand: it is basically a cut-out of a document with some parts marked as more and some as less important. This allows schemata to be defined by an author, even for small substructures that just occur repeatedly within a chapter.

While instantiating schemata is the most convenient way to construct a topic map, operations for manual modeling are also available. On this level, the author invests the most effort and has to understand the types available in the topic map, but gets detailed control over the model. The author may insert topics and relations into the topic map, or remove them from it. With the topic map available, general checks can also detect faults in it, such as cyclic Part-Of relations.

A CHASID prototype has been implemented, connecting to ToolBook and Emacs as conventional authoring applications. The topic map and its connection to the conventional document are maintained in a graph database. All semantical operations have been implemented using the graph-based specification language PROGRES. User-defined schemata are stored as XML files conforming to a proprietary DTD.

The approach has been tested by translating advice from conventional writing guides into patterns and schemata. The results were generally satisfactory, but also revealed that more can actually be modeled than is commonly expressed in a guide.

In a side-track of the development, topic maps with only a synonym relation were regarded as a means to characterize and evaluate documents. Such models may be constructed by an attentive reader who does not have to be proficient in the subject area of the document, or they may even be derived automatically from documents written in sufficiently equipped markup languages.

Based on this, properties of topics relating to their order of exports and imports, being introduced only as a synonym, and others were defined. A formal concept lattice has then been constructed, regarding the topics and their properties as the objects and properties of a formal context. This lattice reveals characteristics of the document and can be used as a metric to spot trouble areas. For example, if many topics are imported before they are exported, an entire section may be misplaced.

The experiences from this project indicate that schemata can provide the basis for a semantical model far richer than what may be obtained by manual modeling. This improves creation as well as maintenance of documents.

**Evaluator:** Prof. Dr.-Ing. Manfred Nagl  
**External Evaluator:** Prof. Dr.-Ing. Jörg Haake (FU in Hagen)  
**Date of oral exam:** May 10, 2004
Routing and Addressing in Mobile Ad-hoc Networks

Mesut Güneş

A mobile multi-hop Ad-hoc network (MANET) comprises a set of nodes which can communicate without a dedicated underlying infrastructure. The network topology is continuously undergoing change due to the mobility of the nodes.

Ad-hoc networks are very flexible and thus suitable for a wide range of applications. This holds particularly if only temporary communication relations are required. Yet, the absence of an infrastructure implies that the associated functionality, including addressing and routing, must be provided by the individual nodes.

This thesis presents a new routing algorithm based on swarm intelligence. In addition, a distributed dynamic address allocation scheme for mobile multi-hop ad-hoc networks is presented.

Evaluator: Prof. Dr. O. Spaniol
External Evaluator: Prof. Dr. P. Mähönen
Date of oral exam: January 19, 2004
Quantile based histogram equalization is a method to increase the noise robustness of automatic speech recognition systems. During the feature extraction it reduces an eventual mismatch between the recognition and training data distributions with a non-linear parametric transformation function. This work describes the algorithm and presents detailed experimental evaluations.

Based on the quantiles of the cumulative distributions, the parameters of the transformation functions can be reliably estimated from small amounts of data. The approach is integrated into a modified Mel cepstrum feature extraction, in which the logarithm is replaced by a root function to increase the noise robustness. The actual transformation that is proposed in this work consists of two steps. First, a power function transformation is applied to each output of the Mel-scaled filter-bank, then neighboring filter are channels combined linearly.

To investigate the genericity of the approach and the proposed setup experimental evaluations have been carried out with different speech recognition systems, on several databases with different levels of complexity, ranging from digit strings (SpeechDat Car) to larger vocabulary isolated word (Car Navigation) and continuous speech recognition tasks (Wall Street Journal with added noise).

Consistent recognition results were observed on all databases. The modified feature extraction, with the root instead of the logarithm, already outperformed the original baseline on noisy data. Filter channel specific quantile equalization always improved these results, yielding relative improvements between of 5% and 50%, depending the recognition task and the mismatch of the data. Finally, the combination of neighboring filter channels was able to reduce the error rates somewhat further, especially if the noise, like car noise, was band limited.

**Evaluator:** Prof. Dr.-Ing. Hermann Ney  
**External Evaluator:** Prof. Dr. Harald Häge  
**Date of oral exam:** December 6, 2004
Traceability and Monitoring as Trust-Services on Electronic Marketplaces

Thomas List

One of the main problems preventing the successful use of current electronic commerce systems is the users lack of trust in such systems. Current solutions focus on providing secure communication and authentication methods. It is commonly argued that such methods will increase trust between users and electronic marketplaces. However, trust among companies acting as business partners on business-to-business electronic marketplaces is not addressed in these solutions. This form of trust is of particular importance for small and medium-sized enterprises that require support for the negotiation phase through the marketplace. In this thesis trust services based on the concept of traceability are introduced. In particular, the trust between users of electronic marketplaces is addressed. To create the services, a trust model based on elements from computer science, psychology, and sociology is developed. This models demands a trustworthy realisation of the services. To this end, the principle of a distributed trusted third party is introduced. Here a network of trusted third parties is used as a service provider for trust services. A service environment based on web services is developed for the technical realisation of the trust services. Using the environment, users of a marketplace can then select and configure trust services to their needs and preferences. This combination of trust services with the realisation through distributed trusted third parties can thus be used to enhance trust on electronic marketplaces.

Evaluator: Prof. Dr. Matthias Jarke
External Evaluator: Prof. Dr. Mareike Schoop
Date of oral exam: July 8, 2004
Reverse Engineering of Complex Legacy Telecommunication Systems
André Marburger

Reverse and reengineering of large and complex software systems is a difficult task. As a result, many methods and tools for reverse and reengineering have been developed so far. However, the work in this field has concentrated on sequential, and untimed systems, mainly for business applications. The majority of the approaches deals with decomposing monolithic systems, decoupling user interface/presentation from application logic and data handling/database management, or with identifying reusable components. In particular, numerous approaches have addressed the migration of legacy business applications to an object-based or object-oriented architecture. To a large extent, the corresponding methods are data-centered since they focus on structuring the data maintained by an application.

Another stream of research has dealt with migration to code of programming languages such as C++ and Java which already provide language support for object-oriented programming.

Reverse and Reengineering of process-oriented applications has been addressed less extensively. For example, a telecommunication system is composed of a set of distributed communicating processes which are instantiated dynamically for handling calls requested by the users of the system. Such a system is designed in terms of services provided by entities which communicate according to protocols. Understanding a telecommunication system requires the recovery of these concepts from the current source code and other sources of information. Furthermore, analyzing and visualizing the dynamic behavior is a key to system understanding.

This dissertation describes the concepts and the implementation of integrated tools for reverse and reengineering of telecommunication systems which were developed in close cooperation with ERICSSON in the ECARES project (Ericsson Communication ARchitecture for Embedded Systems). The concepts are based on studies and evaluation of a real telecommunication system - Ericsson’s Mobile-service Switching Center (MSC) for GSM networks called AXE10. These studies led to specific requirements. These requirements and an abstract system structure are described within a conceptual framework, which specifies the problem domain and identifies and interrelates the necessary concepts, thus building the terminological and conceptual foundation of this dissertation.

To guarantee the suitability and applicability of the methods and tools developed in this thesis, tool support was developed step by step in response to the requirements and questions stated by telecommunication experts. This approach implied an iterative and incremental analysis and development process. Each pass of this process concentrates on a subset of the overall functionality and delivers appropriate analysis functionality and result documents, thus providing another portion of the final reverse and reengineering environment.

The essential contributions (concepts, methods, and tools) to reverse engineering of telecommunication systems are as follows:

- Structural, control flow, and data flow information is seamlessly integrated into a modular graph scheme. In addition, the scheme organizes static (e.g., from code
analysis) as well as dynamic information (e.g., from trace analysis). This enables complex analysis operations incorporating all kinds of information.

- The structural analysis part combines aggregation, condensation, and lifting of information from different sources with deduction of additional information and multi-level abstraction and visualization.

- Static and dynamic behavioral analyses are utilized to realize link chain analysis, state machine extraction, and trace analysis. For trace analysis, a comprehensive simulator is introduced.

- The architecture recovery facility introduced allows to inspect software systems on architecture level described in ROOM notation.

- Explicit usage of domain knowledge in the development of concepts, methods, and tools guarantees suitability and user acceptance.

- The analysis of multi-language software systems is possible due to the realization of a seamlessly integrated yet open, modular, extensible, and flexible reengineering system.

Not all of these concepts are new. There are a number of mature techniques that have already proved to work quite well, especially for the static structural analysis of software. So, there was no need to re-invent them but rather to adapt and incorporate them. However, the combination of these techniques within an open, modular, and flexible reengineering system leads to synergetic effects. These result in considerable improvements with respect to power, applicability, and integration within the reengineering system implementation showing the desired functionality and behavior described by the conceptual framework.

**Evaluator:** Prof. Dr.-Ing. Manfred Nagl

**External Evaluator:** Prof. Dr. Jürgen Ebert (Universität Koblenz)

**Date of oral exam:** December 17, 2004
Abstract State Machines: Verification Problems and Computational Power

Antje Nowack

Abstract State Machines (ASMs) provide the basis of a formal method combining advantages of informal methods (understandability, executability) and advantages of formal methods (precision and applicability of mathematical methods and results). Applications of this method motivate numerous computability and decidability problems. The high expressive power is one of the advantages of ASMs but it leads rather directly to undecidability respectively uncomputability results in the unrestricted case. Consequently, we arrive rather early at the question whether there exist expressive classes of ASMs for which we can prove decidability and computability results. In the first part of this thesis, we introduce such a class called guarded ASMs. The idea is similar to the one of the guarded fragment of first-order logic for which satisfiability is decidable. We analyze the expressive power of this class and prove that it is (strictly) stronger than Datalog LITE and the guarded fragment of first-order fixed point logic. In the second part of this thesis, we study the decidability of general verification problems for ASMs corresponding to the question whether all computations of an ASM satisfy a property (usually expressed in some temporal logic). Because of undecidability in the general case, we have to restrict the ASMs and the properties in order to obtain decidability results. Guarded ASMs provide the basis of a decidable instance of the general verification problem. It is rather straightforward to ask for the possibility to weaken the restrictions on the ASMs if we do not aim automatic verification but concepts supporting verification, debugging and testing. One such possibility is the concept of slicing ASMs which we introduce in the third part of this work. The idea is analogous to the one of program slicing aiming to extract statements from a program that are relevant for its behavior at a given point of interest. These statements form again a syntactically correct program called a slice. Previous work has focused on programming languages that differ substantially from ASMs. Although the concept of program slicing does not directly extend to ASMs, it is possible to find an analogous concept for ASMs. We present such an approach. In spite of the fact that a minimal slice is not computable in the general case, we prove that a minimal slice is computable for guarded ASMs. This basic result can be extended in several ways. We present some extensions to larger classes of ASMs and other variants for the notion of slicing.

In the fourth part of this thesis, we change our point of view. We do not merely consider ASMs as a specification formalism but as a computation model. The ASM thesis says that every algorithm, of any kind, can be modeled step by step and on its natural abstraction level by an ASM. The thesis has been derived from basic principles for sequential algorithms, and for parallel synchronous algorithms. The main result of this part is that the ASM thesis also holds for quantum algorithms.

Evaluator: Prof. Dr. Erich Grädel
External Evaluator: Prof. Dr. Wolfgang Thomas
A Service-Based Agent System Supporting Mobile Computing

Anthony S. Park

The ability of autonomous and disconnected operations of mobile agents makes them a high-potential technology for mobile access networks. However, along with the potential benefits, autonomy and disconnected operations of mobile agents in wireless environments raise fundamental problems, which so far have found little attention in existing mobile agent systems.

The Java Agent Environment (JAE) is an infrastructure supporting mobile agent technology and considering the requirements of the agent network at the border to wireless access networks. The focus of the agent system implementation has been on service trading facilities and the support of services in mobile computing. The overview of the architecture is given by a top-down approach, introducing the Java based agent middleware and the core technology for agent mobility, security, services, and communication. Much effort has been put into agent migration and the involvement of small mobile devices which has lead to the Ticket concept, introducing Agent Transport Protocol manipulation and the consideration of mobile agents’ resource requirements. The concepts of mobile agents are suited for personal disconnected operations - especially in wireless access networks. Therefore, a solution to management of disconnected and malfunctioning mobile agents is proposed that enables tracking and handling of mobile agents both during their scheduled execution, and in the presence of unforeseen errors and failures. Finally, some mathematical thoughts on (wireless) network management show possible advantages of an architecture combining the traditional client/server approach with mobile agent technology.

Evaluator: Prof. Dr. O. Spaniol
External Evaluator: Prof. Dr. C. Linnhoff-Popien
Date of oral exam: March 10, 2004
The choice of a programming language quite often depends on the problem domain. Examples are the use of object-oriented languages for distributed systems, the use of functional languages in compiler construction, or the use of logical programming languages in artificial intelligence projects. In the extreme case it even makes sense to develop a domain specific language. In larger software projects it is desirable to implement each module in the programming language which is best suited for the specific module's task. Of course, this raises the question of how to integrate those modules to a coherent, working and efficient overall system. This dissertation focuses on a special case of language integration: the embedding of a language in an existing one. A new embedding-technique is proposed, based on structural type analyses and partial evaluation. In the first part of this thesis a set of three model-languages will be introduced. All these languages are designed to support our new embedding-approach, which will be thoroughly explained. The properties of the model-languages and the restrictions they impose on the guest languages will then be explained in full detail. As a first result, it turns out that many concepts of the model-languages can be simulated in C++ and thus, these languages are well-suited to explain the phenomena of the C++-Template-Metaprogramming technique. The second part of this thesis analyses the practical relevance of our new embedding technique. We will show how to integrate a functional programming language with lazy evaluation, garbage collection and algebraic datatypes into C++. We will show that our approach allows for the generation of code that is comparable with code being generated by established Haskell compilers.

**Evaluator:** Prof. Dr. K. Indermark  
**External Evaluator:** Prof. Dr. F. Hoßfeld  
**Date of oral exam:** December 12, 2004
The continuous progress in network and information technology enables new techniques in software realization. Individual functionalities can be implemented as independent software components, which can be composed on demand to an overall, distributed system. Thus the potential is given to develop an open service market, by which any provider can make his software components available to the broad use for a multiplicity of applications in form of electronic services. During the development of a new application, an integration of already realized partial functionalities can reduce time and costs.

With this progress however also new problems arise. If a customer uses a service offered over the Internet, it purchases an electronic service, against which he has certain demands regarding its quality. To survive in competition, a service provider hast to be able to fulfill these demands. But the quality of a service does not only depend on the components and systems of the provider, but also on the networks used for accessing the service, over which the provider normally has no control. Current techniques are offering no satisfying mechanisms to deal with the resulting quality of a service usage.

Rising requirements of the customers to the quality of the services and increasing complexity of applications make it necessary to set up a platform for service market support which enables the management of services. A management is needed which supports the entire life cycle of a distributed service usage, beginning with the representation of the services, the dynamic selection of services and their integration into the own working process, up to the monitoring and control of the service usage at run-time. In the thesis, a Trader-based approach is developed for realization of such a management. A Trader can be seen as the core of a supporting platform, since it provides a mediating facility, by which two software components (client and server) can be assigned dynamically. Based on the trading concept, the thesis considers three different aspects of management: customer, service provider, and service usage process.

To achieve an acceptance by the customer, a mechanism is developed to consider user requirements within the service selection. A Trader is extended by so-called service metrics, which make the Trader’s selection process flexible and enable a more exact consideration of quality demands. For the consideration of the global system state, a distribution of load is also included into the selection process. Thus, the capacities of the service providers are considered, protecting the providers against overload. However, if highly dynamic systems are involved, the improved selection process of the Trader maybe becomes useless, since the situation, under which a service was mediated, can change fast. In order to observe and hopefully keep the characteristics of an obtained service also at run-time, Management Proxies are introduced into the service usage process, decoupling customer and service provider. The developed components of the management platform are evaluated by run-time measurements and simulations for different scenarios. Thus the benefit of the approach...
is shown. At the same time, the limits in the applicability of the Management Proxies are pointed out.

**Evaluator:** Prof. Dr. O. Spaniol  
**External Evaluator:** Prof. Dr. P. Martini  
**Date of oral exam:** April 28, 2004
Habilitations
We show how the development of approximation algorithms for optimization problems and the comparison of different devices to describe formal languages can be studied in a similar way w.r.t. computational and descriptional complexity.

The most successful approach to solve \( \mathcal{NP} \)-hard problems has become the invention of approximation algorithms for the optimization versions of those problems, forming the class \( \mathcal{NPO} \). To classify a problem by its approximability, an approximation algorithm gives an upper bound, while a lower bound, based on \( \mathcal{NP} \)-hardness, allows to better judge how close the algorithm is to what is possible in polynomial time.

In the class \( \mathcal{NPO} \), the Traveling Salesman Problem (TSP) is a prototypical and thus intensively studied example, covering the whole range of approximability with its sub-problems. Among several other problems, the TSP is the most prominent one studied in our work.

We have developed an algorithm for instances of the Traveling Salesman Problem that obey the relaxed triangle inequality, by extending the Christofides approach beyond the metric case which was conjectured to be impossible, before. This algorithm has practical running time and performs the best approximation ratio for instances that violate the triangle inequality by a factor not too large.

For all sub-cases of the Traveling Salesman Problem that obey either the relaxed or sharpened triangle inequality, we have given a lower bound that was at the time the best one for the metric case, and it is still the only one in case of the sharpened triangle inequality.

In formal language and automata theory, one studies formal methods like automata, grammars, logics, and algebraic methods, that describe (in general infinite) formal languages by finite objects. It appears that some classes of languages, most notably the regular languages, can be described by a large variety of different formalisms. Now, the comparison of these methods w.r.t. their descriptional complexity has become a central task of formal language theory.

This comparison is naturally done by studying algorithms that transform a description using one formalism into one using another formal method. For a transformation the main point is the “blow-up”, that is the increase of descriptional complexity. Like for approximation algorithms, the quality of a transformation algorithm is judged against a lower bound, stating that the considered transformation cannot be performed with a smaller blow-up than described by a certain function.

Here, our main focus lies on the transformation from regular expressions to non-deterministic finite automata. These two formalisms are among the most studied in formal language theory, and of great practical importance, too. We have developed a transformation algorithm from regular expressions to non-deterministic finite automata that, for the first time, performed an only poly-logarithmic blow-up, improving
a more than twenty year old optimum of a quadratic blow-up. For the same transformation, we have given a first non-linear lower bound.

**Habilitationskolloquium:** June 16, 2004
The Complexity of Discrete Optimisation Problems
and the Structure of their Hardness Proofs

Walter Unger

The research on discrete optimisation problems has a long running history. The aim of this work is twofold. The first objective is the uniform presentation of several results from different areas of the wide range of complexity theory, that are motivated by practical applications. The second goal is to elaborate some common pattern for hardness proofs and thus to facilitate such proofs for prospective problems. We will demonstrate that optimisation problems are hard ones if in their structure a multiple flow of information is possible and if distinct informations may be combined. This collection contains results from the following areas:

First we explore the refinement of 2-dimensional grids and their embedding into grids with dilation 1. For a class of grid refinements we construct embeddings with optimal load. Furthermore we show that the general case of the problem of load determination is NP-complete.

The Elastic image matching is the fundamental problem of establishing the resemblance of two images. We show that this problem is NP-complete by reduction from 3-SAT.

Next we consider the problem of centrally scheduling time-constrained communication in linear networks, when each message has both a release time and a deadline. We show that the problem of transmitting an optimal number of messages is NP-hard, as well if messages may be buffered in transit as if they may not; for either case, we present efficient algorithms that produce approximately optimal schedules.

The one side crossing minimisation consists of placing the vertices of one part of a bipartite graph on a straight line on prescribed positions and finding the positions of the vertices of the second part on a parallel line and drawing the edges as straight lines such that the number of pairwise edge crossings is minimised. Typical graphs of practical interest are usually very sparse. We prove that the problem remains NP-hard even for forests of stars of degree 4.

We will show that the problem of placing street names in a Manhattan type map without conflicts is NP-complete and APX-hard. This is the first result of this type in this area.

The bandwidth problem for graphs. This problem has a long history and a number of important applications. We construct, for any $x, \epsilon \in \mathbb{R}$ with $x > 1$ and $\epsilon > 0$, a graph class for which an approximation algorithm with an approximation factor of $x + \epsilon$ exists, but where the approximation of the bandwidth problem within a factor of $x - \epsilon$ is NP-complete.

Habilitationskolloquium: June 16, 2004
System Administration Group

• Faculty:
  Prof. Dr.-Ing. Hermann Ney

• Research Assistants:
  Dipl.-Inform. Willi Geffers

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

• Student Workers:
  Moaffak Assassa
  Uta Christoph
  Sebastian Günther
  Sebastian Krämer
  Enisa Mušović
  Faruk Sari
  Ilhan Ucar
  Sumedha Widyadharma
Overview
Since 1985 the System Administration Group (RBI1) operates several computer labs and provides technical support for the Department of Computer Science at RWTH Aachen. The principal task of the RBI is to install, maintain, and evolve the local network and several central services, including file servers, a database server, mail server, and web server. Students, faculty, and staff have free unlimited access to the computer labs operated by the RBI. The computer labs are used in computer science courses and for student and faculty research projects. Especially for novice users a user helpdesk is offered during business hours. The labs are provided with PCs running the Debian GNU/Linux operating system. The computers are equipped with various hardware extensions and software to support the students in doing their exercises and projects. All computers are part of the local area network and provide unrestricted access to the campus backbone and the internet.

News

- 12 Sun Ultra 5 workstations were put out of operation and replaced by Debian/GNU Linux PCs with 2.8 GHz Intel Pentium IV CPU and 2.0 GHz AMD Opteron CPU, 2-4 GB memory, 80-160 GB hard disk, and gigabit ethernet.

- A computing cluster has been purchased. The cluster consists of 33 IBM eServer 326 computing nodes and 2 Cisco Catalyst gigabit ethernet switches. Each node is equipped with 2 2.2 GHz AMD Opteron CPUs, 4-8 GB RAM, a 160 GB Hard disk, and 2 gigabit ethernet ports. The N1 ONE Grid Engine software is used to schedule jobs on the cluster.

- The wireless network (WLAN) 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. Several WLAN access points have been upgraded from 11 Mbit/s to 54 Mbit/s.

Equipment

Computer Laboratories

Altogether the RBI operates seven labs in the basement of the E1 and E2 building. The labs are provided with various hardware platforms running the Debian GNU/Linux operating system.

1Rechnerbetrieb Informatik
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<tr>
<th>Room</th>
<th>Computers</th>
<th>Platform</th>
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<tbody>
<tr>
<td>4U13</td>
<td>6</td>
<td>Intel P-IV PC</td>
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<tr>
<td>4U15</td>
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<td>Intel P-IV PC</td>
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<td>4</td>
<td>AMD Athlon PC</td>
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<tr>
<td>4U16</td>
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<td>Intel P-IV PC</td>
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<td>6U07</td>
<td>8</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>6U09</td>
<td>8</td>
<td>AMD Opteron PC</td>
</tr>
</tbody>
</table>

Also available are 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.

Most GNU tools and many other free- and shareware tools are installed. For documentation purposes the typesetting system \TeX/\LaTeX{} and desktop publisher OpenOffice are available. Programming languages are particularly important and C, C++, Fortran, Pascal, and JAVA including extension libraries, source code management systems like SCCS, CVS, and subversion as well as source level debuggers are available. Coding is done with popular editors like vi and XEmacs. Especially for students in the first stage of the study course interpreters and compilers for Clisp, Scheme, Prolog, and Modula 3 are installed.

In addition the computers in the labs are configured for cluster grid computing. The Sun ONE Grid Engine software is used to schedule jobs on the cluster.

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**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 Linux speed up and simplify the installation of the computers in the labs. The operating system is automatically installed from network including all customizations.
- A dedicated mailserver provides email service for the students.
- Furthermore the RBI provides the primary webserver of the department.
- A database server running the Oracle database management system contains the database of the computer science library and handles all inquiries.
Local Area Network

Since 1986 the Department of Computer Science runs a computer network according to the IEEE 802.3 standard. Twisted pair cables according to 10BaseT and 100BaseT are widely-used. Previously installed thin and thick wire cables are hardly used today.

The bandwidth increased significantly due to inexpensive switching technology and an increase of the transfer rate from 10 to 100 Mbit/s. Above all an uncoupling of the network traffic and thus a further increase of the network throughput could be obtained by switching technology. Simple Ethernet HUBs with a transfer rate of 10 Mbit/s were replaced by FastEthernet switches using transfer rates of 100 Mbit/s and load balancing.

A CISCO Catalyst 6500 router is used as the primary router for the whole department and provides redundant access to the campus backbone. For services that require high network bandwidth, e.g. fileservers and database servers, we use gigabit ethernet either over twisted pair or over optical fiber. New chairs realize their local network completely based on optical fiber.

A wireless LAN has been installed in all public areas of the department and most chairs and research areas. Currently the wireless LAN is based on the IEEE 802.11 b/g standard and operates at a maximum speed of 54 Mbit/s.

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.
Staff

- Head:
  Dipl.-Bibl. Renate Eschenbach-Thomas

- Assistants:
  Shaohui Li
  Andrea Reinhart
  Michael Rose
  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 33000 monographs and conference proceedings recorded in an online public access catalogue (OPAC)

- “Handapparate”: Required readings for the courses, compiled by professors for their students, accessible on special shelves

- All diploma theses of our department recorded in a separate database

- Complete stock of the Springer “Lecture Notes in Computer Science” up to Volume 3000 as well as “Informatik-Fachberichte / Informatik Aktuell” up to last year; from then on only selected titles

- More than 300 journals

- Always up to date: Magazines like C’t, iX, PC Professionell, Linux-Magazin, Die ZEIT, Wirtschaftswoche, …

- Technical reports from our 59 exchange partners from domestic and foreign universities

- Service for department staff: Books and articles not available on site are procured from the central university library or from international library supplies

- Website containing plenty of information on our stock as well as interesting computer science links

- Four workstations and 60 comfortable work places; separate student group work spaces

- MoPS-zone for laptop users

- Scanner and copier

- Guided tours through the library for new members of our department providing information on our services

- Friendly and qualified consulting and assistance for our visitors

- Up-to-date press reviews on computer science, student life and the RWTH Aachen
2 News

“Lesegarten”
We are very pleased to announce the start of our project “Lesegarten”: an open area next to the library will be rebuilt into a garden for all visitors to read and work outside.

Services
One main focus of our work is literature search training for seminar groups. Its focal points are:

- literature search in local and international databases
- literature acquisition from our stock (with an extensive guided tour of the library) and from external libraries
- advice on writing seminar papers
Cooperation

Our contacts to foreign and domestic computer science libraries have been extended: The computer science librarian of the University of Stuttgart visited us to obtain information about the management and services of our library. Upon invitation of the computer science library of ETH Zürich, we visited the Zürich library for 3 days, giving advice on organization and services. We also completed the stock of the Kiel University computer science library by sending them copies of twelve journal issues that had been lost there.

Stock of books and journals

This year our stock could be extended about 1000 books, among them 29 books and 146 journal volumes as free duplicates from various European libraries.

We also received book presents from three publishing houses. Their value amounts to € 600 - 1000 in each case.

Miscellaneous

For the first time our library took part in “Girls’ Day”. A group of school girls visited our library and was introduced to the profession of a librarian and the managing of an “OPL” (one person library).

Following the weekly Computer Science Colloquium the speaker and interested members of the audience are invited to an informal gathering in our rooms. These are popular events, including the opportunity of having a glass of wine.
Fachschaft I/1

Botzen, Matthias
Bremer, Barbara
Deifuß, Georg
Forster, Jens
Friedrich, David
Günther, Sebastian
Habets, Corinna
Hink, Gregor
Kesselheim, Stefan
Kuramoto, Nobuyoshi
Lehnen, Patrick
Loch, Eva
Martini, Andrea
Matheisen, Axel
Nelles, Anna
Peter, Katharina
Ridder, Klaus
Runte, Sven
Scholtes, Sebastian
Schwark, Christoph
Spiller, Robert
Wüsten, Sebastian
Overview

Fachschaft Mathematik, Physik, Informatik  Tel. (02 41) 80-45 06
Kármánstraße 7, 3rd level (mail at: FS I/1, Templergraben 55, 52056 Aachen)
e-mail: fs@fsmpi.rwth-aachen.de
WWW: http://fsmpi.rwth-aachen.de/
Opening hours during lecture period:  Mo–Fr  12–14 h
  during lecture free period:  Tu & Th  12–14 h
Meetings of the Fachschaft:  Mo 19 h in the rooms of the Fachschaft
  Plenary meetings:  at the beginning of each semester
The Fachschaft (group of student representatives) is a part of the student body and represents
the interests of all students who study mathematics, physics, or computer science at the
RWTH Aachen.

At the beginning of each semester a plenary meeting is held where every student of math-
ematics, 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 con-
cerning the course of study but also on issues not directly related to the university. We
have a collection of old exercises and protocols of exams which can be viewed and copied
in our rooms. We have implemented a digital collection of old exercises and protocols
which is used for all newly incoming exercises and protocols. Furthermore there are books,
magazines and newspapers.

Dealing with the Situation of the Students

To work against the anonymity of the university and help beginners to orient we work
together with the ErstsemesterInnen Projekt der Fachschaften (autonomous fresh(wo)men
project) and support the ErstsemesterInnen-AG. For further information, see next section.

The Fachschaft delegates students into several academic boards in accordance with the elec-
tions.
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 magazin (ES-Info) containing information and guidance to people planning to study mathematics, physics or computer science at the RWTH.

The goals of these activities are:

- Build social contact after the loss of the old environment.
- Help to cope with the transfer from school to university (learning in individual responsibility) and to form groups (studying in a group, teamwork).
- Support in managing their studies.
- Basic approaches to reflect 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 every two weeks.

Publications

Was’n los, magazine of the Fachschaft, once or twice a semester.

ES-Info, information for beginners, once a semester.

Flyers, information about current things.

Joint Projects and Organizations
The Bonn-Aachen International Center for Information Technology (B-IT) is a pioneering activity of the German Federal government and the state of North-Rhine Westphalia in their effort to establish excellence clusters across universities and research institutes in Germany. B-IT is a joint institute of RWTH Aachen University and Bonn University in cooperation with the Fraunhofer Institute Center Birlinghoven Castle and the FH Bonn-Rhein-Sieg in Sankt Augustin. B-IT is aimed at the internationalization and acceleration of study programmes in Applied Informatics. Supported by the B-IT Foundation and supplementary NRW state and federal funds, B-IT offers highly selective English-language master
programmes in Media Informatics, Life Science Informatics, and Autonomous Systems. Moreover, B-IT offers summer and winter schools for qualified undergraduate students from Bonn and RWTH Aachen University. The B-IT programmes are distinguished by a deep integration of teaching and research through close cooperation with the participating Fraunhofer institutes of Applied Information Technology (FIT), Autonomous Intelligent Systems (AIS), Media Communication (IMK), and Scientific Computing and Algorithms (SCAI). From RWTH Aachen University, Prof. Dr. Matthias Jarke serves as Founding Director (together with Prof. Dr. A.B. Cremers, Bonn, and Prof. Dr. K. Witt, FH Bonn-Rhein-Sieg), whereas Prof. Dr. Otto Spaniol is Study Coordinator of the Media Informatics programme and Dr. Jürgen Rapp serves as study advisor. Main highlights of the year 2004 include:

- Seven of the nine endowed professorships funded by the B-IT Foundation are now filled, as two further Full Professors and two further Associate Professors joined the B-IT Faculty. For RWTH Aachen University, Prof. Dr. Thomas Rose, leader of the Business Process group at Fraunhofer FIT, was appointed as Associate Professor of Media Processes in addition to Professors Borchers and Kowalewski who had already joined in 2003.
- In February 2004, NRW Minister of Research Hannelore Kraft signed cooperation treaties with the Chinese provinces of Jiangsu and Sichuan during her visit to China on which she was accompanied by Prof. Jarke. The treaty foresees pre-selection of top students for the B-IT master programmes by these provinces which proved already highly effective for the 2004 class. During the visit, relationships to some of the top Chinese federal universities, including the first-ranked Qinghua University, could also be established and also led to recruitment of top students. Countervisits by the provincial and federal governments confirmed the promising path of the cooperation.
- In September 2004, the Media Informatics programme, together with the Software Systems Engineering curriculum at RWTH Aachen University and the Computer Science departments of the Universities of Trento (Italy) and Edinburgh (UK), was awarded a prestigious Erasmus-Mundus joint European master programme as one of only two successful applications in the computer science field. This programme, called the European Master of Informatics (EuMI), will enable us for the next five years to support top extra-European students with quite generous stipends.
- In October 2004, B-IT was finally - after more than a year of renovations - able to move into the beautiful B-IT building overlooking the River Rhine.
- In November 2004, the B-IT Universities Institute master programmes on Media Informatics and Life Science Informatics underwent a successful accreditation audit by ASIIN, the internationally recognized German accreditation agency for engineering, computer science, and the natural sciences.

After taking on the first full group of master students in the fall of 2003, the total number of students grew to about 130 when the class of 2004 joined B-IT in October, 2004. Undergraduate degrees of our students stem from more than 25 countries world-wide, with the largest groups coming from China and India.
The mission of the Fraunhofer FIT Institute for Applied Information Technology in Bir-linghoven Castle and Aachen is to support human-centered computing in the context of organizational processes. Researchers in FIT study lifecycle-wide methods for the design and evolution of adaptive, user-oriented information and cooperation systems in the interplay of human work practice with organizational processes. With a research staff of about 80, plus about the same number of student researchers, FIT pursues its mission in three major research areas which are complemented by special business fields and competence centers (see www.fit.fraunhofer.de for details):

- **FIT.CSCW** (leader: Prof. Dr. Wolfgang Prinz) investigates the field of Cooperation Systems. In 2004, several major case studies were completed in cooperation with major companies such as Metro, concerning the integration of cooperation and knowledge management. In cooperation with WDR (R. Yogeshwar), a very successful worldwide CSCW experiment with 650 school classes was set up in the context of the Venus Transit in front of the sun in June 2004. In the more technically advanced field of cooperative augmented reality where FIT has developed its own implementation framework called Morgan, several large EU projects were started, addressing the novel issues of Pervasive Gaming and Augmented museum exhibits.
• **FIT.LIFE** (leader: Prof. Dr. Thomas Berlage) investigates the field of Life Science Informatics, addressing navigational support for micro-surgery, systems environments for large-scale bioinformatics research, and assistive devices for users with special needs. Jointly with RWTH’s Informatik V and FIR institutes, an IBM Shared University Grant awarded in late 2004 provides the technical infrastructure. The FIT.BIKA competence center on barrier-free internet access (leader: Dr. Carlos Velasco) completed the development of an automated checker that can diagnose the accessibility of very large websites with thousands of pages in a short time and was successfully commercialized in 2004 under the name of Imergo. In addition, the BIKA group was awarded two large new European projects, addressing an infrastructure for hearing-based communication in Europe and advanced accessibility research. Another European project that addressed the use of biofeedback measurements for learning-impaired pupils, was successfully completed in 2004.

• **FIT/icon** (leader: Prof. Dr. Reinhard Oppermann) develops context-adaptive and mobile systems for eLearning and mobile work. Jointly with Informatik V, they are main partners in the ProLearn European Network of Excellence in Professional Technology-Enhanced Learning; other large eLearning projects include the RAFT EU projects on integration of field trips in highschool eLearning and the AILB project which develops novel tools to enhance the basic professional competencies for hearing-impaired young workers; the latter is a joint project with the DESIRE research team at RWTH Aachen University led by Prof. Dr. Ludwig Jäger. Contextualization in mobile work settings is also the main topic of the MICA project that was recently started to make the SAP software environment more flexibly usable, and of a project with the new Telekom Labs in Berlin that addresses end-user development of advanced phone functionalities.

The FIT group in Aachen is led by Dr. Andreas Becks and addresses information management aspects in business and engineering processes. One major project is the SEWASIE EU project which builds semantic web infrastructure for electronic business in cooperation with Informatik V, an Aachen-based software house, and a number of partners in Italy. Another effort, in cooperation with the Japanese Ricoh corporation, addresses the media change between paper-based and electronic information media in business processes and cooperates closely with the chemical engineering projects at Informatik V. This work is embedded in the Business Process and Decision Support business field at Fraunhofer FIT which is coordinated by Prof. Dr. Thomas Rose. Another project of this group, the Europe-wide citizen information system for air pollution Apnee-Tu, received high attention from the federal government as well as industry leaders as one of the first personalized mobile information systems delivered through mobile phones and was selected as one of the finalists for the Public-Private Partnership award in 2004.
Through these research activities, and through the teaching cooperation in the context of the Bonn-Aachen International Center for Information Technology (B-IT), Fraunhofer FIT has substantially deepened its ties to RWTH Aachen University in 2004.

The Apnee-Tu air pollution citizen information system was successfully demonstrated to government and business leaders such as Kai-Uwe Ricke (Deutsche Telekom) at CeBIT 2004.
Graduiertenkolleg ‘Software für Mobile Kommunikationssysteme’ (Software for Mobile 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 ‘Graduiertenkolleg’ ‘Software for Communication Systems’ has been renamed to ‘Software for Mobile Communication Systems’. Compared to the first period or even to its predecessor ‘Informatics and Technology’ it covers more focused research questions, which concentrate on mobile communication systems and mobile applications. While this narrowing of focus is regrettable we have to recognise that this move satisfies the major intentions behind the concept of the ‘Graduiertenkolleg’.


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/.

New ways of exchanging data through different types of networks are continuously evolving. This includes particularly mobile communication, which has by now become more or less ubiquitous, thanks to an ever increasing level of user acceptance. This, in turn, is largely due to improved standards and a vastly expanded variety of services.

Future application developments will more and more be based on user requirements rather than just feasibility. Here, the most important domains include electronic commerce, transport telematics, new forms of working, and other innovative concepts such as e-learning, e-government, and e-home. For these new applications to be acceptable, new underlying technologies and services are a sine-qua-non. Moreover, the increasing mobility of users will lead to an equally increasing role wireless networks will play in communication infrastructures. Yet, users expect application functionalities to be independent from the underlying communication network. Considerable additional research will be needed to actually meet this requirement.

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 ’Graduiertenkol-
leg’ 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 (Januar 2005) grant holders include:

- 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. Gernot Fabec, Chair Theoretische Informationstechnik, Prof. Dr. Mathar
- Dipl.-Inform. Dominik Schmitz, Chair Informatik V, Prof. Dr. Jarke
- Dipl.-Inform. Ulrich Norbisrath, Chair Informatik III, Prof. Dr. Nagl
- Lucia Draque Penso Rautenbach MSc, Laboratory for Dependable Distributed Systems, Prof. Dr. Freiling (nee Gärtner)
- Janne Riihijaervi MSc, Chair Mobilfunknetze, Prof. Dr. Mähönen
- Satish Narayana Srirama MSc, Chair Informatik V, Prof. Dr. Jarke
- Dipl.-Inform. Christof Mosler, Chair Informatik III, Prof. Dr. Nagl
- Dipl.-Inform. Ulrich Norbisrath, Chair Informatik III, Prof. Dr. Nagl
- Dipl.-Inform. Nico Wallmeier, Chair Informatik VII, Prof. Dr. Thomas
- Dipl.-Inform. Martin Wenig, Chair Informatik IV, Prof. Dr. Spaniol
- Jianhua Wu MSc, Chair Informatik VIII, Prof. Dr. Kobbelt

This represents an extremely international group. The respective home countries include China, Germany, Georgia, Finland and Hungary. Three students left the ‘Graduiertenkolleg’ in the reporting period.

- Dr. Harald Albrecht, Chair Prozesstechnik, Prof. Dr. Epple, reached the maximum scholarship lifetime for post-doctorates (2 years)
• Dr. Imed Bouazizi, Chair Informatik IV, Prof. Dr. Spaniol, successfully finished his studies and is now with NOKIA Research in Tampere, Finland

• Andras Zolnay MSc, Chair Informatik VI, Prof. Dr. Ney, reached the maximum scholarship lifetime and plans to finish his studies early 2005
The Collaborative Research Center (CRC) 476 IMPROVE (Computer Support for Cross-Company Development Processes in Chemical Engineering) is a long-term research project, funded by the Deutsche Forschungsgemeinschaft (DFG) since August 1997. The project is reviewed every 3 years. It is carried out by several institutes and departments of RWTH Aachen University. The partners come from different domains in engineering and computer science. Speaker is Prof. Dr.-Ing. M. Nagl, Department Computer Science III, Speaker Substitute Prof. Dr.-Ing. W. Marquardt, Chemical Engineering.

**Aim**

The aim of CRC IMPROVE is computer support for development processes across different departments/companies in chemical engineering. We regard development processes in their early phases (conceptual design and basic engineering). The long term goal is the formulation of a formalized and integrated process and product model for development processes in chemical engineering. On this basis we develop new tools within an integrated development environment which interact synergetically. The environment uses existing tools to avoid the reimplementation of their functionality. The environment is based on a software architecture which is related to the process and product model and which allows the a-posteriori integration of existing tools. The developed concepts are validated using a reference scenario, namely the development of a polyamide-6 plant. After the successful peer review in 2003 last year was determined by ongoing research work. On the other side the next peer review in 2006 was started to be planned. Peers recommended in 2003 to start transfer projects in the
next phase beginning 2006. Therefore, application-dependent tasks have been strengthened.
In order to intensify the contacts between CRC IMPROVE and the industry, a two days symposium “IT for Development and Production in Chemical Engineering” was organized by LPT and TU Berlin. On the other side there are fundamental research questions for which the CRC wants to get at least a partial solution.

Activities

The progress of the projects in telegram style:

Work Processes for the Model-based Design

The subproject concentrated in 2004 on modeling decision processes for process design in chemical engineering. Thereby, we based on existing results on work process modeling on one side and the developed ontology OntoCAPE on the other. The aim is an integrated model of work processes, of the produced results, as well as the underline design decisions.

Information Models for Conceptual Design

The ontology OntoCAPE, developed in this subproject, was extended by new concepts to describe physical phenomena, numerical methods, and mathematical models. We continue work in direction of modeling domain-specific document contents as soon as the migration of OntoCAPE from DAML+OIL to the new W3C standard OWL is finished.

Experience-based support of cooperative development processes

Work in 2004 focused on the simplification of the underlying PRIME tool architecture for which we regarded results in the area of service-oriented architectures. Some application examples from plastics engineering were studied in order to show the practicality of the tool approach. The interaction between developers and management is going to be studied as well as the extension of currently available decision support.

Incremental integration tools for consistency control

The subproject deals with tool support in order to keep different documents of the development process consistent with each other. Thereby, not only the documents but also their internal structures, and the corresponding links between these structures are regarded. Tools for transformation and consistency checks between documents are controlled by integration rules. The semantics of integration tools was defined by a semiformal approach.

Reactive management system for project coordination

The subproject regards the management of dynamic development processes which have to be steadily reorganized during their execution. In 2004 a more general and more flexible concept was developed in order to cover a broader spectrum of possible forms of collaboration. Furthermore, the coupling of the AHEAD management system with commercial workflow management systems was studied in order to execute structured process parts by a workflow management system.
Cooperative knowledge management

The subproject offers a process data warehouse as ontology-oriented infrastructure for the access to product and process data. The focus of our work was the semantic access to documents which are stored in a document management system. Ongoing work regards the additional problems which are connected to cross-company cooperation.

Service management and service transmission

The service model and the service layer of the subproject was extended. Especially, external web services were incorporated in the service selection and service mediation procedure. Thereby, we started with the integration of common security mechanisms and multiple party security.

Scenario-based analysis of development processes

The tool WOMS for work process modeling developed in this subproject was extended by additional export functionalities. From a WOMS file html pages can be generated which form specific views on the work process and, thereby, allow to analyze the work process under different perspectives. One of our industrial partners uses WOMS successfully for capturing an improvement of work processes.

Labor-organizational structuring of development processes

In the K3 modeling approach, which was used in former phases of the CRC, was extended and formalized in order to be executed by simulation tools. The K3 user guide was newly written thereby preserving the user friendliness of the modeling approach even in case of changes. The modeling tool WOMS was evaluated under software ergonomic aspects.

Software integration and framework development

The integration of the existing tools into the overall development environment is one of the prerequisites for a comprehensive support of development processes. Due to the heterogeneity of tools multiple wrappers are needed in different occurrences. We aim at a mechanical derivation of wrappers by generating the wrapper code from a model-driven specification of the interface. To describe these specifications a formal (meta) model was defined.

The scientifically most important question is, how the new computer-based support for development processes on top of existing tools can be derived by a well-understood and methodical tool development process. This process starts with the determination of application-dependent models, from which the basic as well as the specific functionality of tools can be derived.

Project data at a glance

Partners of RWTH Aachen:
Chemical Engineering
Labor Research
Software Engineering
Information Systems
Distributed Systems

Adjunct project also financed by DFG:
Plastics Engineering Labor
Virtual Reality Center of Computer and Communication
Project running since 1997

External funding
German Research Foundation (Deutsche Forschungsgemeinschaft)

Contact

Prof. Dr. M. Nagl (Department of Computer Science III; Speaker)
Tel.: +49-241-80-21300, Fax: +49-241-8888-218
e-mail: nagl@i3.informatik.rwth-aachen.de
Overview

Lehrstuhl für Informatik VI

TC-STAR is an EU funded integrated project and brings together partners from twelve different European research sites from both academia and industry. It is envisioned as a long term effort focused on advanced research in all core technologies for speech-to-speech translation: speech recognition, speech translation, and speech synthesis.

<table>
<thead>
<tr>
<th>TC-STAR</th>
<th>Participating companies:</th>
<th>Participants from academia:</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.tc-star.org">www.tc-star.org</a></td>
<td>ELDA</td>
<td>IRST (Trento)</td>
</tr>
<tr>
<td>FP6 integrated project</td>
<td>IBM</td>
<td>LIMSI-CNRS (Paris)</td>
</tr>
<tr>
<td>starting April 2004</td>
<td>Nokia</td>
<td>RWTH (Aachen)</td>
</tr>
<tr>
<td>granted for 3 years</td>
<td>Siemens</td>
<td>SPEX (Nijmegen)</td>
</tr>
<tr>
<td>funding 11 million Euro</td>
<td>Sony</td>
<td>UKA Universität Karlsruhe</td>
</tr>
<tr>
<td>total 18 million Euro</td>
<td>SRIT</td>
<td>UPC (Barcelona)</td>
</tr>
</tbody>
</table>

Project Objectives

The objectives of the project are extremely ambitious: to make a breakthrough in speech-to-speech translation research to significantly reduce the gap between human and machine performance. The focus will be on the development of novel algorithms and methods, integrating relevant human knowledge which is available at translation time into a data-driven framework.

Examples of such new approaches are the integration of linguistic knowledge in the statistical approach of spoken language translation, the statistical modelling of pronunciation of unconstrained conversational speech in automatic speech recognition, and new acoustic and prosodic models for generating expressive speech in synthesis.

TC-STAR has been granted for three years with a total funding sum of 11 million Euro. It targets a selection of unconstrained conversational speech domains - i.e. broadcast news and parliamentary debates - and a few languages relevant for Europe’s society and economy: native and non native European English, European Spanish and Chinese.

This work is supported by the collection of language resources. While competition is fostered by the setup of an infrastructure for competitive evaluation, the project supports cooperation by a technological infrastructure (common language resources, workshops, formats, APIs) and strives for the effective dissemination of scientific results within the consortium and the research community.

The EU intends to extend TC-STAR to another 3 year phase via an FP6 competitive call.
This second phase will target more complex unconstrained conversational speech domains - i.e. meetings and social conversations - in other relevant European languages.

In the following, we focus on the contribution of Lehrstuhl für Informatik VI to several of the work packages of the TC-STAR project.

**The Statistical Approach to Speech-to-Speech Translation**

The statistical approach to pattern recognition, highly developed especially in the field of speech recognition, has been successfully applied to the more general field of automatic processing of human language, including the translation of spoken and written language and the understanding of natural language and spoken dialogue systems.

The general framework for our research activities is based on statistical decision theory and problem specific modelling – acoustic–linguistic modelling for speech recognition and linguistic modelling for translation. The probabilistic framework and statistical decision theory have some characteristic advantages:

- The approach is able to model weak dependencies and vague knowledge at all levels of the system.
- Due to the statistical formulation of both the speech recognition and the translation problem, the combined problem of recognizing and translating speech can be described in a single, consistent mathematical framework.
- The free parameters of the models can be automatically learned from training data (or examples), and there exist powerful algorithms for this purpose.
- Using the Bayes decision rule, the final decision is made by taking all available context into account.

As an integral part of the research work, system performance is measured in objective benchmarks on various publicly available language resources. In the strive for an improved system performance, a typical research task is to invent new statistical models which do more exactly represent the real world while being robust to estimate and efficient to compute.

**The Creation of Language Resources**

Lehrstuhl für Informatik VI makes a major effort in building the European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation. The EPPS corpus consists of acoustic data, corresponding transcriptions, and parallel texts/translations of plenary sessions of the European parliament in the languages English and Spanish. We collect the acoustic recordings and transcribe recordings in (accented) English, either original parliamentary speeches or speech from simultaneous translation into English. Spanish transcriptions are produced by UPC. We also take care of the parallel text corpora - this technical term describes texts which consist of pairs, one sentence (sometimes more) in the source language and its translation in the target language. Although the exact correspondences between words or
sub-phrases are not provided, it is possible for the machine translation systems to derive that information from the data in a statistical model estimation process called training.

The typical amount of data used in contemporary state-of-the-art systems and also generated in this project is in the range of some ten hours of acoustic recordings and of about one hundred million running words of text in the parallel texts.

**Automatic Speech Recognition**

A speech recognition system can typically only recognize words that are part of its so-called recognition vocabulary. While this can be very large, new out-of-vocabulary words occur frequently – just think of proper names. We work on open vocabulary methods that target to overcome this restriction.

Another improvements cover lightly supervised transcription where the system is trained using speech of which the text is not exactly known and new optimization criteria for automatic speech recognition systems. Within the speech recognition part of TC-STAR, we cover the languages English and Spanish.

**Spoken Language Translation**

*Lehrstuhl für Informatik VI* is work package leader of the spoken language translation work package. In our own department, we develop translation systems for Chinese-English (business news domain) and for both Spanish-English and English-Spanish (EPPS domain). In EPPS, an interesting aspect is the translation of spoken language (which differs from written language in several aspects) in a large domain – this is a novel task for the research community. Three different types of input to the translation component are considered:

- written style language (the official text editions of the European parliament)
- spoken language (the verbatim transcriptions of speech recordings)
- speech recognizer output (including recognition errors).

Our research focuses on innovative translation methods, use of human-supplied knowledge, and on the integration of machine translation and speech recognition.
Forum Informatik
at RWTH Aachen University

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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. contact: Prof. Matthias Jarke, Chair of Computer Science V, jarke@cs.rwth-aachen.de, further information at: http://www.graeculus.de/

- The SFB 476 IMPROVE (Information Technology Support for Collaborative and Distributed Design Processes in Chemical Engineering) provides support for collaborative process engineering processes through innovative concepts from informatics. It is a long-term research project funded by the Deutsche Forschungsgemeinschaft (DFG) since August 1997. The project is reviewed every 3 years. It is carried out by several institutes and departments of RWTH Aachen University. The partners come from various domains, including chemical engineering, plastic engineering, software engineering, information systems, and communication systems. 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. contact: Prof. Manfred Nagl (Speaker), Department of Computer Science III, nagl@i3.informatik.rwth-aachen.de further information at: http://www-i3.informatik.rwth-aachen.de/sfb476/sfb476.html

- The SFB 540 “model-supported experimental analysis of kinetic phenomena in multi-phase 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.

contact: Prof. Wolfgang Marquardt (Speaker), Department of Process Systems Engineering, secretary@lpt.rwth-aachen.de further information: http://www.sfb540.rwth-aachen.de/

- The “DFG Graduate College”, “Software for mobile Communication Systems” 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'. contact: Prof. Otto Spaniol, Department of Computer Science IV, spaniol@informatik.rwth-aachen.de further information at: http://www-i4.informatik.rwth-aachen.de/Kolleg/

- The Virtual Reality Center Aachen (VRCA) coordinates and promotes the VR research and teaching activities at RWTH Aachen University. Right now, 37 institutes and 8 companies are organized within VRCA, and 35 research activities are being carried out in an interdisciplinary cooperation between RWTH institutes, primarily in mechanical engineering and medicine. The fourth VRCA-workshop took place
in july 2004 and had approximately 90 visitors. In the same year the annual report 2003/2004 of VRCA-activities was published. contact: Dr. Torsten Kuhlen, Center for Computing and Communication, kuhlen@rz.rwth-aachen.de Further information at: http://www.rwth-aachen.de/vrca

Additionally following projects should be mentioned:

- The *Working Group “Parallelism”*, contact: Prof. Christian Bischof, Center of Computing and Communication, bischof@sc.rwth-aachen.de, further information at: http://www.fz-juelich.de/zam/pkoll/index.html

- The “*Bonn-Aachen International Center for Information Technology (B-IT)”*, contact: Prof. Matthias Jarke, Department of Computer Science V, jarke@cs.rwth-aachen.de, further information at: http://www.b-it-center.de

- The “*DFG Research Center Cognitive Technological Systems”*, contact: Prof. Klaus Henning, ZLW/IMA, henning@zlw-ima.rwth-aachen.de, further information at: http://www.ccts-aachen.com

- The “*Multiscale-Based Grid Adaptation*”, contact: Prof. Wolfgang Dahmen, Institut for geometry and practical mathematic, dahmen@igpm.rwth-aachen.de, further information at: http://www.igpm.rwth-aachen.de/www/forschung1.html

- The “*BuchIn - Accounting Software for University Institutes*”, contact: Prof. Klaus Henning, ZLW/IMA, henning@zlw-ima.rwth-aachen.de, further information at: http://www.zlw-ima.rwth-aachen.de/forschung/projekte/buchin/index.html

- The “*A Multiscale Method for Multicomponent-Mixture Separation Processes*”, contact: Prof. Wolfgang Dahmen, Institut for geometry and practical mathematic, dahmen@igpm.rwth-aachen.de, Prof. Wolfgang Marquardt, Department of Process Systems Engineering, secretary@lpt.rwth-aachen.de, further information at: http://www.lpt.rwth-aachen.de/Research/fluidmixture.php and http://www.igpm.rwth-aachen.de/brix/vielstofftrennprozesse.php

- The “*HeRBiE: binaural hearing for mobile robots*”, contact: Prof. Dr. Gerhard Lakemeyer, Knowledge-Based Systems & Cognitive Robotics Group, lakemeyer@informatik.rwth-aachen.de, Prof. Dr. Hermann Wagner, Institute for Biology II, wagner@bio2.rwth-aachen.de, further information at: http://www.bio2.rwth-aachen.de/research/ITDrobot-e.htm
Competence Network REGINA

Under the banner “Cooperation makes power”, REGINA has been engaged successfully for nearly fifteen years in strengthening the region’s IT industry. REGINA is a combination of 100 Aachen-based companies, educational establishments, and research institutes. Although competitors in some areas, the mainly small to medium-size enterprises which make up the network have formed an alliance to bring mutual benefit to all its members. Many of the general tasks they face are dealt with through collaboration within REGINA, in order to prevent unnecessary repetition or duplication of work. In the 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
- Media / Media Production
- Technology transfer
- Research and training

REGINA companies include world market leaders in specialized sectors, such as AIXTRON (semiconductor technology), DSA (quality assurance for the automobile industry), Parsytec (surface inspection systems) and CSB (application domain-specific software for the food industry).
Board:

Dr. H. Röllinger, SOPTIM AG (chairman)
Prof. Dr.-Ing. M. Nagl, RWTH (chairman substitute)
Dipl.-Ing. Dipl.-Wirt.Ing. J. Terbrüggen, Technology Transfer, RWTH Aachen (manager)
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Dipl.-Ing. Dipl.-Wirt.Ing. V. Hepple, Chamber of Industry and Commerce
Dr. J. Mansfeld, DSA GmbH
Dipl.-Ing. M. Wallrath, Ascom Deutschland GmbH

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Activities in 2004

REGINA’s Events

The events organized by the REGINA IT network are not private meetings, as they address real technical, economic, and strategic issues affecting the business of the network’s members. When members meet at the management get-togethers, information events, specialist conventions, and in working groups organized by REGINA, each of the members can expect to benefit from the experience of the others. This was traded on a wide variety of topics in the last year(examples:


Round-table Discussion: No New Economy without Old Economy

Workshop: Open Source / Linux
Looking for partners?

Great interest was shown by IT companies in the region when REGINA organized the company presentation event INFOrmatica. This event contained a wide variety of topics relevant to the information and communication technology sector, giving both young and established companies the opportunity to present themselves and those activities for which they seek to cooperate with partners. The event included a presentation of the German IT alliance BITKOM giving an overview about IT market development trends in the near future.

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 100 active participants today. The Aachen region is home to around 400 IT companies, which makes it a veritable power of this sector in Germany. With almost one in four of these companies as its members, REGINA has a clear and concise vision of its work in the years ahead: To preserve and extend Aachen’s position as Germany’s Silicon Valley, while actively welcoming new participants and ideas that allow the network to grow even more.
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