Annual Report 2006

Computer Science Department
of the
Faculty for Mathematics, Computer Science,
and Natural Sciences
at
RWTH Aachen University
Published by: Computer Science Department
RWTH Aachen University
Ahornstraße 55
52074 Aachen, Germany

Editors: Claudia Nick
Prof. Dr. Leif P. Kobbelt
Preface

Another year has passed and another annual report has been compiled providing a summary of all the scientific and non-scientific activities that our department performed in the course of the year 2006. As the speaker of the Computer Science Department at RWTH Aachen University I am happy to observe that, again, we can look back on a very successful year in terms of scientific merits as well as teaching success and progress in our project work.

The year 2006 has been declared the national Year of Computer Science by the Federal Ministry of Education and Research. On this occasion the Computer Science Department was engaged in a variety of activities and events in order to promote Computer Science topics to the broad public. This included a major local event in Aachen with public presentations and panel discussions. Later in this annual report you will find an article highlighting some of those activities.

With a team of 19 full-time professors, 7 affiliated professors, about 130 scientific staff members (85 of them funded by third party grants), 35 non-scientific staff members (some of them in part-time) and about 2000 students on the graduate and under-graduate level, our department constitutes one of the larger units within RWTH Aachen University. In addition to that, members of the department are actively cooperating with other research groups and industry companies on a local, national, and international level. All this amounts to a considerable outreach and impact of our work.

The successful execution of scientific research projects is well documented by the number of international publications (380) and the amount of third party funding raised for research projects (7.2 million euro), the major sources for our research funding being the German Science Foundation (DFG), the European Union, the Federal Ministry of Education and Research as well as various partners from industry. Beyond these “countable” achievements, members of the department have been involved in the organization of quite a number of international workshops and conferences, e.g., by chairing program committees or by hosting events in Aachen.

Another highlight was the successful participation in the first round of the National Excellence Initiative. Members of the Computer Science Department act as principal investigators in both research clusters “Ultra High Speed Mobile Information and Communication” (UMIC) and “Integrative Production Technology for High-Wage Countries” as well as in the graduate school “Aachen Institute for Advanced Study in Computational Engineering Science” (AICES) that were awarded to RWTH. This demonstrates that the department performs cutting edge research in the most relevant and active areas and is prominently involved in most major research initiatives.

Several international scientific awards and honors were won by members of the department (see later sections of this report), two prominent examples being the honorary doctorate received by our colleague Prof. Otto Spaniol from the Bulgarian Academy of Science and the appointment of Prof. Wolfgang Thomas as a member of the Academia Europaea.
Moreover, with Prof. Matthias Jarke being in office as the president of the German Computer Society (GI) and Prof. Manfred Nagl being elected as the new chair of the Fakultätentag Informatik, members of our department are actively participating in shaping the future of the field on the national level.

In 2006 we started our new Bachelor program — enrolment into the Diploma program is no longer possible. Overall the switch worked out very well. The Master program in Computer Science will start in 2008 complementing our already existing international Master programs in Software Systems Engineering and Media Informatics. We consider this transition as a good opportunity to re-think our established structures and to introduce an intermediate level of qualification. Our Bachelor graduates will be well prepared to work in the IT industry, e.g. as a software developer, and will have the fundamental knowledge to continue their training on the job or return to university after some years of practical experiences. Future Master graduates will receive the same breadth and depth in their education as our current Diploma students. With the additional funds emerging from the newly introduced tuition fee, we are now able to provide an even more individualized support to our students.

This year, our department has welcomed two new faculty members. Prof. Klaus Wehrle is heading the “Distributed Systems” group and Prof. Felix Wolf is leading the Helmholtz Junior Research Group “Performance Analysis of Parallel Applications” (located in the Jülich Research Center).

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

Leif Kobbelt
Chair of the Computer Science Department
Aachen, August 2007
## Contents

### Faculty Life

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Open Day, 2006</td>
<td>7</td>
</tr>
<tr>
<td>Computer Science Summer Party, 2006</td>
<td>9</td>
</tr>
<tr>
<td>Bright Brains in Computer Science</td>
<td>11</td>
</tr>
<tr>
<td>The Year of Computer Science</td>
<td>12</td>
</tr>
<tr>
<td>Algorithm of the Week</td>
<td>17</td>
</tr>
<tr>
<td>UMIC</td>
<td>19</td>
</tr>
<tr>
<td>New Professors</td>
<td>22</td>
</tr>
</tbody>
</table>

### Teaching

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diploma Programme: Computer Sciences</td>
<td>27</td>
</tr>
<tr>
<td>Bachelor Programme: Computer Science</td>
<td>30</td>
</tr>
<tr>
<td>Magister Programme: Technical Communication</td>
<td>33</td>
</tr>
<tr>
<td>Programme for Secondary School Teachers</td>
<td>36</td>
</tr>
<tr>
<td>Software Systems Engineering</td>
<td>37</td>
</tr>
<tr>
<td>Media Informatics</td>
<td>38</td>
</tr>
<tr>
<td>Girls Day</td>
<td>41</td>
</tr>
<tr>
<td>Study Day for Girls</td>
<td>42</td>
</tr>
<tr>
<td>Courses: Summer term 2006</td>
<td>43</td>
</tr>
<tr>
<td>Courses: Winter term 2006/2007</td>
<td>49</td>
</tr>
<tr>
<td>Computer Science Colloquium</td>
<td>55</td>
</tr>
<tr>
<td>Diploma and Master Theses</td>
<td>57</td>
</tr>
<tr>
<td>Statistics</td>
<td>70</td>
</tr>
</tbody>
</table>

### Research Reports

#### Chair for Computer Science 1

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithms and Complexity</td>
<td>77</td>
</tr>
<tr>
<td>Theoretical Computer Science</td>
<td>89</td>
</tr>
</tbody>
</table>

#### Chair for Computer Science 2

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Modeling and Verification</td>
<td>96</td>
</tr>
<tr>
<td>Programming Languages and Verification</td>
<td>113</td>
</tr>
<tr>
<td>Chair for Computer Science 3</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---</td>
</tr>
<tr>
<td>Software Engineering</td>
<td>124</td>
</tr>
<tr>
<td>Software Construction</td>
<td>147</td>
</tr>
<tr>
<td>Chair for Computer Science 4</td>
<td></td>
</tr>
<tr>
<td>Communication and Distributed Systems</td>
<td>156</td>
</tr>
<tr>
<td>Distributed Systems</td>
<td>176</td>
</tr>
<tr>
<td>Security Engineering</td>
<td>188</td>
</tr>
<tr>
<td>Chair for Computer Science 5</td>
<td></td>
</tr>
<tr>
<td>Information Systems and Database Technology</td>
<td>195</td>
</tr>
<tr>
<td>Knowledge-Based Systems and Cognitive Robotics Group</td>
<td>223</td>
</tr>
<tr>
<td>Chair for Computer Science 6</td>
<td></td>
</tr>
<tr>
<td>Human Language Technology and Pattern Recognition</td>
<td>233</td>
</tr>
<tr>
<td>Chair for Computer Science 7</td>
<td></td>
</tr>
<tr>
<td>Logic and Theory of Discrete Systems</td>
<td>256</td>
</tr>
<tr>
<td>Mathematical Foundations of Computer Science</td>
<td>265</td>
</tr>
<tr>
<td>Chair for Computer Science 8</td>
<td></td>
</tr>
<tr>
<td>Computer Graphics and Multimedia</td>
<td>273</td>
</tr>
<tr>
<td>Chair for Computer Science 9</td>
<td></td>
</tr>
<tr>
<td>Data Management and Data Exploration</td>
<td>292</td>
</tr>
<tr>
<td>Computer-supported Learning</td>
<td>305</td>
</tr>
<tr>
<td>Chair for Computer Science 10</td>
<td></td>
</tr>
<tr>
<td>Media Computing</td>
<td>314</td>
</tr>
<tr>
<td>Chair for Computer Science 11</td>
<td></td>
</tr>
<tr>
<td>Embedded Software</td>
<td>332</td>
</tr>
<tr>
<td>Chair for Computer Science 12</td>
<td></td>
</tr>
<tr>
<td>Scientific Computing</td>
<td>343</td>
</tr>
<tr>
<td>Software and Tools for Computational Engineering</td>
<td>355</td>
</tr>
<tr>
<td>Young Investigators Group</td>
<td></td>
</tr>
<tr>
<td>Performance Analysis of Parallel Programs</td>
<td>360</td>
</tr>
</tbody>
</table>

**Dissertations** 369
Central Services
System administration .......................................................... 391
Computer science library ....................................................... 396
Student union ................................................................. 400

Joint Projects and Organizations
Bonn-Aachen International Center for Information Technology ........ 405
Fraunhofer FIT ...................................................................... 407
Graduate college 'Software for Communication Systems' ............. 411
Collaborative research center 'IMPROVE' ................................ 414
AlgoSyn: Algorithmic Synthesis of Reactive and Discrete-Continuous Systems . 417
Computational Science ............................................................ 419
Forum Information Technology ............................................... 421
Industry club REGINA .......................................................... 425

List of technical reports .......................................................... 429
Faculty Life

The “Tag der Informatik” is the main annual Computer Science event at RTWH Aachen University which combines technical presentations, live demonstrations and expositions, the graduation ceremony and a big party at the first Friday in December of each year. The day is open to all people interested in the department’s activities. It is an established part of the university’s academic calendar: On December 1st, 2006, we were celebrating already the 20th Computer Science Day.

As the number of participants had grown steadily in the past and the limits of room capacity had been reached in 2005, we decided to change the venue and the structure of the event. For the first time, the Computer Science Day was held in the Aula 2, and the PhD colloquium was moved to the morning. This turned out to be the right answer to the strong attendance. At peak times, the Aula 2 was stuffed with people and we had to bring in extra seats. All in all, an estimated crowd of more than 400 visitors expressed their interest in the Computer Science Department.

In the morning session, research assistants from different computer science chairs presented current research topics of the department. The list includes Carsten Kern (“Synthesis of Design Models from Scenarios by Learning”), Arno Rasch (“Strategien für eine semantische Transformation von parallelen Programmen”), Tim Seipold (“Middleware & Telematik”), Stefan Schiffer (“Football is coming home”), Boris Bierbaum (“Rechnerkopplung für par-allele Anwendungen im Grid”), Ebadollah Varnik (“Sparse Jacobian Accumulation”), and Rafael Ballagas (“iStuff Mobile: Rapidly Prototyping New Mobile Phone Interfaces for Ubiquitous Computing”).

After lunch, the main program started. Following the traditional opening address by the department’s spokesperson Prof. Dr. Leif Kobbelt, our two new colleagues, Prof. Dr. Klaus Wehrle (“Lehr- und Forschungsgebiet Informatik 4, Distributed Systems”) and Prof. Dr. Felix Wolf (“Helmholtz-Nachwuchsgruppe Informatik 12”, Performance analysis of distributed programs) introduced themselves to the public.

The set of guest talks was started by Prof. Dr. Jürgen Roßmann from the Faculty of Electrical and Information Technology. He demonstrated in an illustrative manner how Virtual Reality can be used in various industrial applications ranging from robotics control to automation in forestry. An entertaining highlight was the next presentation with the arcane title “Rewind the future. On the deflationary time currency and generational shifts.” The speaker, Herman Konings from Pocket Marketing, Antwerpen, displayed a fireworks of striking statistics, insights and challenges about trends in our technology-addicted society and the relation between the current generations. After that, Dr. Thomas Kropf from Robert Bosch GmbH invited the audience to a virtual ride in the car of the future which will be safer and more comfortable thanks to advanced driver assistance systems. His highlighting of the challenges
to system and software design process for such systems was not only interesting to the researchers but also to the students looking for attractive areas of employment.

In the next session, our students moved into the focus of attention. First, Prof. Dr. Manfred Nagl moderated the annual stipend awards. Masrur Doostdar received a grant from IVU Traffic Technologies AG which was handed over by the founder and CEO of IVU, Prof. Dr. Ernst Dehnert. Arne Pott, board member of AMB Generali Informatik Services, handed over an AMB-stipend to Simona Pricope. After that, the final competition of the Sun Software Award was carried out live, moderated by Dipl.-Inform. Bastian Schlich. The four best student groups tested their programmed strategies in a virtual robot game. Sun Microsystem’s representative Thorsten Maier then handed over the prizes to the members of the first three groups, winner: Linus Atorf, Malte Nuhn, runner-up: Marc Schnabel, Sebastian Pick, Dominik Rausch, third: Ren Bohne, Sven Kratz.

For the graduation ceremony, the Aula 2 was filled up to its capacity limit. Prof. em. Dr. Klaus Indermark caught the audience’s attention by a enjoyable and thought provoking speech. He emphasized that our graduates are indeed part of an elite, but that this is not only an privilege but also an obligation. The head of the examination board, Prof. Dr. Stefan Kowalewski, could then hand out the certificates to more than 70 proud graduates.

With the official part of the day being over, the evening banquet took place. More than 400 guests enjoyed their dinner with piano music by Judith Bruns. The graduates, their families, the current students, alumni and members of the Computer Science Department took the chance to relax, talk and celebrate. The banquet smoothly moved over to a party with some computer scientists actually daring to dance to the DJ music. At one o’clock in the morning the last guests left and another exciting and successful Computer Science Day ended. Thanks to all who made it possible, in particular to the staff and students of Informatik 11 who were mainly responsible for the excellent preparation and efficient organisation.
Sommerfest der Informatik – Computer Science Summer Party 2006

Each year, towards the end of the summer term, the Computer Science Department organises a summer party for the ceremonial presentation of diploma certificates to the graduates of the past six or so months. This year, the location of the event was once more the Computer Science Centre. The summer party 2006 took place on Friday, 7 July, 2006. Prof. M. Nagl opened the event with an introductory talk, followed by a ceremonial talk given by Prof. em. W. Oberschelp. The official part ended with the presentation of the diploma certificates, moderated by Prof. S. Kowalewski. Over 50 students received their diplomas at this summer party.
After the official graduation celebration, the informal part of the summer party began with a small buffet and several kinds of drinks. Various DJs provided the (background?) music. About five hundred people attended the 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 Vodafone, Ericsson, sd&m, Kirchhof Software, as well as ComConsukt and SAP. 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 went on until late.
Bright Brains in Computer Science - Helle Köpfe der Informatik

Starting in summer 2006, the Department of Computer Science joined the support program *Aachener Model* for highly talented pupils from elementary schools in city and county of Aachen. An external steering committee selected 16 children who attend the new program called *Helle Köpfe in der Informatik*. During six course meetings, faculty members of the department introduce the talented pupils to basic topics of computer science. They particularly stress the insight that computer science exceeds just working with computers by far.

The first round in summer 2006 addressed the following topics:

- Why is it possible to scratch a CD? (Prof. Rossmanith)
- Searching and Sorting (Prof. Seidl)
- The needle in the haystack (Prof. Katoen)
- Kara, the programmable ladybug (Prof. Lichter)
- Programming a robot (Prof. Kowalewski)
- Create your own music instrument on the computer (Prof. Borchers)

The experiences made in the first round were very positive, and the program will be continued next year.
Since 2000, each year has been dedicated by the German Federal Ministry of Education and Research (BMBF) to the public presentation and discussion of a particular field of science. In 2006, this so-called Science Year was dedicated to the field of Informatics.

Coordinated by the BMBF, the organization Science in Dialog, and the Gesellschaft für Informatik (GI), more than 430 partners organized about 1,500 events with roughly half a million participants in 150 German cities. Some of the events, such as the 10th RoboCup World Championship held in Bremen in parallel to the human soccer world championship, were also highly publicized in national TV and other media. Incidentally, Germany took the largest number of championship titles in this event, including the world championship in homecare robotics by a team from RWTH Aachen’s Knowledge-Based Systems Group (Prof. Gerhard Lakemeyer).

As president of GI, Prof. Matthias Jarke (Information Systems) chaired the scientific steering committee of Informatikjahr 2006 and took active part in over seventy events during the year, including of course the opening ceremony on Jan. 17 in Berlin and the final ceremony on Dec. 18, which was held in conjunction with the first-ever National IT Strategy Summit called by Chancellor Angela Merkel in Potsdam with leaders from politics, business, and science.

Aachen was one of the most active participants in Informatikjahr 2006. Many colleagues from the Department of Computer Science and from the Electrical Engineering/Information Technology Faculty contributed to the organization of major activities and events.
In May 2006, Prof. Stefan Kowalewski participated as scientific expert in one of the largest events of the Informatikjahr, explaining together with a moderator from RTL the role of software in advanced racing cars to almost 12,000 highschool students invited by Informatikjahr 2006 to the Formula 1 Training at Nürburgring.

Aachen participated in the Informatics Year with a regional event on May 5, 2006. The event was themed “IT = Informatics for New Technical Applications” and addressed the everyday-relevance of informatics. The program started at 8 am and ended at 10pm. The different activities were aimed at all kinds of people and were very well-attended.

- **8.00–9.20: Learning Worlds 1 “How does the computer work?”** Kármán-Auditory, RWTH Aachen. This lecture was particularly aimed at pupils in 5th and 6th grade and gave a vivid introduction to informatics. With more than 500 registered attendants it filled one of the large lecture halls of RWTH Aachen University.

- **10.00–12.30: Learning Worlds 2 “Complicated, but useful”**. Elisenbrunnen, Aachen. This expo in the heart of the city center was visited by school classes and additionally attracted many pedestrians. The program was complemented by live music. The interesting exhibitions of useful applications of informatics were manifold:
  - Conducting Mozart: Virtually conduct a real symphony orchestra, *J. Borchers, RWTH Aachen*
  - Intelligent Wheelchair: Wheelchairs for handicapped controlled by facial expressions and gestures, *K.-F. Kraiss, RWTH Aachen*
  - MyHeart Intelligent Clothing: Sensors integrated into clothing monitor cardiovascular data, *J. Habetha, Philips*
Algorithm of the Week: Smart solutions to solve problems efficiently, B. Vöcking, RWTH Aachen

Automotive Electronic Check: Checking the bits and bytes of modern cars, V. Gehring, DSA

Flight Simulator, C. König, CAE

13.00–18.00: Girls Informatics Day. Informatics Center, RWTH Aachen. This workshop informed school girls from 9th to 11th grade about professions in the field of computer science. This was done by two hands-on examples: programming e-toys and creating film sequences for computer games.

14.00-16.00: Innovation World “Informatics and Engineering”. Informatics Center, RWTH Aachen. Four invited talks, accompanied by tool demonstrations from institutes and industry, informed roughly 250 interested people about interesting applications of informatics in engineering.

– Mobile Telephony Everywhere, R. Mathar, Theoretical Information Technology, RWTH Aachen

– Teaching Rapid Control Prototyping, D. Abel, Process Control Engineering, RWTH Aachen

– The World Wide Grid, V. Sander, Aachen University of Applied Sciences

– Virtualization of Reality, L. Kobbelt, Computer Graphics & Multimedia, RWTH Aachen

17.00–18.30: Discussion World “Internet and Democracy”. Informatics Center, RWTH Aachen. Panel discussion on current societal topics of informatics:
Viruses, Worms, and Trojans – Political Issue or Boogaboo?
Virtual World – Which Information Can We Trust in the Future?
Unlimited Access to Information or Censorship?

Moderated by M. Kröher (Manager-Magazin), participants were K. Brunstein (IFIP President), M. Kerner (Historic Institute, RWTH Aachen), M. Schmitz (Political Science, RWTH Aachen), O. Spaniol (Informatics, RWTH Aachen), and O. Urchs (Internet Consultant, Offenbach).

19.00: Talk and Discussion by the Fireside “InS – Informatics, Internet, and Industry”. Mansion Königshügel, Guesthouse of RWTH Aachen. Participants from politics, commerce, organizations, and science discussed the consequences of broad application of informatics and automation for society. Moderated by M. Kröher (Manager-Magazin), participants were U. Epple (Process Systems Engineering, RWTH Aachen), M. Jäkel (ver.di Cologne), T. Lieven (Founder of Vobis AG), J. Mansfeld (REGINA Aachen), and M. Nagl (Association of Informatics Faculties in Germany).

The regional event was a common effort of RWTH Aachen University, Department of Computer Science and Faculty of Electrical Engineering and Information Technology, Forum Informatik, student councils of RWTH Aachen, REGINA, Aachen University of Applied Sciences, GI regional group Aachen, Chambers of Industry and Commerce Aachen, and the City of Aachen. The event was organized by M. Nagl, U. Schroeder, O. Spaniol, B. Vöcking, members of their groups and many students. Sponsoring from the following organizations was very appreciated: Federal Ministry of Education and Research, RWTH Aachen University, proRWTH!, Forum Informatik, REGINA, City of Aachen, and GI.

In September 2006, the RWTH Aachen Computer Science Department hosted the final round and award ceremony of the 24. Bundeswettbewerb Informatik (BWINF), the national German highschool student Informatics competition, where the best 30 of about 800 participants competed for the top prizes which were handed out by GI President Jarke, BMBF Department Head Dr. W.-D. Lukas and Dr. S. Zahedani from the Management Board of sponsor Microsoft Germany.

In October 2006, the VDE/ITG Congress “Innovations in Europe” was held in Aachen, together with the final round and award ceremony of the competition “Invent a Chip” which
was part of the Informatikjahr 2006. Awards were handed out by political and business leaders, including European Commissioner Günther Verheugen.

Throughout the year, Prof. Vöcking coordinated one of the most interesting internet-based initiatives of the Informatikjahr, namely the “Algorithm of the Week” initiative of Fakultätentag Informatik in which some of the most important basic algorithms in computer science were presented with attractive application example, in order to excite the interest of young people in the field.

More detailed information about the events and materials of Informatikjahr 2006 is still available from the website www.informatikjahr.de.
Algorithmus der Woche

The “Algorithm of the Week“ (Algorithmus der Woche) was an initiative of the Fakultätentag Informatik on the occasion of the German year of computer science in 2006 (Informatikjahr 2006). The idea behind this initiative was to present, week by week, a new algorithm in a language understandable by pupils at the age of about 13 and higher. The web presentation of this project was done by the Lehrstuhl Informatik 1 at the RWTH Aachen, especially by Dirk Bongartz and Heiko Rögl. They were supported by a few student assistants that were founded by a small BMBF grant. The project went online for the first time on March 7 under the following web addresses.

- http://www.informatikjahr.de/algorithmus
- http://www-i1.informatik.rwth-aachen.de/~algorithmus/

The initiative should give first insights into the field of algorithms as a central element from the studies of computer science. Its purpose was to revive interest in the field of computer science to attract talented students in coming years.

During the year, a total of 43 articles with many illustrations and animations has been published. The articles have been written by 69 authors from 30 universities in Germany and German-speaking countries. Every article has been peer-reviewed in detail by two out of seven members of a selection committee. The chair of this commission was Prof. Vöcking. Four of the 43 articles have been written by authors from our department.

- Binary Search (Jost Enderle and Thomas Seidl)
- The Knapsack Problem (Rene Beier and Berthold Vöcking)
- Drawing Cycles with Turbo (Leif Kobbelt and Dominik Sibbing)
- Simulated Annealing (Peter Rossmanith)

![Figure 1: Picture from the article about binary search.](image)
All articles have been illustrated by pictures, graphics and, in some cases, animated applets. For example, the picture shown in Figure 1 has been taken from the contribution of Jost Enderle and Thomas Seidl.

Schools all over the nation have been informed about the “Algorithm of the Week“ by a newsletter concerning the year of computer science. Reports about the project also appeared in local newspapers and in radio transmissions. Furthermore, the web page is quite visible in the world wide web. A search with the key words “Algorithmus der Woche“ using Google yields more than 12,000 hits. Towards the end of the project, the page was accessed by more than 500 different users every day. The sites guest book contains various enthusiastic comments from pupils, teachers and students.

We plan to keep the web page online as long as possible since we expect a long term interest by pupils and teachers to use the published materials as a source for classes and presentations. Remarkably, even after publication of the last article in December 2006 the amount of accesses did not decrease. To further increase awareness of the project and to reach even more pupils and teachers, we plan to release a book covering all of the 43 articles.
Cluster of Excellence ”Ultra High-Speed Mobile Information and Communication” (UMIC)

In the early 90s cellular telephones were used primarily by a rather small circle of business people, and the Internet was only just becoming more widely known. About 15 years later, there are as many mobile phones in Germany as there are inhabitants, and the Internet is virtually ubiquitous. Today, it is safe to say that these technologies will merge, that the Internet will go mobile, and that data services will become at least as important for mobile users as voice transmission. As a result, a huge number of new mobile applications and services will emerge in the not-too-distant future. However, mobile wireless networks are facing specific problems. For one, compared to wire-based networks it is far more complicated to transmit at high data rates with an acceptable quality of service (QoS). This is due to, for instance, bandwidth limitations and changing transmission quality (e.g., because of adverse weather conditions). It is even more complicated to offer such high data rates to a large number of users located in a comparably small geographical area (e.g., in a city centre). Today’s systems offer a transmission rate of 2 Mbps at best, and even this comparably low rate can only be achieved under ideal conditions (which hardly ever occur). In the future, though, QoS levels will be required that are far beyond everything that can be offered today. Accordingly, the UMIC Cluster of Excellence aims to develop Ultra High-Speed Mobile Information and Communication systems providing an order of magnitude of improvement of the perceived quality of service. Concepts and demonstrators for smart, mobile, broadband, low-cost systems will be developed which support the demanding applications of the next-decade mobile Internet. To actually reach this ambitious goal, inter-disciplinary co-operation between different chairs and institutes from both Computer Science and Electrical Engineering and IT will be required. The UMIC activities is structured around three vertical pillars

- ’Mobile Applications and Services’
- ’Wireless Transport Platform’
- ’RF Subsystem and SoC (System on a Chip) Design’

These are supported by the research area ’Cross Disciplinary Methods and Tools’ (see Figure).
Mobile Applications and Services

Future such systems will need to support a broad variety of usages, most of which are still completely unheard of today. In this context, this area focuses on key application classes and their interplay with the underlying wireless transport network. Representative applications in the fields of, e.g., Mobile Multimedia Processing and Peer-to-peer Mobile Information Processing will be developed and analysed.

Wireless Transport Platform

Intelligent broadband systems are the backbone of future mobile communication platforms. These systems need to be able to recognise, and to adapt to, the characteristics of their respective environment. This implies finding a meaningful compromise between contradicting requirements of, for example, high data rate, transmission range, and energy consumption. To reach the mass market, such systems must also not be overly expensive. To reach these goals, the Cognitive Radio paradigm will be consistently pursued. Adaptive re-configurability at the air interface, including multi-hop capabilities, will be provided. The goal is to achieve a degree of spectrum efficiency, co-existence abilities, robustness and reliability, throughput capacities, and delay performance miles beyond the current state-of-the-art.

RF Subsystems und SoC Design

This area - almost exclusively pursued by our colleagues from EE & IT - will develop advanced integrated analogue and digital circuits under the conflicting regimes of flexibility and energy efficiency, taking into account constraints of future technology such as current leakage and soft errors. The extreme complexity can only be handled by integrating extremely large numbers of processors on a single chip.

Cross Disciplinary Methods and Tools

The UMIC approach will require new formal methods and software tools for design, optimisation, verification, and operation of
components and systems. This will be supported by the research area Cross Disciplinary Methods and Tools. This is a highly inter-disciplinary area, where the individual groups’ different experiences and views will be brought together for both problem analysis and the subsequent design of novel solutions. Test Lab A testbed for proof of concepts and the verification of solutions developed within UMIC will be set up. The UMIC challenges with respect to performance cannot be solved through piecemeal solutions at each individual layer of a communication system. Rather, the necessary quantum leap in innovation can only be achieved by a truly cross-disciplinary approach, which brings together the necessary disciplines ranging from computer science via information theory and communications engineering to complex system-on-chip design. The lab will help provide proof of concept of the novel solutions. The focus will be, on the one hand, on building critical new components, and on the other hand on the verification of the underlying concepts through scalable prototypes and through simulation. The Cluster will not work though pre-defined projects. Rather, it will only provide the framework, and the general guidelines, for semi-annual Calls for Proposals. The most promising and innovative proposals will then be selected by the Cluster management for funding. Initially, the Cluster will be funded for a period of five years. It is as yet completely unclear if UMIC will continue to exist after this period, and in which form. Nonetheless, many well-known firms, active in the area of wireless communication, have expressed an interest to collaborate with UMIC. The cluster members are convinced that it is desirable, and feasible, to continue the work of UMIC beyond the initial phase of funding, even without further public money. For further information please visit http://www.umic.rwth-aachen.de
1 New Professors

In 2006, two new colleagues joint our department: Klaus Wehrle and Felix Wolf.

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

1.1 Klaus Wehrle

In April 2006, I joined the Computer Science Department at RWTH Aachen University as head of the Distributed Systems Group (Lehr- und Forschungsgebiet Verteilte Systeme) at the Chair of Computer Science 4. Stefan Götz, Olaf Landsiedel and Simon Rieche accompanied me as PhD students from Tübingen University. Before joining RWTH Aachen University I passed through the following locations. I started my studies of Computer Science at the Technical University of Karlsruhe in 1993. After graduating in 1999 I joined the Institute of Telematics headed by Prof. Dr. Dr. h.c. mult. Gerhard Krüger at the Technical University of Karlsruhe as research assistant. In July 2002 I received my doctoral degree with honors for my dissertation on flexible and scalable quality-of-service mechanisms for the next generation Internet. It was awarded with the Doctoral Dissertation Award of Südwestmetall Association and the FZI Doctoral Dissertation Award.

Supported by a scholarship from the German Academic Exchange Service (DAAD) my family and I moved to California, in August 2002. At Berkeley, I joined the Internet Research (ICIR) group of Prof. Scott Shenker at the International Computer Science Institute (ICSI) as postdoctoral fellow in the area of Peer-to-Peer networking and overlay networks. Attracted by an Emmy Noether grant by the German Research Foundation (DFG), I came back to Germany in September 2003 to set up an independent junior research group in the area of Communications Systems Engineering and Distributed Systems at Tübingen University. The junior research group got additional funding from the Baden-Württemberg state foundation and Microsoft Research. I was also announced fellow of the Baden-Württemberg excellence program for young researchers. Since April 2006, I am holding a tenured professorship for Computer Science (Distributed Systems) at RWTH Aachen University. My research interests are focused on (but not limited to) engineering of communication protocols, implementation techniques for protocols, formal description techniques for protocols, quality-of-service, multicast, network simulation, peer-to-peer systems as well as all operating system issues of networking. Next to my research efforts in communication systems engineering and massively distributed systems, I have contributed to Internet standardization. Recently, the Internet Engineering
Task Force (IETF) passed RFC 3662 and RFC 3754 which were outcomes of my prior work on quality-of-service for the next-generation Internet. I am member of IEEE, ACM, Sigcomm, SCS, GI and GI/ITG-Fachgruppe KuVS (also serving in the KuVS steering board). Last but definitely not least, I am married to Anja Wehrle and I am the proud father of Felix (11), Lena (9), Samuel (5), and Julius (2). My hobbies are tennis, badminton, biking, kiting, table soccer and all kinds of electronic gadgets ;-) 

1.2 Felix Wolf

After my appointment as head of the Helmholtz University Young Investigators Group *Performance Analysis of Parallel Programs* at the Central Institute for Applied Mathematics of Forschungszentrum Jülich in September 2005, I joined the Computer Science Department of RWTH Aachen University as Juniorprofessor according to the *Jülicher Modell* in July 2006. Throughout my academic career, the goal of my research activity has been to make the optimization of parallel applications both more effective and more efficient. Unfortunately, parallel programs often achieve only a minor fraction of the theoretical performance limit, but making them run faster is a very complex and time-consuming process that requires adequate tool support for performance analysis.

I had already become interested in this topic as a computer science student at RWTH Aachen University, where I obtained my diploma in 1998. As a doctoral researcher in Jülich under the supervision of Professor Friedel Hoßfeld, I worked on automatic identification of wait states in event traces of parallel programs, resulting in the first prototype of the performance-analysis tool KOJAK. During this period, I spent several months at the IBM T.J. Watson Research Center in Yorktown Heights, NY, to become acquainted with industry-style research in high-performance computing. After completing my Ph.D. degree in Aachen in February 2003, I joined Professor Jack Dongarra’s Innovative Computing Laboratory at the University of Tennessee (UT) for two and a half years, during which I developed a number of new approaches to enhance KOJAK’s analysis capabilities. As an adjunct assistant professor with UT’s Computer Science Department, I also gave lectures on parallel programming.

With the emergence of large-scale custom clusters, such as the IBM Blue Gene/L now operating in Jülich, it has become clear that increased concurrency levels are placing much higher scalability demands not only on applications but also on software tools. In the abovementioned Helmholtz research group, we therefore started developing a successor to KOJAK named SCALASCA that scales up to more than 16,000 processors by analyzing
the trace data in parallel. As further advances in multicore technology force applications to harness progressively higher degrees of parallelism, we are convinced that the demand for such tools offering insights into the performance behavior on very large configurations will grow significantly.
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.

<table>
<thead>
<tr>
<th><strong>Degree:</strong></th>
<th>Diploma</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard period of study:</strong></td>
<td>9 semester (average duration: 12 semester)</td>
</tr>
<tr>
<td><strong>Registered students:</strong></td>
<td>1582 (total number in fall term 2006)</td>
</tr>
<tr>
<td><strong>Female rate:</strong></td>
<td>approx. 11.25 %</td>
</tr>
</tbody>
</table>

**Required qualifications**

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

Overall structure

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

Stage I (Vordiplom)

The technical and methodical basic knowledge in computer science is taught over approx.
80 semester hours in total. The pre-degree examination, which extends over five individual
exams, is passed study-attendant and comprises the topics computer science I (programming,
data structure), computer science II (computer structures, system programming), computer
science III (theoretical computer science), mathematics I and II as well as one subsidiary sub-
ject. 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, elec-
trical 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. Pos-
sible topics are amongst others: parallel algorithms, programming languages, software tech-
niques, 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 the

*Computer Science Program*

*(Bachelor and Master of Science RWTH Aachen University)*

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:** Bachelor/Master of Science RWTH

Aachen University (B.Sc. RWTH/M.Sc. RWTH)

**Standard period of study:** 6/4 semester

**Registered students:** 192 (total number in fall term 2006)

**Female rate:** approx. 12.5 %
**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 favored) while no deeper knowledge of a specific programming language or industrial experiences are required. During the study, good English knowledge is essential.

**Overall Structure**

**Bachelor of Science RWTH Aachen University (B.Sc. RWTH)**

The Bachelor study program in Computer Science aims at a broad education in the scientific fundamentals of Computer Science. In the Bachelor program, methodic competence and occupational field-specific qualifications shall be imparted, which build the basis for the subsequent Master program or an occupational activity. The Bachelor program comprises 180 ECTS Credits, which are a measure of the extent of the courses, and of the study time needed. The Bachelor exam comprises courses from the areas of Applied Computer Science (Programming; Data Structures and Algorithms; Databases and Information Systems; Introduction to Software Engineering), Technical Computer Science (Introduction to Technical Computer Science; Electrical Engineering Fundamentals of Computer Science; Operating Systems and System Software; Hardware Programming; Dependable Distributed Systems), Theoretical Computer Science (Discrete Structures; Formal Systems, Automata, Processes; Computability and Complexity; Mathematical Logic), Mathematics (Analysis; Linear Algebra; Stochastics; Numerical Calculus), Compulsory Selectable Courses, Subsidiary Courses from a related non-Computer-Science area, as well as seminars, lab courses, and thesis. In general, all courses include weekly (oral or written) problems, of which 50% are required for examination entry. Examinations mainly are done study-attendant in form of a written or oral test.

**Master of Science RWTH Aachen University (M.Sc. RWTH)**

The Master study program provides advanced knowledge, skills, and methods in the area of Computer Science and shall lead to a high degree of scientific qualification and independence. The Master program comprises 120 ECTS Credits. The Master program comprises the areas of Theoretical Computer Science, Applied Computer Science, Software and Communication, Data- and Information Management, as well as Subsidiary Courses from a related non-Computer-Science area. Within each of the areas, courses can be chosen from a broad range of Compulsory Selectable Courses. The Master examination consist of study attendant exams for lectures, two seminars, a lab course, and the modules of the Subsidiary
Area. Finally a specialized exam covering 12-18 ECTS Credits, as well as the Master thesis have to be performed.

Subsidiary Courses

In both the Bachelor and Master study programs, a subsidiary study course has to be chosen from: business administration, biology, electrical engineering, mathematics, physics. Other study courses, if offered at RWTH Aachen University, 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.

Subject-Related Specialty

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

Professional Areas

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

*Principles of Computer Science*

as second major of the

*Technik-Kommunikation (Magister/Magistra Artium)*

Program

at RWTH Aachen University

Short description

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

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

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

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

*Degree: Magister/Magistra Artium*

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

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

Overall Structure

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

Stage I

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

Stage II

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

Professional Areas

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

The subject of computer science at school

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

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

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

An overview of the curriculum

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

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

The essential prequisites for a successful study of computer science are similar as for the diploma curriculum: a certain acquaintance with abstract methods and constructions as they are learned and trained in mathematics. Moreover, the ability to communicate with others (and of course, in particular with children) is a necessary condition for future success as a teacher.
The International Master Program

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.
Media Informatics
Master Programm of RWTH Aachen University

Goals of the Programme

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

Formal Entrance Requirements

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

Special Entrance Requirements

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

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

Career Opportunities

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

Language of Instruction

The Programme will be taught completely in English

Duration of the Programme

Two years
**Beginning of the Programme**

October

**Deadline for application:**

March 1st the same year the programme starts

**Further information**

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

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

E-Mail: msc-mi@b-it-center.de
Webpage: http://mi.b-it-center.de/
The Girls’ Day is organized nationwide once a year. It provides an opportunity for 10- to 16-year-old female pupils to get to know professions especially in technical areas and in the domain of science. In 2006, the workshop was attended by about 22 pupils.

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

In the afternoon, the pupils visited different institutions of the Computer Science Faculty. The Computer Science Library gave an overview of their work and the services they offer. The software engineering group (i3) demonstrated an eHome environment which simplifies and supports the everyday life. For example, the environment is able to recognize the people staying in a room and play their favorite music. The chair for pattern recognition and human language technologies (i6) presented a speech translation system. The system recognizes German speech and automatically translates it into English. Afterwards, the English sentences are uttered via a speech synthesis component.

In the second workshop, a music video was produced with the girls both as actors and editors. Using an electric guitar, a DJ turntable and a giant wig among many other things, they turned the computer science building into a video clip scenery. Two groups produced a music video for some of their favorite tracks using a digital video camera and a computer-based video editing system while a third group created their own track using a loop-based music software. The girls could take the results of their work home with them on CD.
Schnupperstudium - Study Day for Girls

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

The computer science workshop is offered by female computer science students and scientists from different research areas. It introduces the study program at RWTH university through students currently enrolled in the program. They present the organizational and technical aspects of the studies as well as their personal experiences. Furthermore, several professions in the area of computer science are presented. Scientists give an impression of the variety of research activities the computer science departments are engaged in. The pupils may get an impression of life at university and the personal skills necessary for studying computer science.

About ten pupils aged 16 to 19 had the chance to get their own impression of computer science by learning a little bit about programming accompanied by some theoretical aspects. It was an opportunity to put this into practice by actually programming in a computer science lab which was very much enjoyed by the pupils.

The Markt der Möglichkeiten, a fair organized for all pupils taking part in any of the technical workshops, gave an overview of different study programs and offered information about central institutions such as Fachschaften, Studienberatung, and Berufsberatung.
1 Courses in Summer term (Sommersemester 06)

1.1 Undergraduate Courses 2nd semester

Esser
Differentialgleichungen und Numerik (Differential Equations and Numerics)

Lakemeyer
Rechnerstrukturen (Computer organisation)

Nebe
Diskrete Strukturen (Discrete structures)

Ney
Datenstrukturen und Algorithmen (Data structures and algorithms)

1.2 Undergraduate Courses 4th semester

Borchers, Spelmezan, Holman
Mensch-Maschine-Interaktion

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

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

Katoen, Bohnen
Automatentheorie und Formale Sprachen (Automata Theory and Formal Languages)

Katoen, Kern, Rieger
Softwarepraktikum: Implementierung heuristischer Algorithmen für Brettspiele

Kobbelt, Schmitz
Proseminar: Ausgewählte Kapitel der Computergraphik

Kowalewski
Proseminar: Small Memory Software

Löding, Wallmeier
Softwarepraktikum: Webprogrammierung und das Satzsystem LaTeX

Nagl, Hase, Heller
Proseminar: Web Services für verteilte Anwendungen

Naumann
Programmanalyse

Ney
Softwarepraktikum: Muster- und Bilderkennung

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

Ohm
Grundgebiete der Elektrotechnik IV
1.3 Graduate Courses

Bemmerl  
Betriebssysteme II

Bischof  
Grid Computing

Bischof  
Rechnergestütztes Differenzieren

Bischof  
Einführung in High-Performance Computing

Borchers, Lee, Holman  
Current Topics in Media Computing and HCI

Borchers, Lee, Ballagas, Spelmezan, Holman  
Designing Interactive systems II

Bücker, Vehreschild  
Automatisches Differenzieren in MATLAB

Giesl  
Logikprogrammierung

Grädel  
Komplexitätstheorie

Günes, Spaniol  
Simulation

Jarke, Klamma, Chatti  
Implementation of Database

Katoen  
Probabilistische Modelle für verteilte Systeme

Kobbelt  
Computergraphik II

Kowalewski, Palczynski  
Formale Methoden für eingebettete Systeme

Kowalewski, Polzer  
Sicherheits- und Zuverlässigkeitsstechnik (Safety and Reliability Engineering)

Kowalewski, Klünder  
Entwurf eingebetteter Software (Embedded Software Design)

Kraiss  
Mensch-Maschine Systeme II

Lichter  
Software-Qualitätssicherung und Projektmanagement
Mantel Formal Methods for Information Security
Mathar Kryptographie I
Mathar Kommunikationsnetze II
Nagl, Kraft, Fuß Modellierung von Software-Architekturen
Naumann Kombinatorische Probleme im wissenschaftlichen Rechnen
Niebert Vermittlungssysteme
Noll Software Model Checking
Prinz CSCW und Groupware: Konzepte und Systeme zur computergestützten Zusammenarbeit
Rokitansky Stochastische Simulation II
Rossmanith Effiziente Algorithmen
Schlüter, Ney Automatic Speech Recognition
Spaniol, Günes, Thißen Modellierung und Bewertung von Kommunikationssystemen
Thißen, Wienzek, Spaniol Verteilte Systeme
Thomas Infinite-State System Verification
Thomas, Rohde Rekursionstheorie
Vöcking Netzwerkalgorithmen
Wehrle Massively Distributed Systems
Westermann Approximationsalgorithmen
Borchers Club i10
Giesl, Thiemann, Schneider-Kamp Seminar: Verifikationsverfahren
Grädel Seminar: Logik und dynamisches Wissen
Jarke, Quix Seminar: accenture Campus Challenge
Jarke, Klamma, Chatti, Cao Seminar: Community Building in Ubiquitous Computing Environment with Contextualized Metadata
Katoen, Noll, Bohnenkamp Seminar: Formale Methoden zum Testen von Software
Kobbelt Diplomanden- und Doktorandenseminar

45
Kobbelt, Deserno, Ney, Rossmanith, Seidl, Spitzer Seminar: Medizinische Bildverarbeitung
Lakemeyer Diplomandenseminar
Lichter Lehrgebietsseminar
Lichter, Schackmann Seminar: Software-Wartung
Mantel Arbeitsgruppenseminar/ Diplomandenseminar
Mathar Seminar zur Kommunikationstheorie
Nagl, Mosler, Schultchen Seminar: Modellierungstechniken in der Softwareentwicklung und -wartung
Nagl, Marquardt, Haberstroh, Jarke, Spaniol, Schlick Seminar: Seminar: SFB 476 IMPROVE SFB
Ney Lehrstuhlseminar Advanced Topics in Speech and Language Processing
Ney Seminar: Speech Recognition and Language Processing
Schroeder, Giani Forschungsseminar eLearning und Fachdidaktik
Schumacher Seminar: Lokale Datennetze für industrielle Anwendungen
Seidl Seminar: Aktuelle Entwicklungen des Data Mining
Spaniol, Thißen Seminar: Ubiquitous Computing
Thomas, Löding Seminar über Automatentheorie
Unger Seminar: Algorithmische Graphentheorie
Vöcking Seminar: Buch der Beweise
Vöcking, Franke Seminar: Komplexitätstheorie
Wehrle Lehrgebietsseminar
Wehrle Seminar: Massively Distributed Systems
Westermann, Englert, Franke Seminar: Approximationsalgorithmen
Bischof, Kuhlen, Valvoda Praktikum: Virtuelle Realität
Borchers, Ballagas Praktikum: The Media Computing Project
<table>
<thead>
<tr>
<th>Name</th>
<th>Praktikum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jarke, Oppermann</td>
<td>Praktikum: User-oriented system design and personalized information services</td>
</tr>
<tr>
<td>Jarke, Quix, Kensche</td>
<td>Praktikum: Entwicklung von Web Services mit .NET Technologien</td>
</tr>
<tr>
<td>Katoen, Neuhäuer</td>
<td>Praktikum: Model Checking</td>
</tr>
<tr>
<td>Kesdogan, Pimenidis, Wehrle</td>
<td>Praktikum: Hacking-Lab</td>
</tr>
<tr>
<td>Kobbelt, Habbecke, Hornung</td>
<td>Hauptpraktikum: Building a vision-based 3D Scanner</td>
</tr>
<tr>
<td>Kowalewski, Salewski</td>
<td>Praktikum: Entwurf sicherheitskritischer Regelsysteme</td>
</tr>
<tr>
<td>Kowalewski, Wilking</td>
<td>Praktikum: Programmierung eingebetteter Hardware</td>
</tr>
<tr>
<td>Nagl, Armac, Retkowitz</td>
<td>Softwaretechnik-Projektpraktikum: Mobilität in eHomes</td>
</tr>
<tr>
<td>Ney</td>
<td>Praktikum: Data Mining Cup (Practical Course Data Mining Cup)</td>
</tr>
<tr>
<td>Schroeder, Giani</td>
<td>Praktikum: eLearning Engineering</td>
</tr>
<tr>
<td>Spaniol, Krempels</td>
<td>Praktikum: Agententechnologie</td>
</tr>
<tr>
<td>Wehrle, Landsiedler</td>
<td>Praktikum: Sensor-Netzwerke</td>
</tr>
<tr>
<td>Grädel, Thomas</td>
<td>Arbeitsgemeinschaft: Logik und Automaten</td>
</tr>
<tr>
<td>Jarke, Quix</td>
<td>Arbeitsgemeinschaft: Model Management (Working Group Model Management)</td>
</tr>
<tr>
<td>Jarke, Schlüter</td>
<td>Arbeitsgemeinschaft: Verfahrenstechnische Informationssysteme</td>
</tr>
<tr>
<td>Jarke, Klamma</td>
<td>Arbeitsgemeinschaft: Deduktive Objektbanken (Working group deductive object bases)</td>
</tr>
<tr>
<td>Kesdogan, Spaniol</td>
<td>Arbeitsgemeinschaft: Privacy Enhancing Techniques</td>
</tr>
<tr>
<td>Freiling</td>
<td></td>
</tr>
<tr>
<td>Kobbelt</td>
<td>Arbeitsgemeinschaft: Geometrische Modellierung</td>
</tr>
<tr>
<td>Seipold, Kritzner, Spaniol</td>
<td>Arbeitsgemeinschaft: Multimedikommunikation (Study Group: Multimedia Communication)</td>
</tr>
</tbody>
</table>
Spaniol

Arbeitsgemeinschaft: Mobilkommunikation (Study Group: Mobile Communications)

Thißen, Diepolder, Spaniol, Wehrle

Arbeitsgemeinschaft: Verteilte Systeme

Borchers

CHI Club

Grädel

Informatik-Kolloquium

Spaniol

Graduiertenkollg Software für Kommunikationssysteme
(Graduate School Software for Communication Systems)

Courses for Other Curricula (“Service Courses”)

Dietrich

Einführung in das Computeralgebrasystem MAPLE

Reichelt

Kompaktkurs C++
2 Courses in Winter term (Wintersemester 06/07)

2.1 Undergraduate Courses 1st semester

Aach

Elektronische Grundlagen für Informatiker

Bischof, Vehreschild

Programmierung (Programming Concepts)[Prog]

Spaniol

Systemprogrammierung

Stens

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

2.2 Undergraduate Courses 3rd semester

Aach

Elektronische Grundlagen für Informatiker

Grädel

Mathematische Logik (Mathematical Logic)

Naumann

Compilerbau für wissenschaftliches Rechnen

Spaniol

Systemprogrammierung (System Programming)

Vöcking

Berechenbarkeit und Komplexität (Computability and Complexity)

Katoen, Willems

Proseminar: Verteilte Algorithmen

Neuhäußer

Proseminar Datenkompression (Seminar Data Compression)

Ney, Schlüter

Proseminar Methoden und Werkzeuge

Seidl

Proseminar Internet-Technologie (Internet Technology)

Thomas, Löding

Proseminar Petri-Netze

Westermann, Franke

Proseminar Algorithmenentwurf und -analyse

Bemmerl, Finocchiaro

Softwarepraktikum: Parallelrechnen (Software Lab: Parallel Systems)

Borchers, Lee, Spelmezan

Softwarepraktikum: Multimodal Media Madness

Kobbelt, Hornung, Pavic

Softwarepraktikum: Computer Graphics and Physical Simulation

Bommes, Sibbing

49
2.3 Graduate Courses

Bemmerl
Betriebssysteme I

Berlage
Einführung in die Bioinformatik

Borchers, Holman, Ballagas
HCI Design Patterns

Borchers, Karrer, Holman
Designing Interactive Systems I

Broll
Virtual and augmented Reality

Bücker, Rath
Algorithmen zur Simulation und Optimierung physikalischer Prozesse: Von der Erdreich-Tomographie zur 3D-CAVE-Visualisierung

Giesl
Termersetzungssysteme

Grädel
Quantum Computing

Habetha, Walke
Kommunikationsnetze I

Katoen
Advanced Model Checking

Kobbelt
Geometrische Modellierung II

Kobbelt, Deserno, Ney, Rossmanith, Seidl, Spitzer
Ringvorlesung Medizinische Bildverarbeitung (Lecture Medical Image Processing)

Kobbelt
Computergraphik I

Kowalewski, Palczynski, Klünder
Dynamische Systeme für Informatiker

Kowalewski, Wilking
Introduction to embedded systems

Kuhlen
Virtuelle Realität

Lakemeyer
Introduction to Artificial Intelligence

Lichter
Objektorientierte Software-Konstruktion
Mähönen
Sensornetze und ihre Anwendungen

Mathar
Kryptographie II (Cryptography II)

Mathar
Kryptographie I (Cryptography I)

Nagl, Fu, Hassani, Mengi
Modellierung von Software-Architekturen

Nagl, Heer, Retkowitz
Einführung in die Softwaretechnik

Naumann
Rechnergestütztes Differenzieren

Noll
Compilerbau

Rokitansky, Einhaus, Walke
Stochastische Simulation I

Rößmann
Mensch-Maschine-Interaktion und Robotik I

Schlüter, Ney
Digitale Signalverarbeitung für Sprache und Bilder

Seidl
Modelle der Datenexploration

Thißen, Spaniol
Mobilkommunikation

Thißen, Spaniol, Wienzek
Datenkommunikation und Internet-Technologie (in Aachen)

Thomas
Strukturtheorie regulärer und kontextfreier Sprache

Thomas
Automata and reactive Systems

Unger
Algorithmische Kryptographie

Vöcking
Effiziente Algorithmen (Teil 1)

Walke
Grundgebiete der Informatik 3

Wehrle
Sensor Networks (Massively Distributed Systems II)

Wehrle
Peer-to-Peer Systems and Applications (Massively Distributed Systems I)

Wolf
Architektur und Leistung von Rechnersystemen

Borchers, Ballagas, Karrer
Seminar: Post-Desktop User Interfaces

Giesl, Thiemann, Schneider-Kamp, Swiderski
Seminar: Termersetzungssysteme - aktuelle Themen und Erweiterungen

Grädel
Seminar
Katoen, Noll, Rieger, Abraham  
Seminar: Zeigeranalyse

Kobbelt, Marinov  
Diplomanden- und Doktorandenseminar

Kobbelt, Marinov, Pavic  
Seminar: Current Topics in Computer Graphics

Kowalewski, Schlich  
Seminar: Testen von eingebetteten Systemen

Kuhlen, Bischof  
Seminar: Aktuelle Themen der virtuellen Realität

Lakemeyer  
Diplomandenseminar

Lichter  
Lehrgebietsseminar

Mantel, Katoen  
Seminar: Quantitative Aspects of Security

Mantel  
Arbeitsgruppenseminar/ Diplomandenseminar

Mantel, Katoen  
Seminar: Quantitative Aspects of Security

Mantel  
Seminar: Formal Methods for Information Security (Advanced Topics)

Mathar, Reyer  
Seminar zur Kommunikationstheorie

Nagl, Fu, Ranger, Körtgen  
Seminar: Unterstützung modellgetriebener Entwicklungsprozesse

Naumann  
Seminar: Diskrete Probleme im wissenschaftlichen Rechnen

Ney  
Lehrstuhlseminar: Fortgeschrittene Methoden in der Sprachverarbeitung

Quix, Kensche, Jarke  
Seminar: Model Management

Roßmann, Schlette  
Seminar: Virtual Human- Von der Roboter- zur Menschsimulation

Schroeder, Giani  
Forschungsseminar: eLearning und Fachdidaktik Informatik

Spaniol, Thißen  
Seminar: Ubiquitous Computing

Thomas, Löding  
Seminar Automatentheorie

Unger  
Seminar: Kommunikationsprobleme in Netzwerken

Vöcking, Ackermann  
Seminar: Network Algorithms

Vöcking  
Lehrstuhlseminar: Effiziente Algorithmen

52
<table>
<thead>
<tr>
<th>Name</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vöcking, Franke</td>
<td>Seminar: Netzwerkalgorithmen</td>
</tr>
<tr>
<td>Wehrle</td>
<td>Lehrgebietsseminar</td>
</tr>
<tr>
<td>Wehrle, Landsiedler</td>
<td>Massively Distributed Systems</td>
</tr>
<tr>
<td>Jarke, Oppermann</td>
<td>Praktikum: User-oriented system design and personalized information services for nomadic information and eLearning systems</td>
</tr>
<tr>
<td>Kowalewski, Salewski</td>
<td>Praktikum: Entwurf und Implementierung mit Mikrocontrollern</td>
</tr>
<tr>
<td>Lakemeyer, Ferrein, Schiffer</td>
<td>Praktikum: Servicerobotik</td>
</tr>
<tr>
<td>Lichter, Schackmann, Nyßen</td>
<td>Praktikum: Software-Konstruktion</td>
</tr>
<tr>
<td>Nagl, Schultchen, Wörzberger</td>
<td>Softwaretechnik-Projektpraktikum: Dynamisches und verteiltes Workflow-Management</td>
</tr>
<tr>
<td>Ney</td>
<td>Praktikum: Sprach- und Bildverarbeitung</td>
</tr>
<tr>
<td>Prinz</td>
<td>Current Topics in Computer Supported Cooperative Work (CSCW)</td>
</tr>
<tr>
<td>Rossmanith</td>
<td>Probability and Randomization in Computer Science</td>
</tr>
<tr>
<td>Schroeder, Bischof, Giani</td>
<td>Praktikum: eLearning Engineering</td>
</tr>
<tr>
<td>Seidl</td>
<td>Praktikum: Data Mining Algorithmen</td>
</tr>
<tr>
<td>Spaniol, Krempels</td>
<td>Praktikum: Agenten-Technologie</td>
</tr>
<tr>
<td>Spaniol</td>
<td>Graduiertenkolleg: Software für Kommunikationssysteme</td>
</tr>
<tr>
<td>Wehrle, Landsiedel</td>
<td>Praktikum: Sensor-Netzwerke</td>
</tr>
<tr>
<td>Grädel, Thomas</td>
<td>Arbeitsgemeinschaft: Logik und Automaten (Working Group on Logic in Computer Science)</td>
</tr>
<tr>
<td>Jarke, Schlüter</td>
<td>Arbeitsgemeinschaft: Verfahrenstechnische Informationssysteme</td>
</tr>
<tr>
<td>Jarke, Quix</td>
<td>Arbeitsgemeinschaft: Model Management</td>
</tr>
<tr>
<td>Jarka, Klamma</td>
<td>Arbeitsgemeinschaft: Deduktive Objektbanken</td>
</tr>
<tr>
<td>Kesdogan, Spaniol</td>
<td>Arbeitsgemeinschaft: Privacy Enhancing Techniques</td>
</tr>
<tr>
<td>Kesdogan, Wienzek, Spaniol,</td>
<td>Arbeitsgemeinschaft: Sicherheit in der Kommunikationstechnik</td>
</tr>
<tr>
<td>Wehrle</td>
<td></td>
</tr>
</tbody>
</table>

53
Kobbelt

Arbeitgemeinschaft: Geometrische Modellierung

Ney

Arbeitgemeinschaft: Bilderkennung

Ney

Arbeitgemeinschaft: Spracherkennung

Ney

Arbeitgemeinschaft: Sprachübersetzung

Seipold, Spaniol

Arbeitgemeinschaft: Multimediakommunikation

Spaniol

Arbeitgemeinschaft: Mobilkommunikation

Thißen, Diepolder, Spaniol, Wehrle

Arbeitgemeinschaft: Verteilte Systeme
3 Talks within the Computer Science Colloquium

January, 12  Dr. Ralf Klasing, CNRS, LaBRI - Universite Bordeaux 1
Bringing internet into villages using wireless communication

January, 20  Prof. Dr. Rüdiger Westermann, Technische Universität München
Interactive Visuelle Datenanalyse

January, 24  Assoc. Prof. Dr. Lubos Brim, Masaryk University, Brno
LTL Model Checking on Computer Clusters

February, 2   Prof. Dr. Dr.hc. Hans Langmaak, Christian-Albrechts-Universität zu Kiel
Formale Prozeduren versus Klassen und Objekte - Über K. Nygaards These zur Programmstrukturierung

February, 15 Dr. Dino Distefano, Queen Mary University of London
An automatic local heap analysis based on Separation logic

February, 16 Dr. Ir. Arend Rensink, University of Twente, NL
Model Checking Quantified Computation Tree Logic

March, 7     Prof. Dr. Shi-Min Hu, Tsinghua University, Beijing
Feature sensitive geometry processing

April, 6     Mariëlle Stoelinga, University of Twente
From Quality to Quantity: Quantitative Logics and System relations for quantitative transition systems

April, 26    Prof. Dr. Heike Wehrheim, Universität Paderborn
Softwaremodellierung mit vielen Sichten

May, 19      Dr. Peter Haumer, Rational Software, IBM Software Group
An overview to IBM’s development process strategy, the Eclipse Process Framework, and the OMG SPEM 2.0 Initiatives

July, 12     Dr. Dogan Kesdogan, RWTH Aachen
Vertraulichkeit in Kommunikationsnetzen

October, 19  Eröffnungskolloquium des DFG-Graduiertenkollegs AlgoSyn, Prof. Dr. W. Thomas, RWTH Aachen
Die Ziele von AlgoSyn

October, 19  Eröffnungskolloquium des DFG-Graduiertenkollegs AlgoSyn, Prof. Dr. B. Jonsson, Uppsala University
Using Synthesis for Verification and Testing of Reactive Systems

October, 19  Eröffnungskolloquium des DFG-Graduiertenkollegs AlgoSyn, Prof. Dr.-Ing. J. Raisch, Technische Universität Berlin
Hybrid Control Systems - How to deal with Heterogeneity and Complexity

October, 25  Dr. Pierre Alliez, INRIA GEOMETRICA
Surface Tiling through Contouring
November, 16  Prof. Dr. Martin Hofmann, LMU München  
From Type Systems to Program Logic

November, 23  Prof. Dr. Bart Jacobs, Radboud University Nijmegen, NL  
A security review of the biometric passport

December, 14  Prof. Dr. Bertrand Meyer, ETH Zürich  
Tests and Proofs of Contracted Components
4 Diploma and Master Theses

4.1 Diploma

Abeln, Sven  
Development of a Tool for the Assistance in Code-Evolution Experiments (Kowalewski, Giesl)

Albertz, Marc  
Dependability Analysis of a Local Internet Provider’s Network Infrastructure (Freiling, Spaniol)

Becher, Michael  
Reducing Complexity of the Implementation of Security Requirements by Using an Application Level Firewall (Freiling, Mantel)

Beck, Daniel  
Developing a Physical Simulation Environment for Teams of Soccer Robots (Lakemeyer, Bischof)

Behle, Ralf  
Verification of Functional Programs by Automated Induction Theorem Proving (Giesl, Katoen)

Behr, Axel  
Service Subscription in eHome Systems (Nagl, Spaniol)

Benyassine, Salaheddine  
Entwurf und Implementierung einer semi-strukturierten Produkt- und Firmendatenbank für die Membranentechnik (Jarke, Melin)

Bezrukov, Ilja  
Biologisch inspirierte Merkmale für die automatische Spracherkennung (Biologically Inspired Features for Automatic Speech Recognition) (Ney, Wagner)

Böckers, Phillip  
Automated Tests for Access Control Systems (Nagl, Spaniol)

Bommes, David  
Physically Based Segmentation of 3D Objects (Kobbelt, Bischof)

Börger, Joachim  
Interactive Motion Synthesis for Realistic Humanoids in Virtual Environments (Bischof, Kraiss)

Brandt, Sebastian J.  
Strategies for Storing Unsteady CFD Data on Graphics Hardware (Bischof, Kobbelt)

Braun, Bastian  
Implementing Automatic Addition and Verification of Fault Tolerance (Freiling, Katoen)

Buhr, Stefan  
Implementation and Evaluation of two Algorithms for Reducing the Fuel Consumption of an Automobile by Improving the Energy Conversation Efficiency of its Power Supply (Sebastian, Vöcking)
Chen, Ming
Rule Extraction and Representation for Multimedia Semantics (Jarke, Berlage)

Cheng, Yong
Development of Concepts and Tools for Model Driven Projecting of Distributed FMX Control Systems (Jarke, Brecher)

Comanns, Michael
Tool Support for the Experience-Based Reuse of Process Traces (Jarke, Rose)

Craemer, Alexander
Process control within a heterogeneous network cluster for content-based image retrieval in medical applications (Spitzer, Jarke)

Cüsters, Sandra
Improvement and Extension of an EEPROM Drivers Library (Kowalewski, Rossmanith)

Da, Jing
Evaluation of a Component Model for Embedded Systems (Kowalewski, Seidl)

Derrar, Reda
DNS Client Fingerprint (Freiling, Jarke)

Dick, Thorsten
Development of an Interactive Sign Language Tutor with Video-Based Learning Assessment (Kraiss, Seidl)

Do, Viet-Khoi
CT-based Collision-free Tool Path Generation for Robot Assisted Craniotomy (Lakemeyer, Rau)

Dolch, Carsten
Simulation Environment for Dynamic Order Management and Policy Optimization (Sebastian, Jarke)

Dörhöfer, Stefan
An Empirical Study of WLAN Security Through Wardriving (Freiling, Lichter)

Ellenbeck, Jan
Performance Evaluation of Combined TD-/FD-/SDMA Medium Access Strategies to Support Relay-Enhanced Broadband Cells (Walke, Vöcking)

Enke, Urs
DanSense: Rhythmische Analyse von Bewegungssensordaten mittels Beschleunigungs-Startzeiten (Borchers, Kraiss)

Fanarji, Alexander
Agile Development of a Prototypic Organisational Assistant for Truck Platoons (Henning, Kowalewski)
Filimonov, Inna  
*Development and Evaluation of a Service Oriented Architecture for the Integration of Business Processes*  
(Jarke, Rose)

Filipovic, Marko  
*Implementation of a Mechanism for Dynamic Process Creation in an MPI Message Passing Library for PC Clusters*  
(Bemmerl, Bischof)

Fröhlich, Arndt  
*Design of a Secure Digital Copying Machine*  
(Freiling, Jarke)

Funk, Mathias  
*Generating Efficient C-Code from ULM2 Composite Structure Diagrams*  
(Lichter, Nagl)

Gall, Jan  
*On Network-Layer Mobility in WiMAX Environments*  
(Spaniol, Nagl)

Georgantopoulos, Katharina  
*Modelling and Implementation of a Framework for a Systematic Development of Situated Learning Environment for an Introduction to Object-Oriented Programming*  
(Schroeder, Hromkovic)

Gliewe, Olaf  
*Service Migration Concepts in Virtual eHome Environments*  
(Spaniol, Nagl)

Göbel, Jan  
*Advanced Honeynet Based Intrusion Detection*  
(Freiling, Bischof)

Goeres, Alexander  
*Designing Safety Critical Embedded Systems Using Design Patterns*  
(Kowalewski, Lichter)

Hahn, Stefan Christof  
*Unsupervised Training in Large Vocabulary Speech Recognition*  
(Ney, Seidl)

Hahnen, Jochen  
*Development of a Mobile Cooperative System for Sport Communities*  
(Prinz, Lakemeyer)

Haritonov, Aleksandr  
*Near-Worst-Case Approximation for Lower Bounds in Branch-and-Bound Algorithms*  
(Rossmanith, Vöcking)

Häßler, Frank  
*Analysis and Extension of a Workflow Modelling Language*  
(Spaniol, Nagl)

Heer, Thomas  
*Knowledge Modules and their Integration for Conceptual Design in Civil Engineering*  
(Spaniol, Nagl)

Hegerath, Andre  
*Patch-based Object Recognition in Images*  
(Ney, Seidl)

Heinz, Carsten  
*Design and Evaluation of a Management Platform for Mobile Service Provisioning to Nomadic Users*  
(Spaniol, Nagl)
Henkel, Sven  
*Network Synchronization in the Crash-Recovery Model*  
(Freiling, Mantel)

Heracles, Robert  
*Application of Signal Processing Algorithms for Health-Monitoring of Rocket Propulsion Engines*  
(Freiling, Kowalewski)

Holtmann, Jrg  
*Speicherreduktion für Strategien in unendlichen Spielen*  
(Memory Reduction for Strategies in Infinite Games)  
(Thomas, Katoen)

Hülsdau, Tobias  
*Protecting a Datacenter Against External Attecks Using Virtual IDS-Sensors and Honeypots*  
(Freiling, Bischof)

Hünten, Jonas Peter  
*Dynamic Shortest Paths in Transport Networks*  
(Rossmannith, Vöcking)

Jahanpanah, Armin  
*Mutation-based Energy Distribution and Path Tracing for Global Illumination*  
(Kobbelt, Bischof)

Janßen, Axel  
*Methods for Temporal Source Code Analysis in Software Engineering Processes*  
(Kowalewski, Lichter)

Jaroschek, Artur  
*Network Visualization*  
(Spaniol, Nagl)

Kamphausen, David  
*Robust-Face-Detection using Textured Shape Models*  
(Kobbelt, Bischof)

Karanfil, Hakan  
*Agent-based Modelling and Simulation of Network Rules in Inter-Organisational Networks*  
(Jarke, Lakemeyer)

Keller, Rene Karsten  
*Influence of External Factors on Hospital Logistics*  
(Spaniol, Nagl)

Klaus, Christian  
*Indexunterstützung für das Postprocessing von CFD-Daten*  
(Index Support for the Postprocessing of CFD-Data)  
(Seidl, Bischof)

Klein, Tobias  
*Investigation on Word Graphs in Automatic Speech-Recognition*  
(Ney, Kowalewski)

Kneifel, Andreas  
*Modelling and Planning Monitoring Activities in Trust-Based Inter-Organizational Networks*  
(Jarke, Lakemeyer)

Körtgen, Anne-Therese  
*Model-Based Wrapper Development: A Framework for the Specification of Interface Mappings*  
(Nagl, Spaniol)
Köster, Immo

Krämer, Clemens
Analysis of Alternative Hardware Architectures in Embedded Systems Regarding Safety and Reliability (Kowalewski, Mantel)

Kranen, Philipp
Dimensionsreduktion für die Earth Mover’s Distanz für schnelles Multimedia Retrieval (Dimensionality Reduction for the Earth Mover’s Distance for fast Multimedia Retrieval) (Seidl, Jarke)

Krasnov, Waldemar
Grasping of Virtual Objects without Tactile Feedback (Bischof, Kraiss)

Krebs, Martin
Preference-based Scheduling of Airline Crews (Spaniol, Nagl)

Kulenko, Katharina
A User-Centric Approach to Security Awareness (Spaniol, Nagl)

Laraki, Fatima Zahra
Travelling Salesman Problem with Deadlines (anerkannt, anerkannt)

Latzke, Tobias
Imitative Reinforcement Learning for Soccer Robots (Nebel, Lakemeyer)

Laube, Tim
Beschleunigung der Suche bei der Erkennung kontinuierlich gesprochener Sprache mit großem Vokabular (Acceleration of Search in Large Vocabulary Continuous Speech Recognition) (Ney, Rossmanith)

Lauer, Patrick
Modular Design and Implementation of secure Autonomous Networks (Spaniol, Nagl)

Lay, Alexander
Development of mobility Concepts for Moving Networks with Dynamical Composition (Walke, Gärtner)

Ley, Sebastian
Implementation and Evaluation of a Web-Based Userprofile-Management Protocol (Spaniol, Nagl)

Li, Juanmin
PLD-Programming for Safety Critical Embedded Systems (Kowalewski, Freiling)

Lingner, Markus
Loadbalancing of Map Represenation Updates in Telematics (Spaniol, Nagl)

61
Liu, Xin  
Enhancement of Term-Statistic Approaches for Supporting the Medical Literature Retrieval by Terminological Knowledge (Spitzer, Seidl)

Lukas, Sven  
Concept and Implementation of a Vehicular Communication Gateway and its Performance Analysis (Walke, Spaniol)

Lülfesmann, Michael  
Graph Coloring for Partial Jacobian Computation (Bücker, Rossmanith)

Majuntke, Matthias  
Termination Detection in Systems where Processes may Crash and Recover (Freiling, Mittal)

Mao, Rui  
Extension of a Workflow Managementsystem to Support Dynamic Processes (Nagl, Spaniol)

Meis, Ulrich  
Integration of Wireless Mesh and Mobile Ad-Hoc-Networks (Spaniol, Nagl)

Meisen, Philipp  
Data-Mining-Verfahren zur Planung und Organisation von LKW-Konvois (Data-Mining-Techniques for Planning and Organization of Truck Platoons)(Henning, Seidl)

Mömke Tobias  
Job Shop Scheduling with k-Units Length Tasks (Hromkovich, Rossmanith)

Mungard, Nan Frederik  
Feature Model based Product Derivation in Software Product Lines (Lichter, Schroeder)

Nguyen, Tran Huy  
Implementation and Comparison of GPU-based and CPU-based Computation of Particle Trajectories (Bischof, Kobbelt)

Ni, Cheng  
Design of a Documentation System for Interactive Annotation of Flow Features in Virtual Environments (Bischof, Borchers)

Ohrner, Gunter  
Database-Driven Consistency Checking in the Design of Automotive Communication systems (Seidl, Jarke)

Palczynski, Jacob  
Requirements for a Model Checker for Matlab/Simulink (Kowalewski, Thomas)

Palm, Stephan  
Datenimport und Datenmigration in Objektdatenbanken (data import and migration in object databases) (Spitzer, Jarke)

Penner, Alexej  
Synchronisation Mechanisms for Decoupled Processed Workflows (Nagl, Spaniol)
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pham, Dang Vinh</td>
<td>Analysis of Attacks on Chaumian Mixes (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Polzer, Andreas</td>
<td>Analysis of Application Potential of Formal Verification in the Field of Engine Control Software (Kowalewski, Katoen)</td>
</tr>
<tr>
<td>Rauchenberger, Johanna</td>
<td>Development of an Expert System for the Analysis and Evaluation of the Muscular Coordination in Children with Spastic Disorders (Rau, Kobbelt)</td>
</tr>
<tr>
<td>Reichenbach, Olga</td>
<td>Development of a Software tool for the Support of a Workshop-Concept to Analyse Costs and Benefits (Henning, Schroeder)</td>
</tr>
<tr>
<td>Reiners</td>
<td>The Patch Panel GUI: A Graphical Development Environment for Rapid Prototyping of Physical Interfaces for Ubicomp Environments (Borchers, Prinz)</td>
</tr>
<tr>
<td>Reinhard, Alexander</td>
<td>Analyzing Multi-Threaded Programs under Intransitive Security Policies (Mantel, Freiling)</td>
</tr>
<tr>
<td>Richterich, Claus</td>
<td>Collaboration in OSGi-based eHomes (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Rick, Tobias</td>
<td>Development and Implementation of Parallel Algorithms on Graphics Hardware for Radio Wave Propagation (Mathar, Kobbelt)</td>
</tr>
<tr>
<td>Rohrbach, Michael</td>
<td>An Approach to Modelchecking of Software for Embedded Systems Software (Kowalewski, Van de Pol)</td>
</tr>
<tr>
<td>Rostek, Dagmar</td>
<td>Analysis of Basic Moderation Techniques Concerning the Application and Transformation in Problem-Based Blended Learning with the Objective of an Implementation of a Tool for Computer-Aided Application (Schroeder, Spijkers)</td>
</tr>
<tr>
<td>Sabath, Dirk</td>
<td>MPLS based Multicast Architecture for MPLS-based Mobility (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Sari, Faruk</td>
<td>Optimal Backup Solutions in MPLS Networks using Facility Backup (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Schätzle, Roman</td>
<td>Recent Methods for Surface Reconstruction of Range-Scanned Data (Kobbelt, Bischof)</td>
</tr>
<tr>
<td>Schneider, Daniel</td>
<td>Speaker Adaptive Sign Language Recognition (Kraiss, Ney)</td>
</tr>
<tr>
<td>Schnettker, Martin</td>
<td>Modeling worldwideweb User Traffic (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Scholten, Marius</td>
<td>Development and Performance-Evaluation of a Geo-Web-Service of Derivation of Information from Distributive Grid-Data (Jarke, Azzam)</td>
</tr>
<tr>
<td>Schöneberg, Tobias</td>
<td>Parallel Processing of Shared Gigabyte Datasets (Bischof, Bemmerl)</td>
</tr>
<tr>
<td>Schramm, Martin</td>
<td>Implementation and Evaluation of a Mobile TV-System with fast Channel Switching (Implementierung und Bewertung eines Mobile-TV-Systems mit schnellem Kanalwechsel) (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Schwabe, Peter</td>
<td>Efficient Implementation of Elliptic and Hyperelliptic Curves for Cryptographic Applications (Mathar, Vöcking)</td>
</tr>
<tr>
<td>Schwerdtner, Tim</td>
<td>Strategies for Specifications of eHome-Systems (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Schwittay, Bastian</td>
<td>Towards Automating Analysis in Computer Forensics (Freiling, Mantel)</td>
</tr>
<tr>
<td>Seitz, Torsten</td>
<td>Interval Data and Temporal Aspects in Change Management Databases (Seidl, Jarke)</td>
</tr>
<tr>
<td>Sensen, Andreas R.A.</td>
<td>Security Analysis of Web Services (Freiling, Mantel)</td>
</tr>
<tr>
<td>Sibbing, Dominik</td>
<td>Fast Impulse Based Mechanical Simulation with Friction (Kobbelt, Bischof)</td>
</tr>
<tr>
<td>Skopalik, Alexander</td>
<td>Approximation of Equilibria in Congestion Games (Vöcking, Rossmanith)</td>
</tr>
<tr>
<td>Skora, Thomas</td>
<td>Security in Voice-Over-IP-Systems (Spaniol, Nagl)</td>
</tr>
<tr>
<td>Spelten, Alexandra</td>
<td>Rewriting Systems over Unranked Trees (Thomas, Grädel)</td>
</tr>
<tr>
<td>Stein, Christian</td>
<td>The Dependency Pair Framework for Automated Termination Analysis of Equational Rewriting (Giesl, Katoen)</td>
</tr>
<tr>
<td>Stephan, Phillip</td>
<td>Deterministic Visibly Pushdown Automata over Infinite Words (Thomas, Katoen)</td>
</tr>
<tr>
<td>Sunadi, Lilian Silvia</td>
<td>Definition and Implementation of Categories Modelling Mathematical Exercises in E-Learning Systems (Schroeder, Hromkovic)</td>
</tr>
<tr>
<td>Swiderski, Stephan</td>
<td>Automatic Termination Analysis of Haskell Programs (Giesl, Indermark)</td>
</tr>
<tr>
<td>Terboven, Christian</td>
<td>Shared-Memory Parallelization of C++ Programs (Bischof, Lippert)</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Theidel, Sandra</td>
<td>Design and Implementation of a Drive-by-Wire Architecture (Kowalewski, Freiling)</td>
</tr>
<tr>
<td>Theisen, Rene</td>
<td>Checking LTL Properties at Runtime (Indermark, Katoen)</td>
</tr>
<tr>
<td>Theres, Arne</td>
<td>Untersuchung der blichen Approximationen in der HMM-basierten Spracherkennung (A Review on Commonly Used Approximations in HMM-based Speech Recognition(Ney, Katoen)</td>
</tr>
<tr>
<td>Tielmann, Andreas</td>
<td>Relations between Asynchronous Systems with Crash-Stop and Asynchronous Systems with Omission Failures (Freiling, Mantel)</td>
</tr>
<tr>
<td>Tuttlies, Verena</td>
<td>Further Language Constructs for Rule-Based Model Integration (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Elisabeth</td>
<td></td>
</tr>
<tr>
<td>Vogel, Christoph</td>
<td>Constrained Multiresolution Deformations (Kobbelt, Bischof)</td>
</tr>
<tr>
<td>Vorst, Franz Phillip</td>
<td>Readylog Agents for the RoboCup 3D Soccer Simulation League (Lakemeyer, Jarke)</td>
</tr>
<tr>
<td>Wahl, Carsten</td>
<td>Resource-Envelope Methods for Scheduling the Ground Handling Processes at Airports (Rossmanith, Vöcking)</td>
</tr>
<tr>
<td>Weisemöller, Ingo</td>
<td>Distributed Execution of Dynamic Development Processes in Heterogeneous Process Management Systems (Nagl, Spaniol)</td>
</tr>
<tr>
<td>Welter, Petra E.</td>
<td>Locally Selective Classification with Subspace Clusters (Seidl, Lakemeyer)</td>
</tr>
<tr>
<td>Werner, Michael</td>
<td>JAVA Engine Control Systems - A first Approach (Kowalewski, Lichter)</td>
</tr>
<tr>
<td>Wernerus, Peter</td>
<td>3D Reconstruction with Variable Intrinsic and Extrinsic Camera Parameters (Kraiss, Kobbelt)</td>
</tr>
<tr>
<td>Weymann, Frederic</td>
<td>Representation and Query of Time Aspects in a Web-based, Object-oriented Information System about hospitals (Spitzer, Jarke)</td>
</tr>
<tr>
<td>Herbert Georges</td>
<td></td>
</tr>
<tr>
<td>Willems, Daniel</td>
<td>Abstraction for Continuous Time Markov-Chains (Katoen, Kowalewski)</td>
</tr>
<tr>
<td>Willems, Carsten</td>
<td>Automatic Behaviour Analysis of Malware (Freiling, Mantel)</td>
</tr>
<tr>
<td>Wolf, Marius</td>
<td>REXband: A multi-User Interactive Exhibit to Explore Medieval Music (Borchers, Schroeder)</td>
</tr>
</tbody>
</table>

65
Xu, Linlin  
Reengineering of Telecommunication Systems: Source Code Transformations According to Software Architecture Modifications (Nagl, Spaniol)

Yin, Weiwei  
Implementation and Evaluation of Point-based Visualization Techniques for the Analysis of Large Volume Data (Bischof, Kobbelt)

Yu, Eugen Hon Wai  
Evaluation of Focus Methods in a Ubiquitous Computing Environment (Borchers, Kraiss)

Zhang, Lanlan  
Development of a Web-Based Tool for the Assistance in Code-Readability Experiments (Kowalewski, Borchers)

Zhang, Xuan  
Improving the Performance of Derivative Computations in Matlab ( Bücker, Schroeder)

Zhao, Wei  
Graph-Based Redesign Algorithms for Embedded Systems (Nagl, Spaniol)

Zhu, Yi  
Session Management of Mobile Web Service Applications Using SIP (Walke, Kowalewski)

Ziegelmayer, Dominique  
Decision Theoretic Planning in the Dynamic Logic ES (Lakemeyer, Jarke)

4.2 Master Thesis

4.2.1 Software Systems Engineering

Abbas, Zaheer  
Performance Evaluation of IEEE802.15.4/ZigBee for Light Management Network ( Mähönen, Spaniol)

Afzal, Muhammad Zubair  
Retrieval of Spoken Documents Using Fuzzy Keyword Search in Syllable Transcript (Seidl, Reiser)

Andonakis, Georgios  
Semantische Module zur Unterstützung des konzeptuellen Entwurfs in einem CAD-System (Nagl, Jarke)

Badral, Sanlig  
Gras/GXL Code Generator for Fujaba (Nagl, Stetter)

Bhatia, Pankaj  
Model-Driven User Interface Generation - A foundation for Bi-Directional Abstract-Concrete Syntax Mapping Editor (Lichter, Muller)

Butt, Muhammad Salman  
A Project Management Tool for a Chemical Engineering Design Environment (Nagl, Spaniol)
Cai, Luoxin  Development of a WLAN 802.11b Physical Layer Description as Basis of a Model-Driven Code Generation Process (Kowalewski, Spaniol)

Denev, Dimitar  Multidimensional Patterns of Disturbance in Digital Social Networks (Jarke, Lakemeyer)

Edala, Anilkumar  Tracking of Server Software used During Clinical Study (Jarke, Berlage)

Falaleev, Andrey  Structure-based Frameworks Representation with Respect to Software Quality Management (Nagl, Spaniol)

Farmaki, Georgia-Anna  Time Window: An Interactive Exhibit to Explore Multi-Layer Historical Maps (Borchers, Prinz)

Hu, Yuxiao  A Declarative Semantics for a Subset of PDDL with Time and Concurrency (Lakemeyer, Jarke)

Kaul, Anupam  On Line Matching of Semantic Web Services in Ambient Intelligence Environments (Spaniol, Noll)

Khan, Umar Farooq  An Experiment on the Effects of Refactoring for Embedded Systems (Kowalewski, Lichter)

Memon, Faraz Ahmed  iStuff Mobile: Rapidly Prototyping Novel Interactions For Mobile Phones (Borchers, Kowalewski)

Nguyen, Huu Hoa  Topological Modification of Deformable Objects in Virtual Environments (Bischof, Meskouris)

Quiros Arayas, Gustavo Ar-turo  Static Bytecode Analysis for State Space Reduction (Katoen, PD Dr. Noll)

Relangi, Sri Kedarnath  A Dynamic UML View for Customizing a Chemical Engineering Design Tool (Nagl, Spaniol)

Roesli, Aristoma  Agent Evolution in a Modeling and Simulation Environment for Inter-Organizational Networks (Jarke, Lakemeyer)

Sajjad, Muhammad  Concept and Implementation of a Mobile Publish/Subscribe Context Dissemination Middleware (Walke, Jarke)

Sharma, Arun  Lightweight Synchronization of Ontologies (Jarke, Euzenat)

Sodhi, Tim  Freeform Digital Ink Annotations of E-Learning Content – Using Alternate Input Media (Jarke, Specht)

Tariq, Fahad Bin  Target Specific Transformation of an Abstract OS API for Multiprocessor SoC-Platforms (Ascheid, Kowalewski)
Toprak, Adem  
*Mobile Web Service Discovery in JXTA/JXME (Jarke, Prinz)*

Zhang, Xiaomin  
*Reengineering DSHplus for a Modularized Fluid Power System Simulation Environment (Jarke, Rose)*

### 4.2.2 Media Informatics

Ahmed, Waheed  
*Automatic RTL Implementation of Reconfigurable ASIPs from High-level Description (Ascheid, Kowalewski)*

Aijaz, Fahab  
*Implementierung und Leistungsbewertung einer UDP Bindung an SOAP (Implementation and Performance Analysis of a UDP Binging for SOAP) (Walke, Jarke)*

Barakat, Kamal  
*Tracking with Ultrasonic Model Recognition, an Approach towards Ultrasonic Vision (Prinz, Lakemeyer)*

Bashar, Mohammad Abul  
*Design and Implementation of an Interactive Graph Visualization Framework for Eclipse (Cremer, Borchers)*

Ephram, Robina  
*Incorporating E-Accessibility in the Workflow and Design Process of Content Management Systems (Jarke, Berlage)*

Espinosa Carlin, Juan Miguel  
*Effective Bandwidth Management for Roaming Users in an 802.11 Wireless Man (Spaniol, Nagl)*

Gupta, Vivek  
*Creating and Explaining Ontogogy for Flexible and Natural Voice and Multimodel Dialogs (Reiser, Borchers)*

Jain, Avinash  
*A Multimodal Digital Map System with Mutual Disambiguation (Reiser, Rose)*

Javeed, Zeeshan  
*Contextualization of Office Artefacts Using RFID (Prinz, Oppermann)*

Jenabi, Mahsa  
*Adapting User Interfaces to Mobile Input Devices (Borchers, Prinz)*

Kadirov, Hurshid  
*Matching Operators for Models Represented in a Generic Meta Model (Jarke, Lakemeyer)*

Khan, Sajid  
*Deployment and Evaluation of GMPLS Networks in Context of Scalability (Spaniol, Nagl)*

Khan, Muhammad Faroog  
*Digital Map-Based Communities (Prinz, Rose)*

Konya, Iuliu  
*Development of a Newspaper Image Understanding System (Reiser, Klein)*

68
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li, Xiang</td>
<td>Generic Schema Merging Based on Complex Mappings (Jarke, Lakemeyer)</td>
</tr>
<tr>
<td>Memon, Mohammad Sh</td>
<td>A Reliable Grid Information Service Using a Unified Information Model (Wolf Bischof)</td>
</tr>
<tr>
<td>Muhtaroglu, Ilke</td>
<td>Model Driven Approach in Voicexml Application Development (Reiser, Borchers)</td>
</tr>
<tr>
<td>Narunjan, Kumar</td>
<td>Grid Data Policy Aware Scheduling (Cremers, Spaniol)</td>
</tr>
<tr>
<td>Pajo, Sanjin</td>
<td>Secure Distribution of Closed Group Data for the BSCW System (Prinz, von der Gathen)</td>
</tr>
<tr>
<td>Pendyala, Kiran Kumar</td>
<td>Security Aspects Analysis in Mobile Web Service Provisioning (Jarke, Prinz)</td>
</tr>
<tr>
<td>Ravindra, Chilaka</td>
<td>A Comparative Study of Static Software Analysis Tools with a Special Focus on Software Visualization (Cremers, Borchers)</td>
</tr>
<tr>
<td>Tahayna, Bashar</td>
<td>Development of Robust Video Recognition System and Alignment Tool (Reiser, Weber)</td>
</tr>
<tr>
<td>Zhang, Yudong</td>
<td>An Integrated Approach to Biological YML Data Management Based on ER Modeling (Berlage, Rose)</td>
</tr>
</tbody>
</table>
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.  

<table>
<thead>
<tr>
<th>Semester</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13±</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>WS72/73</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WS73/74</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WS74/75</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WS75/76</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WS76/77</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WS77/78</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WS78/79</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SS79</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\*13 or more terms
\*2number of PhD students

70
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>
</tr>
</thead>
<tbody>
<tr>
<td>WS72/73</td>
<td>64</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WS73/74</td>
<td>150</td>
<td>52</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>WS74/75</td>
<td>161</td>
<td>43</td>
<td>31</td>
<td>0</td>
</tr>
<tr>
<td>WS75/76</td>
<td>205</td>
<td>43</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>WS76/77</td>
<td>215</td>
<td>54</td>
<td>37</td>
<td>1</td>
</tr>
<tr>
<td>WS77/78</td>
<td>291</td>
<td>65</td>
<td>36</td>
<td>21</td>
</tr>
<tr>
<td>WS78/79</td>
<td>312</td>
<td>86</td>
<td>42</td>
<td>26</td>
</tr>
<tr>
<td>WS79/80</td>
<td>366</td>
<td>97</td>
<td>68</td>
<td>33</td>
</tr>
<tr>
<td>WS80/81</td>
<td>431</td>
<td>98</td>
<td>50</td>
<td>24</td>
</tr>
<tr>
<td>WS81/82</td>
<td>516</td>
<td>108</td>
<td>83</td>
<td>37</td>
</tr>
<tr>
<td>WS82/83</td>
<td>614</td>
<td>129</td>
<td>78</td>
<td>23</td>
</tr>
<tr>
<td>WS83/84</td>
<td>808</td>
<td>162</td>
<td>99</td>
<td>49</td>
</tr>
<tr>
<td>WS84/85</td>
<td>833</td>
<td>140</td>
<td>101</td>
<td>52</td>
</tr>
<tr>
<td>WS85/86</td>
<td>958</td>
<td>162</td>
<td>107</td>
<td>62</td>
</tr>
<tr>
<td>WS86/87</td>
<td>1012</td>
<td>173</td>
<td>88</td>
<td>74</td>
</tr>
<tr>
<td>WS87/88</td>
<td>1077</td>
<td>183</td>
<td>102</td>
<td>97</td>
</tr>
<tr>
<td>WS88/89</td>
<td>1098</td>
<td>194</td>
<td>117</td>
<td>77</td>
</tr>
<tr>
<td>WS89/90</td>
<td>1131</td>
<td>183</td>
<td>116</td>
<td>110</td>
</tr>
<tr>
<td>WS90/91</td>
<td>1174</td>
<td>162</td>
<td>85</td>
<td>95</td>
</tr>
<tr>
<td>WS91/92</td>
<td>1212</td>
<td>163</td>
<td>115</td>
<td>100</td>
</tr>
<tr>
<td>WS92/93</td>
<td>1170</td>
<td>155</td>
<td>115</td>
<td>89</td>
</tr>
<tr>
<td>WS93/94</td>
<td>1215</td>
<td>138</td>
<td>117</td>
<td>108</td>
</tr>
<tr>
<td>WS94/95</td>
<td>1248</td>
<td>121</td>
<td>115</td>
<td>111</td>
</tr>
<tr>
<td>WS95/96</td>
<td>1310</td>
<td>127</td>
<td>117</td>
<td>108</td>
</tr>
<tr>
<td>WS96/97</td>
<td>1361</td>
<td>137</td>
<td>97</td>
<td>138</td>
</tr>
<tr>
<td>WS97/98</td>
<td>1389</td>
<td>140</td>
<td>76</td>
<td>124</td>
</tr>
<tr>
<td>WS98/99</td>
<td>1515</td>
<td>163</td>
<td>87</td>
<td>103</td>
</tr>
<tr>
<td>WS99/00</td>
<td>1704</td>
<td>203</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>WS00/01</td>
<td>1994</td>
<td>284</td>
<td>110</td>
<td>69</td>
</tr>
<tr>
<td>WS01/02</td>
<td>2177</td>
<td>405</td>
<td>145</td>
<td>76</td>
</tr>
<tr>
<td>WS02/03</td>
<td>2185</td>
<td>383</td>
<td>155</td>
<td>90</td>
</tr>
<tr>
<td>WS03/04</td>
<td>2087</td>
<td>337</td>
<td>191</td>
<td>91</td>
</tr>
<tr>
<td>WS04/05</td>
<td>1774</td>
<td>277</td>
<td>201</td>
<td>107</td>
</tr>
<tr>
<td>WS05/06</td>
<td>1178</td>
<td>261</td>
<td>147</td>
<td>155</td>
</tr>
<tr>
<td>WS06/07</td>
<td>1515</td>
<td>203</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Development of the number of students: First-year students and total

First-year students and diploma per academic year
Research Reports
Algorithms and Complexity

Staff

- Faculty:
  Univ.-Prof. Dr. Berthold Vöcking (chair)
  Priv. Doz. Dr. Walter Unger
  Dr. Matthias Westermann (DFG Research Group)
  http://www-i1.informatik.rwth-aachen.de

- Secretary:
  Helga Jussen
  Phone: +49 241 8021101
  Fax: +49 241 8022216
  Email: jussen@cs.rwth-aachen.de

- Research Assistants:
  Dipl. Inform. Heiner Ackermann
  Dipl. Inform. Helge Bals (until September 2006)
  Dr. Dirk Bongartz (until July 2006)
  Dipl. Inform. Matthias Englert (DFG Research Group)
  Dipl. Inform. Alexander Fanghänel (since November 2006)
  Dipl. Inform. Simon Fischer
  Dipl. Inform. Thomas Franke
  Dipl. Math. George Mertzios (since October 2006)
  Dr. Harald Räcke (July – August 2006)
  Dipl. Inform. Heiko Röglin
  Dipl. Inform. Alexander Skopalik (since September 2006)
• PhD scholarship holders:
  Dipl. Math. Lars Olbrich (since July 2006)

• Technical Staff:
  Math.-Techn. Ass. Viktor Keil

• Student Researchers and Teaching Assistants:
  Yen Cao
  André Camp
  Thomas Kesselheim
  Christian Martelock
  Tilo Müller
  Marcel Ochel
  Torsten Sattler
  Anne Schüller
  Nadine Schlonies
  Sebastian Sieberts
  Katrin Twickler
  Melanie Winkler

• Guests:
  René Beier (MPI Saarbrücken)
  Dimo Brockhoff (TIK-ETH Zürich)
  Ralf Klasing (LaBRI - Université Bordeaux)
  Christian Scheideler (TU München)
  Philipp Woelfel (University of Toronto)
Overview

The group focuses 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.
Research Projects

UMIC - Mathematical Analysis of and Resource Allocation on Cognitive Radio Networks

A. Fanghänel, B. Vöcking
(funded by DFG, Research Cluster in the Excellence Initiative, in cooperation with Prof. Dr. Petri Mähönen, MobNets)

The efficient cross-layer optimization based resource allocation is recognized as one of the key possibilities and challenges to increase flexibility and capacity of the future wireless networks, especially if this approach is tied in with the cognitive radio approach. Cognitive radio is a new paradigm in the cross-layer design of wireless communication networks as the current state-of-the-art transmission systems are still quite limited in their adaptability. Although cognitive radio and cross-layer approaches are very tempting approaches, they are not studied in a mathematically rigorous way with any reasonable details. Few existing results are based on rather rudimentary arguments based on classical and static game theory or some simple optimization arguments.

There is an opportunity to establish a successful long-term research line on studying cognitive radio networks based on advanced mathematical tools. This project proposal is starting an initial project and collaboration between groups that can define both practically oriented specific (wireless) problems, conduct some experimental testing and most importantly use the state-of-the-art mathematical methods to study optimization, stability, algorithmic strategies and implementable solutions for cognitive radios and cognitive radio networks.

vtraffic: Managing Variable Data Streams in Networks (Management variabler Datenströme in Netzwerken)

S. Fischer, T. Franke, B. Vöcking
(funded by DFG in cooperation with Prof. Anja Feldmann, TU Berlin und Deutsche Telekom)

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

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

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

For many problems, average-case analyses do not provide much insight either since inputs which occur in practice usually possess certain properties and a certain structure which cannot be reflected by an average-case analysis alone as it is not clear how to choose the underlying probability distribution over the set of possible inputs. In this project, we turn our attention to more general probabilistic input models like, e.g., the model of smoothed analysis. The semi-random input model used in a smoothed analysis consists of two stages. First an adversary chooses an input, then this input is randomly perturbed in the second step. In particular, the adversary can specify a worst-case input with certain properties which is only slightly perturbed in the second
The focus of our research are problems which can be expressed in the form of integer linear programs. In our previous analyses we have characterized the class of integer optimization problems with polynomial smoothed complexity. The algorithms with polynomial smoothed complexity we designed, however, are clearly outperformed by common heuristics used in practice, like, e.g., Branch and Bound and Branch and Cut approaches. One of the main goals of this research project is the probabilistic analysis of these heuristics in order to understand why they perform so extraordinary well in practice. Our approach consists of two steps: First structural parameters like, e.g., the number of Pareto optimal solutions or the integrality gap, are analyzed. Then the running time of the heuristics is analyzed in terms of these parameters.

Generalized Congestion Games: Analysis, Computation, and Evolution

A. Skopalik

(funded by the German Israel Foundation, in cooperation with D. Monderer and M. Tennenholtz from the Technion, Israel)

The project proposes to bring together two disciplines - computer science and game theory - and by doing so to address some fundamental problems of computing in the Internet era. Combining our expertise we propose to handle several complementary issues in non-cooperative multi-agent systems. Since we can show that congestion and network games with player-specific payoff functions give us the set of all strategic games, while congestion games with player-symmetric payoff functions are the most popular type of games discussed in the computer science literature, the study of generalized congestion games is a most effective way to bridge the gap between computer science and game theory.

When referring to generalized congestion games we refer both to congestion games where agents may have different payoffs functions, as well as to congestion games with uncertainty (e.g. about the number of participants or other agents’ costs). The nice graph-theoretic representation of general strategic games as player-specific congestion games enables to tackle the fundamental problem of existence of solution concepts (e.g. pure strategy equilibrium or strong equilibrium) as a function of the graph structure, as well as determine the complexity of computation and the speed of convergence to solutions as a function of the graph structure. In order to deal with congestion games with incomplete information, our aim is to tackle reasoning about uncertainty in multi-agent systems when exact probabilistic information is not available. For doing so, new equilibrium concepts are to defined and applied to congestion settings.
Other Activities

Courses

Our group offered the following lectures and seminars:

Summer semester 2006

- Lecture on *Approximation Algorithms*
- Lecture on *Network Algorithms*
- Seminar on *Algorithmic Graph Theory*
- Seminar on *BUCH der Beweise*
- Seminar on *Approximation Algorithms*
- Seminar on *Complexity Theory*

Winter semester 2006/07

- Lecture on *Efficient Algorithms*
- Lecture on *Algorithmic Cryptography*
- Lecture on *Computability and Complexity*
- Seminar on *Network Algorithms*
- Seminar on *Communication Problems in Networks*
- Proseminar on *Design and Analysis of Algorithms*
- Bridging Course on *Theoretical Computer Science*

Berthold Vöckings scientific activities

- Organization of the workshop Optimization in Complex Networks in Oxford.
- Host of the annual meeting of DFG-SPP 1126 in Aachen.
- Chair of the initiative “Algorithmus der Woche” within the Informatikjahr 2006.
Talks and Publications

Talks

Heiner Ackermann: Decision Making Based on Approximate and Smoothed Pareto Curves, 2nd Annual Delis Meeting, Paderborn, Germany, January 2006.


Heiner Ackermann: Pure Nash Equilibria in Player-Specific and Weighted Congestion Games, 2nd International Workshop on Internet and Network Economics (WINE), Patras, Greece, December 2006.


Matthias Englert: Lower and Upper Bounds on FIFO Buffer Management in QoS Switches, 14th Annual European Symposium on Algorithms (ESA), Zürich, Switzerland, September 2006.


Simon Fischer: Putting “Selfish Routing” into Practice, Algorithmics of Large and Complex Networks, Aachen, Germany, June 2006.


Heiko Röglin: On the Impact of Combinatorial Structure on Congestion Games, Max-Planck-Institut für Informatik, Saarbrücken, Germany, September 2006.


Alexander Skopalik: Inapproximability of Nash Equilibria in Congestion Games, Technion, Haifa, Israel, November 2006.

Berthold Vöcking: Adaptive Routing with Methods from Evolutionary Game Theory, 6th International Heinz Nixdorf Symposium, Paderborn, Germany, January 2006.


**Publications**


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

- Student Assistants:
  
  Alexander Langer
  Hans-Christian Ebke
Overview
Our teaching and research profile mainly consists of

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

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

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

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

To exemplify this view, consider the problem connected vertex cover: given a graph $G$ and a number $k$, is there a set of at most $k$ nodes in $G$ inducing a connected subgraph and covering every edge? It turns out that this problem, although NP-hard, can be solved in $O(2.7606^k \cdot \text{poly}(n))$ steps.

When developing exact, non-parameterized algorithms for NP-hard problems, we cannot expect anything better than exponential running times. Hence, we are interested in deriving exponential bounds with at least a small base.
In theoretical computer science, the most common way to analyze the running time of an algorithm is the classical worst case analysis, which gives an upper bound on the required computing time as a function of the size of the input. However, the analysis of algorithms is usually a difficult task, and, in practice, the worst case may hardly ever appear at all. Hence, there is usually a huge gap between the best known (mathematically proved) upper bound and the running times observed in realistic applications of an algorithm.

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

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

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

One of the problems investigated in this project is the well-known Steiner tree problem: given an edge-weighted graph $k$ of whose nodes are terminals, find a cheapest tree that connects them. We are able to improve the runtime bound from $O^*(3^k)$ to $O^*((2 + \delta)^k)$, where $\delta > 0$ can be chosen arbitrarily small. In terms of parameterized complexity, this is the first improvement of the famous Dreyfus–Wagner algorithm. Whereas both algorithms rely on the same key idea, namely recombining partial solutions in order to solve the problem.
for increasingly large subsets of the $k$ terminals to connect, our improved version is crafted to work correctly when only small partial solutions are considered for recombination. The bounds we obtain include huge constant factors when $\delta$ is chosen too small, but using an additional trick, they can be decreased in order for the algorithm to become more applicable.

Another main result of the research in this project is the “Enumerate-and-Expand” paradigm. While most hard graph problems consist in finding a certain structure inside the input graph, the combinatorial explosion forbids us to find that structure by exhaustive search. Informally, we address this difficulty by enumerating a bounded number of less complex structures at least one of which can be expanded into a solution (if the input is a yes-instance). For example, let $G$ be a graph and $k$ a number. The problem Connected Vertex Cover asks whether there is a connected subgraph $G'$ of size at most $k$ such that the removal of $G'$ from $G$ leaves an empty graph. We can solve this problem in time $O^*(2^{0.7606k})$ by enumerating a family of subgraphs whose removal from $G$ leaves a cubic graph and expanding them accordingly.

Alternatively, the search for certain structures in a graph can be eased by assigning random colors to its nodes or edges and looking for a structure that is colored in a specific way. This approach, which was first popularized by Alon et al., is known as “Color-Coding.” Its most famous application is the detection of a $k$-node path in time $O^*(5.4366^k)$. By interweaving color-coding with a divide-and-conquer algorithm, we obtain the “Divide-and-Color” paradigm. The key idea is simple: in order to detect a $k$-node path, we cycle through binary colorings of the nodes and check whether the two induced subgraphs contain $k/2$-node paths whose endpoints are connected. This allows us to tighten the runtime bound to $O^*(4^k)$, a result independently obtained by Chen et al. The method is also suitable for the detection of $k$ disjoint copies of some fixed subgraph in a given graph.

This project is funded by the DFG under grant RO 927/6-2 (TAPI).

**Intuitive Algorithms**

Joachim Kneis, Stefan Richter, Peter Rossmanith

Using the graph-theoretical concept of treewidth, we were able to develop a new approach to solving a plethora of graph and satisfiability problems. The basic idea is to branch recursively only where it seems—at least locally—to be cheap, until only a simple instance of the investigated problem remains.

It can be shown that algorithms based on the above method do not branch too often. In fact, our new approach yields practical algorithms and improved runtime bounds for many important problems. Since we are only using branching and small simplification rules, the derived algorithms are easy to understand, implement, and verify.

Generalizing this method, we developed the paradigm of intuitive algorithms, focusing on algorithms that obey these properties. We thus try to keep the algorithms as simple as
possible, whereas nearly all the effort lies in the analysis. In order to obtain tighter and tighter runtime bounds under this restriction in algorithm design, we therefore have to employ more and more complex methods of analysis.

Even if the resulting algorithms might be only second-best in terms of theoretical runtime bounds, they are often the fastest algorithms on all instances with practicable input-size due to very small hidden constants. Surprisingly, these intuitive algorithms often are even the fastest algorithms when analyzed in terms of worst-case complexity.

One of the curious facts about this paradigm is that it contrasts with the classical way of developing algorithms, which are usually made more and more complicated (e.g., by case distinctions) in order to ease the analysis. In 2006, we applied these concept to two fields of application, partial coverings being the first.

The well-known Vertex Cover problem asks for a subset of \( k \) nodes covering all edges in a graph. Recently, a generalization of this problem was studied, where not all but only a certain amount \((t)\) of the edges needs to be covered. Similar generalizations were introduced to other covering problems, for example Dominating Set, leading to a class of problems called partial covering problems.

Interestingly, classical Vertex Cover belongs to FTP, whereas Partial Vertex Cover can easily be shown to be \( \text{W}[1] \)-hard. Since Dominating Set is \( \text{W}[2] \)-complete, Partial Dominating Set obviously is \( \text{W}[2] \)-hard, too. Using the paradigm of intuitive algorithms, we developed very simple algorithms improving the runtime bounds for both problems. Partial Vertex Cover can be solved in \( O^*(2.0911^t) \), improving the previously known bound of \( O^*(4^t) \). This new bound is reached by a randomized branching algorithm that always selects a node of highest degree or one of its neighbors for the partial cover. Moreover, we recently found a way to improve the runtime bound so as to beat the important threshold of \( 2^t \). Using the color-coding technique, we also developed an intuitive algorithm for Partial Dominating Set with a running-time of \( O^*((4 + \varepsilon)^t) \). Again, this algorithm is very easy to implement, understand and verify.

Our second focus is the famous Independent Set problem. We have begun to analyze a very intuitive algorithm for this problem, namely one that is solely based on local branching. Instead of using many case distinctions within our algorithm, we take a closer look at a huge amount of cases in the analysis. To ease this task, we implement a program that verifies our claims for millions of cases, whereas all other cases are easy to check manually (they belong to one of four categories). Using the HPC cluster, the program takes a few days to analyze millions of different local neighborhoods. Another important task in this approach lies in constructing witnesses that prove our automated reasoning correct.

This project is funded by the DFG under grant RO 927/7-1.

**Other Activities**

Organizer of the final round of the Bundeswettbewerb Informatik 2006

Program committee SOFSEM 2006 and IWPEC 2006
Talks and Publications

Talks

Stefan Richter: A Faster Algorithm for the Steiner Tree Problem, STACS 2006, Marseille, France, February 2006

Peter Rossmanith: Enumerate and Expand: Improved Algorithms for Connected Vertex Cover and Tree Cover, CSR 2006, St. Petersburg, Russia, June 2006


Peter Rossmanith: Divide and Color, Hualin University, R.O.C. Taiwan, December 2006

Peter Rossmanith: Design and Analysis of Intuitive Algorithms, Alishan, R.O.C. Taiwan, December 2006

Peter Rossmanith: Parameterized Algorithms and Complexity I & II, National Chung Cheng University, R.O.C. Taiwan, December 2006

Joachim Kneis: Intuitive Algorithms and t-Vertex Cover, ISAAC 2006, Kolkata, India, December 2006

Publications


94
Software Modeling and Verification

Staff

- Professors:
  
  Prof. Dr. Ir. Joost–Pieter Katoen PD
  Prof. em. Dr. Klaus Indermark
  http://moves.rwth-aachen.de/

- Secretary:
  
  Elke Ohlenforst

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

- Researchers:
  
  Dr. Erika Ábrahám (since April, from Univ. Freiburg)
  Dr. Henrik Bohnenkamp
  Tingting Han, M.Sc. (funded by the NWO)
  Dipl.-Inform. Carsten Kern
  Dipl.-Inform. Martin Neuhausser (funded by the NWO)
  Dipl.-Inform. Stefan Rieger
  Dipl.-Inform. Volker Stolz (until February)
  Dipl.-Inform. Daniel Willems (since June, funded by the DFG)
  Ivan Zapreev, M.Sc. (funded by the NWO)

- Technical Staff:
  
  Arnd Gehrmann

96
• Diploma/Master Students:
  Berteun Damman
  Lars Helge Haß
  Tim Kemna
  Alexandru Mereacre
  Marcel Oldenkamp

• Student Researchers:
  Frank Birbacher
  Jonathan Heinen
  Thomas Kesselheim
  Christian Lücking
  Daniel Neider
  Denise Nimmerrichter
  Roman Rabinovich
  Michael Rohrbach
  Andreas Röll
  Franziska Roloff
  Ulrich Schremp
  Stefan Schulz
  Henning Stein
  Evamarie Storch
  Benedikt Westermann

• Visiting Scientists:
  Dr. Benedikt Bollig (ENS Cachan, F)
  Prof. Dr. Luboš Brim (Masaryk University, Brno/CZ)
  Dr. Dino Distefano (Queen Mary Univ. of London, GB)
  Prof. Dr. Bart Jacobs (Radboud University, Nijmegen/NL)
  Dr. Martin Leucker (TU Munich, D)
  Dr. Ir. Arend Rensink (University of Twente, NL)
  Dr. Mariëlle Stoelinga (University of Twente, NL)
  Nikola Trcka (TU Eindhoven, NL)
  Prof. Dr. Heike Wehrheim (Universität Paderborn, D)
Overview

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

Major research topics of interest are:

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

Our research is conducted in the context of several projects that are funded by the NWO (Dutch Research Council), NWO and DFG, and the European Union. We participate in the Research Training Group on the Algorithmic Synthesis of Reactive Systems (ALGOSYN) and the UMIC Excellence Cluster.

In 2006, Volker Stolz obtained his PhD with a dissertation on run-time verification and received a position at the International Institute for Software Technology at the United Nations University in Macau. Erika Abráham (University of Freiburg) joined our group in May 2006. She is working on the interregional SFB AVACS. Daniel Willems started his PhD work within the Research Training Group ALGOSYN. Welcome to the MOVES group!

Joost-Pieter Katoen
Research Projects

Bounded Model Checking of Hybrid Systems
E. Ábrahám et al. (Albert-Ludwigs-Univ. Freiburg, Carl-von-Ossietzky Univ. Oldenburg, Univ. des Saarlandes)

In the context of the DfG Transregio AVACS project WP H1/2 we are investigating bounded model checking of hybrid systems. Given some system together with a specification expressing requirements on the system, the approach formulates the existence of a counterexample of a fixed length by a formula, and uses satisfiability checkers over different domains to check the formula for satisfiability.

We are interested in developing new techniques to accelerate the existing algorithms and to extend the domain that can be handled.

Observability and Fully Abstract Semantics for Class-Based Languages
E. Ábrahám, M. Steffen (Univ. of Oslo, NOR), A. Grüner (Christian-Albrechts-Univ. Kiel, D)

We are interested to define the externally observable behaviour of class-based object-oriented languages, including different language features like exceptions, sequentiality, concurrency, monitors, etc.

The semantics gives insight into the inherent language features, and allows to decide whether two components are observably equivalent. This is important in many practical fields, for example for compiler optimizations. Furthermore, fully abstract semantics are a good basis for the development of compositional proof methods.

The MoDeST Tool Environment

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

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

---

**Model-Based Testing**

*H. Bohnenkamp, A. Belinfante (Univ. Twente, NL), M. Stoelinga (Univ. Twente, NL)*

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

We work on two topics in this area.

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

2. In timed testing, reaching a verdict depends on time measurements. The imprecision of measurements can lead to false positives (a test fails although the implementation behaves correctly). We work on an extension of the ioco theory,
where the verdicts are not binary (pass/fail) but of a quantitative nature: it is measured how close to the specified behaviour the implementation behaves.

**Dependable Global Computing**

*J.-P. Katoen, R. De Nicola (U. Florence, I), D. Latella (CNR-ISTI, I), M. Loreti (U. Florence, I) and M. Massink (CNR-ISTI, I)*

*(funded by the DAAD and CNR-ISTI)*

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

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

**Synthesis and Stochastic Assessment of Cost-Optimal Schedules**

*H. Bohnenkamp, A. Mader (Univ. Twente, NL), Y. Usenko (Univ. Eindhoven, NL), H. Hermanns (Univ. Saarbrücken, D), David Jansen (Univ. Twente, NL), Johann Hurink (Univ. Twente, NL).*

It is well-known that model checkers can be used to solve scheduling problems. Schedules can be obtained by forcing the model checker to produce a counter-example for the claim “There is no solution to the scheduling problem” in the model at hand.
We apply schedule generation with model-checkers to a case study from the area of lacquer production, where lacquers are produced according to certain recipes, and production resources (vessels, mixers, dispersers and what not) are prone to failures. Failures cause the completion of a job to be late, which incurs costs (the later, the most expensive).

Although there are model checkers which can deal with costs (notably UPPAAL Cora), and optimise schedules to minimise cost, the stochastic nature of failures is something that can not be captured. We therefore combine schedule-generation with simulation in order to find good schedules:

1. We simulate each recipe to obtain the optimal time needed for it to incur minimal cost.
2. We incorporate this information into the model used for schedule generation.
3. We assess the quality of the generated schedules with simulation again.

The results show that this approach does indeed produce good schedules. Research is however still needed to refine this method.

<table>
<thead>
<tr>
<th>QUPES: Verification of Quantitative Properties of Embedded Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. Han, J.-P. Katoen, M. Neuhäußer, D. Willems</td>
</tr>
<tr>
<td>(funded by the NWO)</td>
</tr>
</tbody>
</table>

The research challenge faced by the QUPES project is to adapt and enrich model checking, a successful technique for checking the logical correctness of system designs, to meet the requirements of state-of-the-art embedded software engineering. Embedded software typically executes on devices that, first and foremost, are not computers. This imposes high requirements on performance and economical resource usage. Due to its embedded nature, its robustness is of prime importance, and timely reactions to stimuli from its—mostly physical—environment are essential. This project proposes to assess these “non-functional” aspects (e.g., timeliness and robustness) as an integral part of the embedded software validation phase. The aim is to obtain a single framework that supports both the validation of qualitative (i.e., functional) as well as quantitative aspects of embedded software.

To accomplish this, model-checking techniques will be extended with ample means to reason about costs (power consumption, memory usage, and the like), efficiency, and robustness. In particular, we aim to develop verification algorithms for real-time systems that exhibit both (continuous-time) randomness as non-determinism and
extend this approach with *cost* aspects. Furthermore, advances to model checking of stochastic systems will be made by developing aggressive *abstraction* techniques and methods that effectively exploit the (compositional) structure of embedded software specifications for verification purposes. The latter activities are aimed at making stochastic model checking applicable to state spaces that are several orders of magnitude larger than currently can be handled. Our techniques will be tailored to hierarchical design notations (statechart diagrams) for embedded software.

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

### Verifying Concurrent Pointer Programs with Unbounded Heap

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

The incorrect use of pointers is one of the most common source of software errors. Concurrency has a similar characteristic. Proving the correctness of concurrent pointer manipulating programs with unbounded heap, let alone algorithmically, is a highly non-trivial task. This project attempts to develop automated verification techniques and accompanying tool support for concurrent programs that manipulate dynamic, linked data structures. Initially, we focus on linked lists. As verification technique, we investigate the use of automata-based model-checking algorithms. First and second-order (monadic) temporal logics are employed for the specification of properties of such concurrent programs. These logics can easily express the dynamic creation and deletion of data. In our approach, we consider abstractions of linked data structures that are tailored to both the property and the program to be analysed. The main challenge is to achieve a fully automated technique to prove the correctness of concurrent pointer programs such as deadlock avoidance protocols, concurrent garbage collection algorithms and so forth.

### MC=MC: Model Checking Infinite-State Markov Chains

*J.-P. Katoen, I. Zapreev, B. Haverkort (Univ. Twente, NL), A. Remke (Univ. Twente, NL)*

(funded by the NWO)
The MC=MC project focuses on model checking techniques for infinite-state systems, thereby combining previous work on model checking finite-state Markov chains and the evaluation of infinite-state stochastic models (e.g. as generated from infinite-state stochastic Petri nets).

As a part of this project we implement an experimental tool named MRMC (Markov Reward Model Checker). MRMC is a model checker for discrete-time and continuous-time Markov reward models. It supports reward extensions of PCTL and CSL (PRCTL and CSRL), and allows for the automated verification of properties concerning long-run and instantaneous rewards as well as cumulative rewards. In particular, it supports to check the reachability of a set of goal states (by only visiting legal states before) under a time and an accumulated reward constraint. Additionally MRMC provides (i) safe on-the-fly steady-state detection for time-bounded reachability, and (ii) bisimulation minimization for PCTL, CSL, PRCTL and CSRL logics, for the latter two in the case without impulse rewards.

MRMC is a command-line tool written in C-language. Which allows MRMC to be small and fast. We support LINUX platform only, but on WINDOWS it can be built and run under CYGWIN. The tool is distributed under the GNU general public license (GPL).

Our current research is concentrated on several topics: (i) the effect of bisimulation minimisation on probabilistic model checking, (ii) an empirical comparison of model checkers for probabilistic systems, and (iii) model checking CSL logic using simulation techniques. The idea behind the latter is to apply discrete event simulation instead of conventional techniques for model checking CTMCs. We employ regenerative and terminating simulations as underlying techniques.

Our future plans are (i) to investigate combinations of symmetry reduction with bisimulation minimization, and to extend our experimental work towards MDPs and simulation preorders, (ii) to use the results of the empirical tool comparisons in order to improve efficiency of our model checker, and (iii) to implement simulation techniques in it.

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

| Three-valued Abstraction for Continuous-Time Markov Chains |
| J.-P. Katoen, D. Willems, M. Leucker (TU Munich), V. Wolf (Univ. Mannheim) |

In traditional model checking, abstract models contain may and must transitions as over- and under-approximation, respectively of the concrete transition relation. This
concept can be lifted to Markov chains in a rather natural way by replacing transition probabilities by intervals where lower and upper bounds act as under- and over-approximation, respectively. We investigate such techniques for continuous-time Markov chains (CTMCs). The main technical complication is that besides transition probabilities, one has to determine the residence time of an abstract state that results from concrete states with distinct residence times. We show that intervals of transition probabilities and intervals on residence times (or combinations thereof) are not satisfactory in terms of precision. Instead, we suggest to overcome this imprecision by using uniform CTMCs, i.e., CTMCs in which all states have equal residence times and use transition probability intervals. The abstraction is shown to preserve simulation: concrete states are simulated by their abstract counterparts. We can show that extreme schedulers suffice, i.e., schedulers that only consider lower and upper bounds. This allows to compute reachability probabilities up to a given tolerance $\epsilon$ rather efficiently. Using a three-valued semantics of the Continuous Stochastic Logic it can be shown that the abstraction is indeed conservative for affirmative and negative verification results.

Synthesis of Design Models from Scenarios by Learning

J.-P. Katoen, C. Kern, B. Bollig (ENS Cachan, F), Martin Leucker (TU Munich)

The elicitation of requirements is the main initial phase in the typical software engineering development cycle. Popular requirement engineering methods, such as the Inquiry Cycle, exploit use cases and scenarios to specify the system’s requirements. A scenario is a partial fragment of the system’s behavior, describing the system components, their message exchange and concurrency. Their intuitive yet formal nature has resulted in a broad acceptance. Such scenarios can be either positive or negative, indicating a desired or unwanted system behavior, respectively. Different scenarios together form a more complete description of the system behavior.

The following design phase in software engineering is a major challenge as it is concerned with a paradigm shift between the requirement specification—a partial, overlapping and possibly inconsistent description of the system’s behavior—and a conforming design model, a complete behavioral description of the system (at a high level of abstraction). During the synthesis of design models, usually automata-based models that are focused on intra-agent communication, conflicting requirements will be detected and need to be resolved. Typical resulting changes to requirements specifications include adding or deleting scenarios, and fixing errors that are found by a thorough analysis (e.g., model checking) of the design model. Obtaining a complete and consistent set of requirements together with a related design model is thus a highly iterative process.
Our main goal is to bridge the gap between requirements, provided as a set of scenarios, and conforming design models. The novel aspect of our approach is to exploit learning for the synthesis of design models. In particular, we derived a procedure that infers a message-passing automaton (MPA) from a given set of positive and negative scenarios of the system’s behavior provided as message sequence charts (MSCs). Furthermore we investigated which classes of regular MSC languages and corresponding MPA can or cannot be learned. Moreover we developed a dedicated tool (called Smyle) that supports our approach.

Verification of Erlang Programs

Th. Noll, M. Neuhäuser, L.H. Haß, C.K. Roy (Queen’s Univ., Kingston, CA)

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

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

We are tackling this problem from two different sides:

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

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

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

J.-P. Katoen

• Member of the Steering Committee of ETAPS (European Joint Conferences on Theory and Practice of Software).

• Member of the Steering Committee of QEST (Quantitative Evaluation of Systems).

• Board Member of the Dutch Society on Theoretical Computer Science (NVTI).

• Member of the Program Committee of the following events:
  – 2nd Int. Symp. on Leveraging Applications of Formal Methods (ISoLA 2006)
  – 3rd International Verification Workshop (VERIFY 2006)
  – Quantitative Aspects of Programming Languages (QAPL 2006)
  – 3rd Int. Conf. on Quantitative Evaluation of Systems (QEST 2006)
  – 150 Years Markov Anniversary Symposium (NSMC 2006)
  – 6th Int. Andrei Ershov Memorial Conf. on Perspectives of System Informatics (PSI 2006)

• Member of the IFIP Working Group 1.8 on Concurrency Theory.

• Member of the EPSRC Review College (Engineering and Physical Sciences Research Council).

• Member of external PhD committees.

• Member of the editorial board of the Journal of Software.

• Guest editor (together with M. Woodside and G. Franceschini) of a special issue of IEEE Transactions on Software Engineering on QEST 2004 (vol 32, no. 8)

• Guest editor (together with P. Buchholz and M. Verhoef) of a special issue of Journal on Software Tools for Technology Transfer on ISOLA 2004 (vol. 8, no. 6)
K. Indermark

- 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)

Th. Noll

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

## Talks and Publications

### Talks

E. Ábrahám: *Parallel SAT Solving in Bounded Model Checking*, Presented at PDMC’06

E. Ábrahám: *Bounded Model Checking mit Parametric Data Structures*, Presented at the Fourth International Workshop on Bounded Model Checking (BMC06)

E. Ábrahám: *Dynamic Heap-Abstraction for Open, Object-Oriented Systems with Thread Classes*, Invited talk at Logical Approaches to Computational Barriers (CiE’06)


H. Bohnenkamp: *Are you still there?*, IPA Herfstdagen 2006, Bergen, NL

H. Bohnenkamp: *Axxom, Scheduling, Costs and Optimums*, Voss-Meeting January 2006, Twente University

H. Bohnenkamp: *Timed Testing with TorX*, IPA Lentedagen 2006, Vught, NL

H. Bohnenkamp: *Timed Testing with TorX*, ITG Workshop Model-Based Testing 2006, Nürnberg
T. Han: *Counterexamples in Probabilistic Model Checking*, VOSS2 Workshop, Rolduc NL, Sept. 2006

T. Han: *Counterexamples in Probabilistic Model Checking*, IPA Herfstdagen on Stochastic Systems, Bergen NL, Nov. 2006

K. Indermark: *Farewell addresses to the Computer Science Graduates, Sommerfest, July 7, and Tag der Informatik, December 1, 2006,*


J.-P. Katoen: *Model Checking LTL and SPIN*, IPA Basic Course on Formal Methods, Jan. 2006

J.-P. Katoen: *Model Checking Probabilistic Systems*, Four lectures at the University of Florence, June 2006

C. Kern: *MSCan - A Tool for Analyzing MSC Specifications*, TACAS March 2006 (Wien)

C. Kern: *Synthesis of Design Models from Scenarios by Learning*, RWTH Aachen University, Doctoral Symposium, December 2006


I.S. Zapreev: *On-the-fly Steady-state detection*, University of Freiburg, Germany, July 2006


**Publications**


E. Ábrahá m, M. Herbstritt, B. Becker, M. Steffen: Bounded Model Checking mit Parametric Data Structures, Proc. of the Fourth International Workshop on Bounded Model Checking (BMC’06)

E. Ábrahá m, A. Grüner, Martin Steffen: Dynamic Heap-Abstraction for Open, Object-Oriented Systems with Thread Classes, Proc. of Logical Approaches to Computational Barriers: Second Conference on Computability in Europe (CiE’06)


E. Ábrahá m, A. Grüner, M. Steffen: Abstract Interface Behavior of Object-Oriented Languages with Monitors, Proc. of the 8th IFIP International Conference on Formal Methods for Open Object-Based Distributed Systems (FMOODS’06)


M. Neuhäusser, Th. Noll: *Abstraction and Model Checking of Core Erlang Programs in Maude*, Proceedings of the 6th International Workshop on Rewriting Logic and its Applications (WRLA'06), Vienna, April 2006, Elsevier Inc., to appear


D. Willems: *Abstraktion zeitstetiger Markov-Ketten*, Diploma Thesis, Faculty of Mathematics, Computer Sciences and Natural Sciences, RWTH Aachen University, April 2006
Staff

- Faculty:
  Univ.-Prof. Dr. rer. nat. Jürgen Giesl
  
  E-mail: giesl@informatik.rwth-aachen.de
  http://www-i2.informatik.rwth-aachen.de/lufgi2/

- Secretary:
  Elke Ohlenforst

- Research Assistants:
  Dipl.-Inform. Peter Schneider-Kamp *(funded by DFG)*
  Dipl.-Inform. Stephan Swiderski *(funded by DFG)*
  Dipl.-Inform. René Thiemann

- Student Researchers:
  Clemens Adolphs
  Ralf Behle
  Thomas Dickmeis
  Carsten Fuhs
  Patrick Kabasci
  Carsten Otto
  Matthias Raffelsieper
  Matthias Sondernmann
  Christian Stein
  Thomas Ströder
  Patrick Wiehe

- Technical Staff:
  Arnd Gehrmann
Overview

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

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

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

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

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

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

In 2006, we held the first-year course on *Computer Science I – Programming Concepts* for almost 500 students and lectures on *Logic Programming* and *Term Rewriting Systems*. We also offered seminars on *Automated Termination Analysis*, on *Verification Techniques*, on *Advanced Topics in Term Rewriting*, and on *Advanced Programming Concepts in Java, Haskell, and Prolog*.

Starting in July 2006, Stephan Swiderski joined our group of research assistants as a scholar of the new DFG research training group *AlgoSyn*. 


Research Projects

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

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

http://aprove.informatik.rwth-aachen.de/
This project is a cooperation with the TU Eindhoven, The Netherlands, and with the KU Leuven, Belgium, funded by the DFG and the FWO. 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 work on new approaches 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. At the same time, we also work on techniques and tools to incorporate ideas from term rewriting into techniques and termination tools that operate directly on logic programs.

The goal of this project (funded by the DFG) is to use the wealth of techniques developed for termination analysis of term rewrite systems in order to perform automated termination analysis for “real” programming languages as well. To this end, programs in these languages have to be translated into term rewrite systems. Then one can prove termination of the resulting term rewrite systems instead. However, it is not trivial to develop translations which yield rewrite systems that are suitable for an automatic analysis. We are working on such techniques for termination analysis of Haskell and (a subset) of Java. Our results are integrated in our system AProVE.
In this project with the Ben-Gurion University, Israel, and the University of Innsbruck, Austria, we work on new efficient algorithms to tackle the search problems arising in automated termination proofs. In particular, our goal is to encode them as SAT problems in a suitable way and to investigate the use of SAT solvers in automated termination analysis. Examples for termination techniques where SAT solving leads to speedups by orders of magnitude are lexicographic and recursive path orders as well as polynomial orders.

**Process Verification by Term Rewriting Techniques**

Jürgen Giesl, Hans Zantema, Peter Schneider-Kamp, René Thiemann

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

**Formal Methods in Signal Processing**

Bernd Schmidt, Stephan Swiderski, Daniel Willems

This project is funded by the DFG within the research training group AlgoSyn. The goal is to construct a signal processing framework for railway systems. The hardware design is based on microcontrollers, for which assembly code should be synthesized automatically. The development of new synthesis techniques is one of the major topics within the scope of AlgoSyn. The task is to use formal specifications instead of source code for the automated synthesis process. We also use probabilistic model checking to compare failure probability and other efficiency properties with well-established frameworks. The assembly code must fulfill requirements regulated by law for security reasons. Therefore, formal methods like verification techniques or termination analysis are applied. These techniques should generate a formal though human readable proof to obtain the operation license from the administration.
This project is funded by the DAAD. In collaboration with the UP Valencia, Spain, we develop and improve techniques for termination analysis of programs with specific evaluation strategies. One way of expressing such strategies is the use of context-sensitive evaluation restrictions. In this context, we are also investigating the automation of modified versions of termination techniques (like polynomial orders on real or rational numbers) with SAT solving.

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

Other Activities
J. Giesl:

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

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

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

- Vice-Chair of the *IFIP Working Group 1.6 on Term Rewriting* and participant of the WG 1.6 meeting in Seattle, USA
• Member of the Steering Committee of the *International School on Rewriting (ISR)*

• Invited Speaker of the *17th International Conference on Rewriting Techniques and Applications (RTA ’06)*, Seattle, USA

• PC-Member and participant of the *6th International Workshop on Reduction Strategies in Rewriting and Programming (WRS ’06)*, Seattle, USA

• PC-Member of the *13th International Conference on Logic for Programming, Artificial Intelligence and Reasoning (LPAR ’06)*, Phnom Penh, Cambodia, 2006

• Lecturer at the *International School on Rewriting*, Nancy, France, 2006

• Reviewer for several PhD theses (including the thesis of Nao Hirokawa, University of Innsbruck, Austria)

• Participant of the *TeReSe* workshops in Utrecht and Amsterdam (The Netherlands)

• Project reviewer for the DFG and the EPSRC

• Reviewer for many international journals and conferences

P. Schneider-Kamp:

• Participant and speaker at the *16th International Symposium on Logic-based Program Synthesis and Transformation (LOPSTR ’06)*, Venice, Italy

• Participant of the *17th International Conference on Rewriting Techniques and Applications (RTA ’06)*, Seattle, USA

• Participant and speaker at the *8th International Workshop on Termination (WST ’06)*, Seattle, USA

• Participant of the *3rd International Joint Conference on Automated Reasoning (IJCAR ’06)*, Seattle, USA

• Participant and speaker of the *TeReSe* workshops in Utrecht and Amsterdam (The Netherlands)

• Reviewer for several international journals and conferences

S. Swiderski:

• Participant of the *17th International Conference on Rewriting Techniques and Applications (RTA ’06)*, Seattle, USA
• Participant of the 8th International Workshop on Termination (WST ’06), Seattle, USA

• Participant of the 3rd International Joint Conference on Automated Reasoning (IJCAR ’06), Seattle, USA

• Participant of the TeReSe workshops in Utrecht and Amsterdam (The Netherlands)

R. Thiemann:

• Participant of the 17th International Conference on Rewriting Techniques and Applications (RTA ’06), Seattle, USA

• Participant and speaker at the 8th International Workshop on Termination (WST ’06), Seattle, USA

• Participant and speaker at the 3rd International Joint Conference on Automated Reasoning (IJCAR ’06), Seattle, USA

• Received the Woody Bledsoe Award at the 3rd International Joint Conference on Automated Reasoning (IJCAR ’06), Seattle, USA

• Participant and speaker at the 13th International Conference on Logic for Programming, Artificial Intelligence, and Reasoning (LPAR ’06), Phnom Penh, Cambodia

• Participant at the 6th International Workshop on the Implementation of Logics (IWIL ’06), Phnom Penh, Cambodia

• Participant and speaker of the TeReSe workshops in Utrecht and Amsterdam (The Netherlands)

• Research visit at the Conservatoire National des Arts et Métiers, Paris, France

• Reviewer for several international journals and conferences

Talks and Publications

Talks

J. Giesl: Praktische Informatik, Beratungstage für Schülerinnen und Schüler, RWTH Aachen, January 2006

J. Giesl: Automated Program Verification, Visit of ENS Cachan, RWTH Aachen, February 2006

J. Giesl: Automated Termination Analysis for Haskell: From Term Rewriting to Programming Languages, Lehrstuhlseminar, RWTH Aachen, August 2006

J. Giesl: Automated Termination Analysis for Haskell: From Term Rewriting to Programming Languages, invited talk at the 17th International Conference on Rewriting Techniques and Applications (RTA '06), Seattle, USA, August 2006

P. Schneider-Kamp: Automated Termination Analysis for Logic Programs by Term Rewriting, *TeReSe* workshop on Term Rewriting, Amsterdam, The Netherlands, June 2006

P. Schneider-Kamp: Automated Termination Analysis for Logic Programs by Term Rewriting, Lehrstuhlseminar, RWTH Aachen, July 2006

P. Schneider-Kamp: Automated Termination Analysis for Logic Programs by Term Rewriting, 16th International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR '06), Venice, Italy, July 2006

P. Schneider-Kamp: Termination Analysis for Logic Programs by Term Rewriting Revisited, 8th International Workshop on Termination (WST '06), Seattle, USA, August 2006


R. Thiemann: Automating Dependency Pairs Using SAT Solving, 8th International Workshop on Termination (WST '06), Seattle, USA, August 2006

R. Thiemann: AProVE 1.2: Automatic Termination Proofs in the Dependency Pair Framework, 3rd International Joint Conference on Automated Reasoning (IJCAR '06), Seattle, USA, August 2006

R. Thiemann: SAT Solving for Argument Filterings, 13th International Conference on Logic for Programming, Artificial Intelligence and Reasoning (LPAR '06), Phnom Penh, Cambodia, November 2006

R. Thiemann: SAT Solving for Argument Filterings, TeReSe workshop on Term Rewriting, Utrecht, The Netherlands, December 2006


R. Behle: Automatisierung von Induktionsbeweisen zur Verifikation funktionaler Programme, Lehrstuhlseminar, RWTH Aachen, January and June 2006
C. Stein: Das Dependency Pair Framework zur automatischen Terminierungsanalyse von Termersetzung modulo Gleichungen, Lehrstuhlseminar, RWTH Aachen, October 2006
C. Fuhs: SAT-based methods for automated termination analysis with polynomial orderings, Lehrstuhlseminar, RWTH Aachen, December 2006
S. Falke: Inductive Decidability Using Implicit Induction Methods, Lehrstuhlseminar, RWTH Aachen, December 2006

Publications
J. Giesl, S. Swiderski, P. Schneider-Kamp, R. Thiemann: Automated Termination Analysis for Haskell: From Term Rewriting to Programming Languages, Proceedings of the 17th International Conference on Rewriting Techniques and Applications (RTA ’06), Seattle, USA, Lecture Notes in Computer Science 4098, Springer-Verlag, pages 297-312
P. Schneider-Kamp, J. Giesl, A. Serebrenik, R. Thiemann: Termination Analysis for Logic Programs by Term Rewriting Revisited, Proceedings of the 8th International Workshop on Termination (WST ’06), Seattle, USA, 5 pages
M. Codish, P. Schneider-Kamp, V. Lagoon, R. Thiemann, J. Giesl: Automating Dependency Pairs Using SAT Solving, Proceedings of the 8th International Workshop on Termination (WST ’06), Seattle, USA, 4 pages
E. Annov, M. Codish, J. Giesl, P. Schneider-Kamp, R. Thiemann: A SAT-based Implementation for RPO Termination, Proceedings of Short Papers at the 13th International Conference on Logic for Programming, Artificial Intelligence and Reasoning (LPAR ’06), Phnom Penh, Cambodia, 5 pages
R. Behle: Automatisierung von Induktionsbeweisen zur Verifikation funktionaler Programme, Diploma Thesis, LuFG Informatik 2, RWTH Aachen, Germany

C. Stein: Das Dependency Pair Framework zur automatischen Terminierungsanalyse von Termersetzung modulo Gleichungen, Diploma Thesis, LuFG Informatik 2, RWTH Aachen, Germany
Software Engineering

Staff

- Faculty:
  
  Univ.-Prof. Dr.-Ing. M. Nagl
  E-mail: nagl@i3.informatik.rwth-aachen.de
  WWW: www-i3.informatik.rwth-aachen.de

- Secretariat:
  
  A. Fleck
  K. Winkler
  Phone: +49 241 80 – 21300
  Fax: +49 241 80 – 22218
  E-mail: {angelika,klaudia}@i3.informatik.rwth-aachen.de

- Research Assistants:
  
  Dipl.-Inform. I. Armac (funded by Graduate College SCS)
  Dipl.-Inform. S. Becker (CRC 476)
  Dipl.-Inform. C. Fuß
  Dipl.-Inform. T. Haase (TC 61)
  Dipl.-Inform. T. Heer (since October, TC 61)
  Dipl.-Inform. M. Heller (CRC 476)
  Dipl.-Inform. A. Körtgen (since July, TC 61)
  Dipl.-Inform. B. Kraft (funded by DFG)
  Dipl.-Inform. C. Mosler (funded by Graduate College SCS)
  Dipl.-Inform. U. Norbisrath (until October, for Computer Science Dept.)
Overview

The research activities of the group can be described with 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 system programming as e.g. for the non-standard data based system GRAS, underlying our tools.

The structure class, the group has worked in for a long time, are interactive, intelligent and integrated development systems, following either an a-priori or an a-posteriori integration approach. In the last two years we have also studied concurrent and dis-
tributed systems in the embedded systems domain. Project types are new development, reengineering, and reuse projects.

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

Funding of the group is by German Research Foundation (Collaborated Research Center 476, and Transfer Center 61 with 3 subprojects, Graduate College SCS, Conceptual Design of Buildings), and Ericsson (E-CARES Project). Furthermore, there exists some funding by the European Union (APPLIGRAPH) and A. v. Humboldt Foundation. Finally, some small cooperations with other institutes or with external companies have been carried out.

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

Teaching

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

On graduate level the group offers courses for the focus “Software Engineering”:

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

Furthermore the following lectures are given from time to time:

- Visual Programming (L2)
- Software Development Environments (L2)
- Management of (Software) Development Projects (L2)
- Specification of Software Systems (L2)
Research Projects

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

*M. Heller, R. Wörzberger, T. Heer, M. Nagl, G. Volkova, Chr. Briem, K. Geilmann, J. Hormes, I. Weisemöller, A. Fischer*

The AHEAD project is part of the CRC 476 IMPROVE/TC 61 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 most important aspects of our research are:

- the dynamic nature of these processes (e.g. handling of feedback, forward engineering),
- tool-support for the process modeler, the project manager and the technical developers,
- integrated modeling of processes, products and resources,
- coordination of developments including distributed, independent organizational units,
- process reuse,
- user-friendly process modeling languages,
- process evolution aspects,
- inter-organizational process management.

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

In 2006, we continued our previous work on support for distributed development processes and completed our new view-based cooperation model supporting a broader
spectrum of cooperation scenarios, so that cross-company cooperation is no longer constrained to a delegation-based scenario. Flexible and dynamically changeable contracts provide a uniform way to couple development processes across enterprises.

In parallel, we completed the implementation of the integration support for several commercial management systems. For example, we coupled AHEAD with MS Project. A project manager can now use the functions offered by MS Project to plan start and end dates for all tasks in a dynamic task net. Document management systems, like CVS or the commercial Documentum system, are now used as document repositories to store all documents of the development project. Additionally, developers can interface with AHEAD using their e-mail client (e.g. if they cannot run the traditional developer environment of AHEAD). Finally, we have developed an approach for the integration of static workflow processes in the overall dynamic process maintained in AHEAD.

The AHEAD project has been again successfully evaluated by the Deutsche Forschungsgemeinschaft on March 16, 2006. On this occasion, we presented our developed concepts, methodologies and tools for process management support including four different demonstration prototypes of the AHEAD system. The demonstrations focused on dedicated aspects of dynamic process management, like our process evolution approach and our inter-organizational process management approach.

Currently, our results are going to be transferred into practice. Since July 2006, the B4 project is continued within the three-year transfer project T6. This transfer project is carried out in close cooperation with our industrial partners AMB Generali Informatik Services, Aachen and innotec GmbH, Bonn.

With innotec GmbH Bonn, we evaluated the possibilities to integrate the process management functionality of AHEAD into their CAE-tool Comos PT. At the same time, we started to implement a workflow engine for Comos PT based on the Windows Workflow Foundation. This will be integrated with the tools for process management in the future.

Together with our partner AMB Generali Informatik Services, we started to transfer our process management concepts to the domain of business processes and particularly to processes of insurance companies. Our partner already uses commercial process management systems, which support the management of only static business processes. Thus, the focus in this subproject is the extension and adaption of existing process management systems and languages to cover also the management of highly dynamic business processes.
Rather than thorough and detailed plans, conceptual design focuses on the functionality of buildings as a whole, consisting of various functional, interrelated entities. This abstraction allows for the identification of the organizational configuration of a building and ensures its usability. Since the conceptual design takes place at the beginning of the building construction process, a consistent sketch forms the basis of all following design stages.

The ConDes-project aims at elaborating new concepts and tools for conceptual design to support architects during this early design phase. The complete scenario of the project comprises two approaches, top-down and bottom-up. The top-down approach aims at elaborating new formal concepts for the early design phase based on graph-technology. The bottom-up approach is more industry-oriented. The goal is here to extend existing CAD-tools with new functionality.

Within the top-down approach a prototype for a CAD tool, the Design Graph Editor, is formally specified, which allows to sketch conceptual designs. This tool is internally realized based on the graph rewriting system PROGRES and the UPGRADE framework. A further graph-based tool, the Knowledge Graph Editor, allows the definition of conceptually relevant knowledge for one specific class of buildings. Consistency analysis enables conceptual designs to be checked against this defined knowledge where notifications are shown to the architect when restrictions are violated. In 2006, the existing tools were extended. The domain knowledge can now be developed in separated knowledge modules. An interactive, graph-based algorithm allows the integration of these modules as a basis for the consistency analysis.

Within the bottom-up approach, by way of example the CAD tool ArchiCAD (GRAPHISOFT) is extended with new functionality for conceptual design and consistency analysis. The main extensions to ArchiCAD are new semantic design elements that figure the meaning of an area, a room, or a part of a room. New functionality enables the architect to interrelate design elements. In 2006, the possibility of representing a sketch and working on it in different levels of abstraction were developed. Tool support with a graphical user interface was realized.

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

---

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

_B. Böhlen, E. Schultchen, M. Breuer, G. Volkova, S. Badral, T. Hermes, M. Kallenbach, T. Lettow, in cooperation with the Fujaba development group_

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

In 2006, an additional storage backend using the Apache Derby DBMS was completed. Derby, as an in-process database, does not require any special server to be set up and thus requires an especially low configuration effort. In addition, DRAGOS was optimized regarding throughput and memory efficiency. Benchmarks show that the performance of its predecessor RGRAS is now met or even exceeded in most situations. We also added support for distributed applications by means of replication. Thus, one DRAGOS instance can replicate the state of another instance, perform changes locally, and synchronize again with the remote database.

By the end of the year we started to implement a new extension module to reflect the graph schema into the instance graph. Using this module, applications can analyse the graph schema by simply investigating a special graph. In future work, this module will be used to implement a customizable query and transformation framework in DRAGOS.

---

**E-CARES (Ericsson Communication Architecture for Embedded Systems)**

_C. Mosler, M. Nagl, M. Pettau, L. Xu, Y. Zhang, W. Zhao_

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

In the first phase of the E-CARES reengineering project, our research concerned the reverse engineering of telecommunication software. The project focused on the detection, extraction, and visualization of information on the system’s structure and behavior. Extraction from static information (code) and from runtime information (traces) was regarded. The information is used to build a so-called system structure graph. This graph contains information on a system’s decomposition into different units in different granularity.
Current work (Ph.D. work of C. Mosler) also regards restructuring of legacy telecommunication systems including their re-design and re-implementation. The aim is to extend the reverse engineering tool to a functional reengineering tool, allowing the engineers to interactively modify and improve the software architecture.

In 2006, several clustering-based algorithms improving the software architecture were successfully implemented. Also new algorithms for improving the runtime performance of the AXE10 system were investigated. New extensions of the reengineering tool comprise facilities for source code modification, by which architectural changes performed on the structure graph can be automatically propagated to the implementation level.

As telecommunication systems are often planned and modeled using state machines and protocols, it seems reasonable to analyze the systems also on the abstract representation level of state machines. For this reason, an extension of the reengineering approach was studied, in which the state machines are extracted from the source code, compared with the original specification documents, and taken into account when suggesting appropriate reengineering steps.

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

C. Fuß, M. Nagl, T. Nguyen, V. Tuttiles, R. Wittek

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

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

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

Within the project the above mentioned models were analyzed and a common meta-model was developed. This meta-model represents the essentials from all AUTOSAR submodels and function net models. The result is a component-based meta-model that focuses on communication aspects in distributed systems. The meta-model includes graph transformation specifications describing the model editing operations. Meta-model extensions were developed for model integration, change traceability, and productline modeling.

The particular domain models were specified based on the common meta-model, and modeling tools were generated from these specifications. The generated tools need a specific tool framework based on the UPGRADE framework, that was also developed within the i-caramba project.

eHome Systems

eHome systems are built on top of integrable net-aware devices in households. This way, eHome services can offer complex functionalities across multiple devices. Areas of application are multimedia and entertainment, medical surveillance and support of elderly people, reducing energy consumption, and security services. Automated smart home environments will have important influence on our everyday life in the future. Due to recent developments in hardware technology and the trend towards pervasive and ubiquitous computing, eHome systems are gaining more importance. Research in this area is also attractive with respect to its increasing market potential. However, there are a number of problems to be solved before eHome systems are ready for the market, e.g. the dynamic aspects, the respective problems concerning configuration and service composition, the interaction of arbitrary devices, and security aspects, just to name a few.

Up to now, we analyzed the life-cycle of eHome services beginning from development and specification via configuration and deployment at the eHome until retirement. In the development phase, eHome services can be implemented in a classical or rule-based way. The latter enables a flexible declarative specification of the service functionality. Furthermore, service interaction conflicts during runtime can be detected and a suitable notification of the user is provided. The business process part has been specified as a workflow. In the domain of low-cost eHome systems, it is essential to automate the configuration process. For this purpose we developed the eHomeConfigurator tool, which supports the specification of eHome services and environments, the
automatic configuration of selected services, and the deployment of the configured services to a residential gateway in the eHome. To evaluate and demonstrate our tools, we developed an eHome software simulator, which allows to simulate home environments with inhabitants and installed devices.

Currently, we work on problems occurring when eHome environments are extended beyond the physical boundaries of individual buildings to enable the migration of personalized service functionality together with the respective users. Service migration can be realized using ad-hoc networks between service gateways and mobile devices. User profiles allow the personalization of eHome services. This will raise problems regarding security and privacy aspects, that have to be solved, e.g. by role-based access control techniques. These dynamics bring up new problems concerning the eHome configuration and have to be solved with as few user interaction as possible. The dynamically changing environments with respect to user requirements and available device functionality have to be considered in a continuous process of specification, configuration, and deployment. To support this continuous process, we will extend our tools to allow an automated, dynamic service composition and deployment. To achieve this goal we develop new concepts for semantically annotated service specifications and a respective composition algorithm.

PROGRES: A Suite For Specifying Prototypes
M. Breuer, M. Heller, J. Hormes, M. Nagl, U. Ranger, G. Volkova, in cooperation with A. Schürr, Technical University of Darmstadt

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

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

In 2006, we have finished the import and export mechanism for exchanging interfaces between heterogeneous specifications via XMI-files. Furthermore, we now provide the possibility to export complete visual graph transformations using the standardized GTXL-format which can be imported by other specifications. To manage large specifications consisting of various pages, we have implemented an “assembly” of specifications. In this way, a large specification can be built from several small specifications leading to a clear structure and an improved maintenance of the specification parts. As we have started to use DRAGOS as the underlying database in 2005, we have enhanced the connection of PROGRES and DRAGOS, such that accessing the database is more efficient. Additionally, we have eliminated some errors of the PROGRES environment and improved its usage.

UPGRADE: A framework for developing prototypic applications

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

In 2006, we first focused on the runtime stabilization of the framework while preparing the DFG evaluation event in march 2006. After that, we exchanged the CORBA remote objects backbone of UPGRADE with a message-based middleware (JAVA Messaging Service) and made several modifications regarding the subsystem for the graphical views, e.g. prototypes can now benefit from a navigation explorer and a better viewing system.

In parallel, we integrated the UPGRADE framework with the DRAGOS database system to allow for UPGRADE prototypes to use either the GRAS database or commercial relational databases like MySQL.

Software Integration and Framework Development

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

The a posteriori integration of heterogeneous engineering tools, where tools are supplied by different vendors, constitutes a challenging task. In particular, this applies to an integration approach where existing engineering tools are extended by new functionality which, again, can be integrated synergetically. Responding to these
challenges, the subproject I3, which is part of the CRC 476 IMPROVE, studies an approach to tool integration which puts strong emphasis on software architectures and model-driven development.

Integration is realized by this subproject on the architectural level. The architecture of the overall environment describes the “gluing parts” necessary for performing the integration. It defines, for example, what kinds of interfaces the tools to be integrated offer, how interfaces are wrapped in order to homogenize them, how tools and wrappers are distributed, how interfaces are accessed via certain middleware techniques, and so on.

To make use of existing tools within a tight integrated environment, components, which are called wrappers, have to be provided which make tools available at a clean level suitable for integration. To reduce the development effort for building a wrapper, we study a model-driven software development approach for constructing wrappers: Based on a formal meta-model a visual model of the wrapper is specified and the executable code for the wrapper is generated and embedded into the general framework.

The problems and solutions of a-posteriori integration studied within the subproject I3 also hold true for the area of business process support as IT landscapes of companies are typically characterized by a portfolio of heterogeneous business application systems. One approach to build up an integrated business application architecture is the so-called service-oriented paradigm: A service-oriented architecture defines an architectural style for constructing an application landscape. By abstracting services, business processes are decoupled from the underlying applications.

In 2006 the subproject I3 has been again successfully reviewed by the German Research Foundation and a successor transfer project T7, titled Service-oriented Architectures and Application Integration, has been approved by the peers. This subproject, which is part of the new Transfer Center 61, aims to transfer and extend the results of the former subproject I3, related to model-driven development of wrapper components, within the area of business applications. Therefore, we cooperate with an industrial partner, namely the AMB Generali Informatik Services GmbH.

Based on the idea of service-oriented architectures, the modeling formalism to specify wrappers is extended to model an integrated business application as a loosely coupled set of interacting services. This extension is not only investigated on the conceptual level, but also covers the prototype for our corresponding modeling environment and its code generator. This way, a test environment for evaluation and exploration of service-oriented concepts in the context of integrated business applications is built up.

The key aspects of our transfer project are: (i) conceptualization and formalization of service descriptions and service compositions, (ii) tool support for declarative specifications of concrete services, and (iii) code generation. Concerning these goals, first results were achieved in 2006: the modeling formalism and the corresponding prototype have been extended to specify and generate a Web Service interface for functional modules.
During development processes in chemical engineering, a plant is described from multiple inter-dependent perspectives by numerous logical documents, which are created by developers with different software tools. Between the contents of these documents fine-granular dependencies exist. The subject of this project are incremental and interactive tools (integrators) to support developers in consistency maintenance concerning these dependencies.

This project is funded by the Deutsche Forschungsgemeinschaft as subproject B2 of the CRC 476. In B2, an approach was developed for a-posteriori integration. It is based formally on rules describing corresponding structures. Fine-granular dependencies are recognized by the integrator by means of the rules, managed and stored explicitly in an integration document. For the definition of rules, a UML-based modelling formalism was developed and realized. Together with our industrial partner innotec GmbH, an integrator framework, which contains an interpreter/compiler that can execute and/or interpret integration rules at runtime was created. A large number of realized integrators - among them an integrator for integrating flow sheets and simulation models - shows the applicability of the developed concepts.

On March 16th 2006, the B2 project was again successfully evaluated by the Deutsche Forschungsgemeinschaft. On this occasion, we presented our developed concepts, methodologies, and tools for consistency maintenance. In June 2006, the B2 project was completed. Since July it is continued by a within the two-year transfer project T5, which is part of the TC 61. This transfer project is carried out in close cooperation with our industrial partner innotec GmbH.

Together with innotec, the integration approach will be on the one hand further elaborated and on the other hand transferred into practice. A central role plays the system Comos PT of innotec, which is used during all engineering phases, e.g. for the creation of flow sheets. A goal of the transfer project is to design and realize a universal integrator platform for Comos PT, including an editor for integration rules. In addition, the integrator framework is to be integrated in Comos PT.

In 2006, we started to integrate our concepts into the Comos PT system. Focused on a scenario of integrating two flow sheets to evaluate the approach, models of flow sheets and a set of integration rules were created. Besides, integrating two flow sheets required new constructs of the rule definition language, which we developed and implemented in our framework. We started with the development of a wrapper to adapt the Comos PT system to our framework. In addition, we began working on so-called repair actions. They give help for re-integration, in cases once corresponding structures get inconsistent after changes have been performed on the documents.
Future work will concern the development of an editor for integration rules as plug-in of the Comos PT system. Within this plug-in, integration rules can be drawn graphically based on Microsoft Visio drawings. In addition, we will adapt our approach for reuse of documents, which is common practice for chemical engineering development processes. Reusing documents is closely related to consistency maintenance. Instead of transforming structures into corresponding structures, we focus on finding correspondences of existing structures.

Vilendis: Visual languages for specifying distributed systems

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

Both PROGRES and Fujaba can be used in various domains. However, they lack the ability of supporting the specification of distributed systems. As the importance of distributed and heterogeneous systems increases, our project’s objective is the investigation and implementation of appropriate concepts, which can be used to model distributed behavior in a visual way. We aim at an extensive framework, making it possible to model a distributed system similar to a local application. For the realization of that framework, we analyze existing and established concepts of distributed heterogeneous systems like Remote Procedure Calls. In 2006, we have focused on the visual specification of distributed systems, consisting of heterogeneous prototypes. For this purpose, we have defined the syntax and semantics of visually modeled graph transformations, which affect several prototypes simultaneously. Based on the defined semantics, the code generation of the PROGRES and Fujaba language environments has been adapted to generate appropriate source code for distributed specifications.

In this way, distributed systems can be specified in a visual manner and executed in a prototype. Furthermore, we have developed concepts for ensuring the consistency of all runtime graphs used within a distributed system. Thus, changes made in one prototype are propagated to the other prototypes, in which changes are performed according to their internal constraints. Additionally, access rights have been realized, so that certain modifications affecting a prototype triggered by another prototype are forbidden. On this stable basis, we have started to investigate advanced features for the specification of distributed systems, like the introduction virtual graph views and the documentation of visual interfaces.
Other Activities

Prototype demonstrations


Becker, S., Campmann, T., Relangi, K.: Inkrementelle Integrationswerkzeuge, Demonstration of two prototypes, DFG evaluation event for CRC 476, RWTH Aachen, March 2006, Aachen


Conference Activities and Academic Administration

I. Armac: Organizer and program committee member of the “First International Workshop on Mobile Services and Personalized Environments 2006”, November 2006, Aachen, Germany; Co-organizer of the “Regional Event” within “Informatics Year 2006”, RWTH Aachen, May 2006, Aachen

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

B. Kraft: Teaching position at Aachen University of Applied Sciences; Member of examination board at the chamber of industry and commerce at Cologne; Member
of the Regina group “Project Management”; Member of the DFG-SPP 1103 group “Distributed Process Modelling”

M. Nagl: Speaker of Collaborative Research Center 476/Transfer Center 61; Member of the Board of “Forum Informatik”; Member of the Board and Speaker Substitute of REGINA; Member of RWTH Aachen University Senate; Additional Member of the Faculty for Electrical Engineering and Information Technology; Member of Faculty Council; Board Informatics Europe; Chairman German Informatics Deans Conference (Fakultentag); Member of the Board of 4ING, Union of Deans Conferences in Mechanical Engineering, Electric Engineering, Civil Engineering, and Informatics; Organizer of “Regional Event” within “Informatics Year 2006” (together with U. Schroeder, O. Spaniol, B. Vcking); Fujaba-Days 2006, University of Bayreuth (Member of PC); Intl. Conference on Graph Transformation, ICGT 2006, Brazil (Member of PC); Co-organizer of Software Engineering, Strategy Meeting 2006; SEI, Software Engineering 2007, Hamburg (Member of PC)

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

U. Ranger: Co-organizer of the “Girls Day”, “Study Day for Girls”, “Scholar information days” for Computer Science, and the “Regional Event” within “Informatics Year 2006”; Faculty representative for the equality commissioner Ms. Diepelt

D. Retkowitz: Organizing and program committee member of the “First International Workshop on Mobile Services and Personalized Environments 2006”, November 2006, Aachen, Germany

E. Schultchen: Co-organizer of the “Scholar information days” for Computer Science and the “Regional Event” within “Informatics Year 2006”

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

Talks


Armac, I.: *Mobility and Privacy in Virtual Home Environments*, International Research Training Groups Workshop (IRTG 2006), November 2006, Dagstuhl, Germany


Armac, I.: *Specification, Configuration, and Deployment in eHome Systems*, Guest Speaker within the Distributed Systems and Networking discipline Seminar Series 2006, RMIT University, December 2006, Melbourne, Australia

Becker, S.: *Konsistenzsicherungswerkzeuge für verfahrenstechnische Entwicklung*, Talk, poster presentation, and prototype demonstration, DFG review for Transfer Center 61, RWTH Aachen, 16 March 2006, Aachen, Germany

Becker, S.: *Deriving Integrator Prototypes from Rule Specifications*, The 1st Triple Graph Grammar Workshop - TGG’ 06, September 2006, Bayreuth, Germany

Becker, S.: *Interactive Execution of Triple Graph Grammars*, The 1st Triple Graph Grammar Workshop - TGG’ 06, September 2006, Bayreuth, Germany

Haase, T.: *Service-orientierte Architekturen und Anwendungsintegration*, Talk, poster presentation, and prototype demonstration, DFG review for Transfer Center 61, RWTH Aachen, 16 March 2006, Aachen, Germany


Heller, M., Wörzberger, R., Heer, T.: *Dynamisches Prozessmanagement in AHEAD und Entwicklung von Prozessmanagementsystemen auf Basis existierender Systeme*, Poster and prototype demonstrations, DFG review for Transfer Center 61, RWTH Aachen, 16 March 2006, Aachen, Germany


Mosler, C.: *E-CARES Project: Reengineering of PLEX Systems*, The 8th Workshop Software-Reengineering (WSR’06), May 2006, Bad Honnef

Mosler, C.: *Specifying Distributed Graph Transformation Systems*, The 3rd International Workshop on Graph Based Tools (GraBaTs’06), September 2006, Natal, Brazil

Mosler, C.: *RePLEX: A Model-Based Reengineering Tool for PLEX Telecommunication Systems*, The 3rd International Workshop on Graph Based Tools (GraBaTs’06), September 2006, Natal, Brazil


Norbisrath, U.: Component-Based Development for eHome Systems, International Conference on Computational Methods in Science and Engineering (ICCMSE’06), November 2006, Chania, Greece

Norbisrath, U.: Functionality Configuration for eHome Systems, 16th International Conference on Computer Science and Software Engineering (CASCON’06), October 2006, Toronto, Canada

Norbisrath, U.: Configuring eHome Systems, January 2006, Tartu, Estonia

Ranger, U.: Search Trees for Distributed Graph Transformation Systems, The 2nd International Workshop on Graph and Model Transformations (GraMoT’06), September 2006, Brighton, United Kingdom


Schultchen, E.: Graph-oriented Storage for Fujaba Applications, The 4th International Fujaba Days, September 2006, Bayreuth, Germany

Publications


Becker, S., Heller, M., Jarke, M., Marquardt, W., Nagl, M., Spaniol, O., Thien, D.: *Synergy by Integrating New Functionality*, to appear in LNCS

Bhlen, B.: *A parameterizable Graph Database System for Development Tools (in German)*, Dissertation RWTH Aachen, 237 pp., RWTH Aachen, Shaker-Verlag, 2006


Fuss, C., Mosler, C., Pettau, M.: *RePLEX: A Model-Based Reengineering Tool for PLEX Telecommunication Systems*, Accepted to the 3rd International Workshop on Graph Based Tools (GraBaTs’06), Natal, Brazil


Meyer, O.: *aTool: Typography as Source for Structuring Texts (in German)*, Dissertation RWTH Aachen, 308 pp., RWTH Aachen, Shaker-Verlag, 2006


Nagl, M.: *Further Education at Universities: State, Challenge, Problems (in German)*, Workshop on Further Education of GI, to appear
Nagl, M., Marquardt, W., Eds.: Collaborative and Distributed Chemical Engineering Design Processes: From Understanding to Substantial Support - Results of the IMPROVE Project, to appear in Lecture Notes in Computer Science, Springer-Verlag

Nagl, M.: The Interdisciplinary IMPROVE Project, to appear in LNCS


Ranger, U., Hermes, T.: Ensuring Consistency within Distributed Graph Transformation Systems, Accepted for the Proceedings of the 10th International Conference on Fundamental Approaches to Software Engineering (FASE’07), Braga, Portugal


Ranger, U., Schultchen, E., Mosler, C.: Specifying Distributed Graph Transformation Systems, Accepted to the 3rd International Workshop on Graph Based Tools (GraBaTs’06), Natal, Brazil

145

Software Construction

Staff

- Faculty:
  Univ.-Prof. Dr. rer. nat. Horst Lichter
  lichter@informatik.rwth-aachen.de

- Secretary:
  Bärbel Kronewetter
  Phone: +49 241 80 21 330
  Fax: +49 241 80 22 352

- Research Assistants:
  Dipl.-Inform. Alexander Nyßen
  (third-party funds position)

  Dipl.-Inform. Thomas von der Maßen
  (until March 2006)

  Dipl.-Inform. Holger Schackmann
  (third-party funds position)

  Dipl.-Inform. Thomas Weiler

- Student Researchers:
  Nan Mungard
  Mathias Funk
  Andreas Walter

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

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

In 2006 Thomas von der Maßen successfully completes his research project aiming in defining a quality model for feature based platform and product models. Furthermore he has headed the development of the tool RequiLine which was assessed to be one of the best product line development tools available. He left our group in April and joined Bertelsmann arvato AG. He received his Phd degree in January 2007.

Finally a new Software Engineering textbook was published by J. Ludewig, University of Stuttgart, and H. Lichter in September.

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 *Product Line Development*
- Lecture *Object-Oriented Software Construction*
- B-IT Seminar *Software Maintenance*
- Seminar *Processes and Models of Software Development*
- Practical Labs

Furthermore we are responsible for the Software Engineering course of the master program Software Systems Engineering at the Thai German Graduate School of Engineering, Bangkok, Thailand.
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 affects the success of projects significantly.

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

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

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

RequiLine has been evaluated in cooperation with Robert Bosch GmbH in the context of the development of motor control units. RequiLine detected several defects in the motor control units PLFM. Additionally RequiLine helped in retrieving information about the variation degree and other needful statistical information, that influences the further development at Bosch.
In the last year we have improved our methodology for developing a product line platform architecture (PLPA) based on a feature model, thus allowing for smooth transition from requirements engineering to architecture modeling. While the single phases of the software development process are mostly self-contained with continuous methodology, notation and also adequate tool support, the transitions often exhibit a gap. To bridge this gap, transformations between the different methodologies and notations used in the adjacent phases are needed. But the abstraction needed for these transformations results in information loss.

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

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

Methodology for PLPA Modelling.

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

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

During identification of the feature components each variability, which is assigned to a feature in the feature model, is analyzed to determine whether it influences one of the feature components derived from the feature. If so, the feature component concerned is also assigned the variability, which is depicted in the figure above, by a red circle (denoting an option) or red diamond (denoting an alternative). Therefore, a variability modeled in the feature model can be distributed over a set of feature components which all have the same variability with the same ID assignment. This way, traceability of the domain variability modeled in the feature model is ensured.
In the next step architectural components must be formed based on the feature components identified before, according to the modularization criteria used at the subsystem level of the architecture. In order to form e.g. classes, each component feature has to be analyzed to determine whether it denotes a class, a responsibility (method) of a class, or an attribute of a class. This way a class diagram representing the static structure of the product line platform architecture is created.

Product Line Development for Embedded Systems
A. Nyßen, H. Lichter

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

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

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

Process and Tool Support for the Maintenance of Hierarchical Product Lines

H. Schackmann, H. Lichter

External cooperation: Kisters AG, Aachen

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

We identified the necessity of investigating the cost effects of product line variabilities during the evolution of the product line. This requires a suitable approach for costing which differs from project-centric cost accounting. The intention is to use this information to enable substantiated decisions to control the evolution of variation points in a software product line. An improved transparency of the different activities, their progress and their costs will support the product-line wide coordination and planning. To improve the monitoring of development projects, several metrics of interest based on change request data were defined. Since existing tools were not sufficient to evaluate the desired metrics, an independent metrics tool was developed, that enables to define metrics in a very flexible way. This tool will further be enhanced and evaluated in practice.

Based on the development process that was designed in cooperation with Kisters AG that is targeted to fit the needs of evolving of multi-products in a multi-project context, we analysed weaknesses in existing tool support. We worked on improvements for tools in the area of change request management and task planning, as well as in the
area of automatic software tests. A framework was developed that basically supports the administration, execution and reporting for different kinds of automatic software tests. It will be extended to support testing in a heterogeneous product environment.

**Other Activities**

Board Member of the GI-Fachgruppe 2.1.6. Requirements Engineering, H. Lichter
Reviewer for dpunkt-Verlag Heidelberg and computing reviews, H. Lichter
Member of the program committee, GI-Conference Modellierung 2006, Innsbruck, March 22-24, 2006, 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 2006, H. Lichter, T. Weiler
Speaker of the GI-Arbeitskreis Werkzeuge für die Produktlinienentwicklung of the GI-Fachgruppe Requirements Engineering, T. von der Maßen

**Talks and Publications**

**Talks**

H. Lichter: *Umsetzung von Prozessverbesserungsmanahmen*, KISTERS AG, Aachen
H. Lichter: *Ein RE-Ansatz für die Einführung eines Data Warehouse Systems*, STAWAG, Aachen
A. Nyßen: *Model-driven development of embedded software applications*, ABB Automation Products GmbH, Göttingen

**Publications**


Communication and Distributed Systems

Staff

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

- Secretary:
  Christiane Gelueck
  Petra Zeidler

- Academic and Research Staff:
  Dipl.-Inform. Yuri Babich (until 30 June)
  Dipl.-Volksw. Heide Coenen (until 31 October)
  Dipl.-Inform. Stefan Diepolder
  Dipl.-Inform. Juan Miguel Espinosa Carlin (since 1 May)
  Dipl.-Ing. Markus Fidler (on leave of absence)
  Dipl.-Inform. Ingo Fliegen (1 February - 31 October)
  Dr. Mesut Güneş
  Dr. Frank Imhoff
  Dr. Dogan Kesdogan
  Dipl.-Inform. Tobias Kölsch
  Dipl.-Inform. Martin Krebs (since 1 November)
  Dipl.-Inform. Karl-Heinz Krempels
Staff

• Academic and Research Staff ctd.:

  Dipl.-Ing. Jan Kritzner
  Dipl.-Inform. Sadeq Makram (since 1 February)
  Dipl.-Designerin Alexandra Meyer
  Dipl.-Ing. Kittisak Ormsup
  Dipl.-Inform. Andrij Panchenko
  Dipl.-Inform. Stefan Penz
  Dipl.-Inform. Rajandra Persaud
  Dipl.-Inform. Dang Vinh Pham (since 1 August)
  Dipl.-Inform. Lexi Pimenidis
  Dr. Ulrich Quernheim
  Dr. Jürgen Rapp
  Dipl.-Inform. Tim Seipold
  Thitinan Tantidham, MSc
  Dr. Dirk Thißen
  Dipl.-Inform. Martin Wenig
  Dipl.-Inform. Ralf Wienzek
  Dipl.-Inform. Alex Zimmermann

• Technical Staff:

  Helen Bolke
  Kai Jakobs
  Rainer Krogull
Overview

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

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

In addition to the research activities, several members of staff have been heavily involved in testing and extending the University’s 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', 'Data Communication and Internet Technology'), 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' have also been offered. For further information please see: http://www-i4.informatik.rwth-aachen.de
Over recent years, mobile networks tend to become more and more decentralized. That is, mobile devices communicate directly via wireless connections without a fixed infrastructure (so called Mobile Ad-hoc networks or Wireless Mesh Networks). The spontaneous nature of such networks raises the need for dynamic and flexible service management systems that enable the users and their applications to discover, access, and use network services (e.g. a printing service or an internet connection service offered by other mobile devices) in an ad-hoc manner. For ease of service access the service management should work transparently with a minimum of administration and configuration effort. In a first phase of the project Informatik 4 developed a flexible service management on the basis of the IETF Service Location Protocol (SLP). In a second step, we extended our service management by a path quality estimation component that determines relevant parameters of communication paths between the user and discovered service providers. With this information, the user is able to consider the characteristics of the corresponding communication paths for provider selection. This is especially important for dynamic wireless networks with sparse communication resources and instable connections between neighboring devices. Amongst others, we developed routing protocol extensions to assess path stability indicators and a probabilistic end-to-end bandwidth measurement system for wireless ad-hoc networks. Additional to provider and path information, we finally want to gather different types of information from nearby network devices that allow to derive the current usage context of the device. This facilitates context-aware computing, which allows software components to dynamically adapt to the environment the user is currently situated in. Our general goal is to provide any relevant information for service discovery and usage over a common programming interface. The project is part of the German Research Foundation’s (DFG) Priority Programme ’Basis Software for Self-Organizing Infrastructures for Networked Mobile Systems’, which currently includes thirteen research projects at German universities. The main topics of this program include routing, middleware and application support of mobile ad-hoc networks. More information can be found at http://www.tm.uka.de/forschung/SPP1140/.
Artificial Policy Agents Supporting Time Scheduling in Hospitals

Karl-Heinz Krempels

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

Core Network Mobility based on Multi-Protocol Label Switching

Rajendra Persaud

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

PRIME is the name of a 4-year project, conducted within the EU 6th Framework Programme, which was launched on March 1st, 2004. It’s objective is the research and development of solutions to empower individuals in managing 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 privacy-compliant data processing of enterprises. We investigate the means of secure and privacy friendly communication providing data confidentiality and hiding sender/recipient relationships. For these goals we research means of encryption and hiding network addresses by means of anonymous communication network layers. But it is well known that secure communication does not exist without context: it is always as strong as it’s weakest link. We therefore do some research in general security issues as well, i.e. teaching security in user education, security awareness in risk management, measuring security and applied IT security.

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

The Co-operative Research Center IMPROVE (SFB 476) aims to support and accelerate design processes in chemical and plastic engineering through computer science concepts. It is promoted by several computer science institutes working on concepts for direct and indirect process support as well as engineering institutes that bring in their domain-specific knowledge and ergonomics experts. The subproject Service Management and Trading for Design Tools provides the other project partners with a service layer that separates the tools used in the design process from the different underlying platforms. This allows an abstraction from the details of systems, networks and applications. In order to account for the heterogeneity of systems and tools and their physical distribution, the service management is based on the Common Object Request Broker Architecture (CORBA).
The service layer has to guarantee high availability and fault tolerance of the applications and tools involved. To set the project partners free from dealing with faults and performance bottlenecks, we use alarm correlation to determine causes of abnormal situations. *Strategic mobile agents* react to these situations. They can decide whether to migrate to a target system or to perform a remote procedure call from the viewpoint of a maximum efficiency, thus realizing a scalable management approach. Likewise, the trading process and service management must ensure a good execution performance of all tools, so *load balancing* is performed when selecting services to execute. The prediction of resource use by different applications and their combinations is investigated along with approaches to composition of distributed services in order to meet tools’ Quality of Service (QoS) requirements.

The uniform access to a-posteriori integrated legacy applications to extract management information and perform management actions (monitoring and control) is a central aspect in an integrated engineering design environment. We use intelligent wrappers, or *management proxies*, that encapsulate the tools and enable uniform access as well as adapted management actions. External services that are implemented in the Web Services technology are loosely integrated by means of a gateway. They reside in foreign administrative domains and are subject to heuristic trading decisions and limited management in the service layer.

Security communication plays a prominent role in the acceptance of developer support systems should the developers cooperate across the boundaries of enterprises. We work on approaches to efficient security mechanisms that work across CORBA, Web Services and, in general, other middleware domains.

---

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

*Kittisak Ormsup*

Existing routing protocols for wireless sensor networks don’t perform very well in real sensor applications due to reasons listed below: 1. Gradient Technique (Directed Diffusion, GRAB, GEAR):

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

2. Flooding Technique (SPIN):

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

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

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

4. Geographic Technique (GPSR, GAF GEAR):

• Not energy aware.

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

Mitigation of malicious behaviour in mobile ad hoc networks

Ralf Wienzek

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

FAST Integration - Framework Architecture Supporting Telematics Integration

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 vary in size and capabilities, the communication networks range from LAN and WLAN to UMTS and TETRA and the middleware on the back end may be CORBA or Webservice-based. This creates 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 a framework was designed, implemented as a prototype and field-tested. It provides a transparent use of communication facilities despite the underlying network technology, especially provisioning continuous connectivity
for highly mobile terminals in spite of intra- and inter-network roaming with varying transmission properties. A tunable dynamic selection of one of concurrently available access networks allows optimization of cost versus QoS and message urgency. To optimize the information transferred to the mobile terminal in regard to terminal and network capabilities, dynamic service adaptation is employed. This mechanisms allow a fast deployment of individually configured telematics systems, as adaption to mobile access technologies, middleware systems etc. is done in individual composable modules.

Parallel to the prototype an emulation solution was implemented that allows the testing of real mobile applications without requiring actual terminal mobility and radio access networks. Based on the ns2 emulation facility, additional modules where implemented to allow life data injection from virtual network interfaces, dynamic network address assignment and export of roaming effects to the virtual interfaces. The emulation facilities where crucial for testing during the implementation of the prototype, and dare suitable to run any type of application transparently over an emulated wireless network. Further, they allowed the benchmarking the framework’s behaviour in artificially created adverse situations.

The prototype was finally field-tested in a parallel installation to an existing telematics system in a mission-critical environment. During the field-test the prototype was used just for a single application, and showed the somewhat expected lack of long term stability. However, the adaption and network selection facilities as well as the general framework architecture have shown their use, as they allowed additional features to be integrated into the telematics system in less development and deployment time than the existing approach. Further, as parallel usage to an existing system was found feasible, easy migration from an existing legacy system to a FAST-based telematics system is possible.

**An Adaptive Checkpoint Placement for Battery-Power Devices in User Level**

*Thitinan Tantidham*

This research focuses on session persistence for personal mobility computing which is based upon the former FAST Integration project (Framework Architecture Supporting Telematics Integration). Since the rapid advance of mobile computing and communication technologies, the ratio of price to performance for battery-power devices like PDA, smart phone and computer laptop as well as peripheral storages has decreased. It becomes popular that people on the move can suspend and restore services from one device to another by capability of wireless communication ports (e.g. WLAN, GSM or UMTS) for accessing their remote storage, or by a USB port for accessing a portable storage. However, a finite battery capacity is a major concern that users are often faced
because of battery exhaustion and inadvertently session interruption. In order to keep service continuation, basic requirements are portable checkpointing and migration techniques in user level for a heterogeneous environment. In recent researches, a checkpointing protocol for a mobile computing environment has been developed on the basis of local storage limitations. This protocol employs a proxy server or a mobile station system for locating a persistent storage and functioning as a checkpoint manager in order to save and maintain the checkpoints on behalf of user devices. However, in real life due to high access cost and inadequate network coverage, while traveling, users are mostly in disconnection mode. To cope with this problem, a self-checkpoint engine with the capability of storing the checkpoint on the peripheral storage is introduced. This research aims to find an optimum checkpoint interval which is optimized between user application time and failure recovery time under the boundaries of battery lifetime. In this case, system lifetime is represented by battery lifetime. Therefore, a checkpoint is placed at least once before battery exhaustion. The checkpoint interval for a given battery lifetime is investigated on the basis of energy consumption, Mean Time to Failure (MTTF) and failure distribution. In order to study battery characteristics and energy consumption, we made an experimental setup based on several laptops with different ages of lithium-ion batteries, USB portable storages, and a remote storage server. In the reality of usage, we assume that users do not know the number of discharge cycles and physicochemical properties as well as electrical measurements. Therefore, we use ACPI (Advanced Configuration and Power Interface) enabled by operating systems for monitoring battery capacity. As the results show, the computation of remaining battery life time from ACPI (which is based only on discharge rate) takes some minutes to predict battery life and has high prediction errors in some cases. To cope with this problem, we propose a methodology based on learning techniques with a combination of some measurable effects such as CPU utilization, CPU frequency, and temperature over time for more accuracy and faster prediction. The expected result is an optimal checkpoint placement scheme which is adaptive to battery lifetime, workload, and failures.

Affordable Communication Technologies for Rural Areas

Martin Krebs

The project is part of the excellence initiative 'Ultra High-Speed Mobile Information and Communication (UMIC)' founded by the German National Research Foundation (DFG). The goal of this cluster is the interdisciplinary design of Ultra high-speed Mobile Information and Communication systems (UMIC) providing an order of magnitude improvement of the perceived quality of service. This project is part of the sub area B1 'Future Mobile Internet Services'. The project start was in November 2006. More information can be found at http://www.umic.rwth-aachen.de/. The
goal of this project follows the vision of ultra high-speed mobile information and communication everywhere at low cost in the special case for rural areas and developing countries. Current communication solutions from industrialized countries like UMTS or wired broadband solutions like DSL are not appropriate for developing countries. We first reviewed existing projects under the auspices of the United Nations and the ITU Development Sector for developing countries. We identified that voice services and internet access are the most demanded services for all developing countries. Many installed proprietary solutions do not scale or are not able to fulfill the upcoming high demand for high speed data and voice services in this scenario. Wireless Mesh Networks are suitable network technologies to data and voice services with regard to cost for devices and deployment for this scenario. But Wireless Mesh Networks still have several drawbacks because of protocol design issues in IEEE 802.11. Due to the multi-hop character of Wireless Mesh Networks, data throughput is reduced by every hop when using only one channel, because within a communication range only one station can send or receive at the same time. This fact highly motivates the usage of multi radio and multi channel wireless mesh networks for future networks. Future work will be done on a theoretical aspect as well as in our UMIC Wireless Mesh Testbed. More information about the testbed can be found at http://mesh.umic.rwth-aachen.de/ The project cooperates with the Chair of Computer Science 5 (Information and Database Systems) and the Chair of Urban History (sbg) within the project 'Virtual Campfire - Mobile Social Software' with an application scenario for Afghanistan. There is also project cooperation with the ComNets (Chair of Communication Networks) in the research area of IEEE 802.11s Wireless Mesh Networks regarding the MAC-Layer.

Privacy in Location Based Services

Tobias Kölsch

From the 1st of July 2005 a cooperative Project exists with the ComNac GmbH. The goal is to investigate possible solutions for privacy enhanced e-commerce and m-commerce applications. The goal is to gain insights into secure multi tier business environments. Location based services as they are existing nowadays, are often problematically from a data protection point of view. The data that is gathered to fulfill the services contain privacy invading information and the responsibility of protecting this data usually lies with the application developers. However, as a wide variety of specialized services exist, usually neither long time relation nor formal contract exist between the user and the service provider. A problem is how the services can be provided in an easy to use fashion without putting the users privacy at stake. This project aims at generating a general framework for data protection and data security in multi tier location based services. To achieve this a multi approach solution is chosen.
Data that definitely has to be transmitted is protected by sticky policies that rule the data handling of the transmitted data even in the remote site.

Data that is not important by itself, is transmitted in a transformed form, such that the goal can be reached without disclosing the concrete content.

Finally some services are delegated to a semi trusted third party and the related data is transmitted to that same party without disclosing it to the actual provider of the service.

In the course of the project two example location based services should be developed that fulfill the requirements of a large scale mobile communication application in terms of performance, security, and scalability.

---

**Realistic Simulation Environments for Wireless Networks**

*Dr. Mesut Günes*

A mobile ad-hoc network is created by a collection of nodes which communicate using radio interfaces and do not rely on any pre-installed infrastructure. Furthermore, it is supposed that ad-hoc networks are inherently adaptive and auto-configured. Therefore, ad-hoc networks offer immense flexibility. In recent years the interest in the deployment of ad-hoc networks for real world scenarios grew. Still the number of real world ad-hoc networks is quite low and most of the testbeds consist only of a small number of nodes. The development and testing of new algorithms and methods nowadays relies heavily on network simulations. Simulating wireless networks, and especially mobile ad-hoc networks, is not a trivial task and consequently there have been discussions about the validity of presented simulation results. Unfortunately, the most simulation scenarios are artificial and do not fit to real world situations. The focus of this project is on several aspects of designing more realistic simulation scenarios for wireless and mobile ad-hoc networks.

---

**Advanced Interactive Mobile Television**

*Jan Kritzner*

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

Robust Access Control in Wireless Sensor Networks
Zinaida Benenson

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

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

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

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

**INTEREST - INTEgrating REsearch and STandardisation**

*Heide Coenen, 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. This was followed by a survey of the different interfaces that exist between research and standardisation. The rationales and incentives schemes that exist within the research communities, and their contacts to standardisation bodies and industry will are being compiled through a survey-based study. Following an indicator based approach, INTEREST is also developing a matrix linking the science and technology base of companies (e.g. their patent portfolios) and their standardisation activities. Through case studies the project has analysed the internal organisational structure of the interface between research and the standards department within companies. Thus, solutions and organisational models can be identified suitable to support the transfer of research results into standards and to appropriate results from research.
institutions in order to transpose them into standards. In addition, the project is analysing the pros and cons of patent pools as a means to transfer complex research results produced by various partners to standardisation processes and to reduce complex IPR-related problems within standardisation processes. Based on these new insights, and on the taxonomies of standards and research outputs, respectively, a taxonomy will be developed to characterise the typical relationships of the two dimensions. This taxonomy will be the basis to identify relevant combinations between R&D, but also innovation and standardisation and to develop specific policies, since standardisation does not only benefit from R&D, but has also positive impacts on innovation. The project is co-funded by the European Commission under their Framework Programme 6. Further information may be found at http://www.interest-fp6.org

Ultra High-Speed Mobile Information and Communication (UMIC) - Research Area D: Advanced Performance Modeling and Analysis Techniques

Dang Vinh Pham

The project is part of the Excellence Cluster UMIC. The goal of this cluster is the interdisciplinary design of Ultra high-speed Mobile Information and Communication systems (UMIC) providing an order of magnitude improvement of the perceived quality of service. Concepts and demonstrators for smart, mobile, broadband, low-cost systems will be developed which support the demanding applications of the next-decade mobile Internet. This project focuses on developing new performance measuring and modeling techniques for dynamic mobile networks. The results of this project should contribute to the efficient exploitation of network resources to increase its performance. Among the problems addressed by this project are the invocation of incentives for resource sharing and the channel assignment in multi-radio and multi-channel wireless networks. The challenge of the first problem is to measure the performance of a network, which would result from the cooperative behavior of different participants of the network. Thereby each participant has restricted resources like battery power or bandwidth and a different degree of willingness to cooperate and to share their resource with other participants. The motivation for the second problem results from the recent development of mobile devices with multi-radio network interfaces. The idea behind equipping mobile devices with several radio interfaces is to reduce radio interferences. Thereby the questions arise how many radio interfaces a device should have and what the possible gain in throughput will be. As there is no answer to these questions yet, we do researches to model this problem and to find appropriate analyses.

Talks and Publications
Talks

Publications


Jakobs, K.: *ICT Standards Development - Finding the Best Platform.*, Proc. Interoperabil-
Distributed Systems

Staff

- Faculty:
  Prof. Dr.-Ing. Klaus Wehrle
  http://ds.cs.rwth-aachen.de/

- Research Assistants:
  Dipl.-Inform. Stefan Götz (funded by Landesstiftung BW)
  Dipl.-Inform. Tobias Heer (since 10/2006, funded by DFG)
  Olaf Landsiedel, MS C.S. (funded by DFG)
  Dipl.-Inform. Martin Mink (until 09/2006)
  Dipl.-Inform. Simon Rieche (funded by DFG)

- Student Researchers:
  Christian Beckel
  Diego Biurrun
  Jó Á. Bitsch Link
  Tobias Heer
  Andreas Monger
  Sebastian Jansen
  Irfan Simsek

- Visiting Researchers:
  Dr. Andrei Gurtov (HIIT Helsinki)
  Dr. Dmitry G. Korzun (HIIT Helsinki)

The Distributed Systems Group joint RWTH Aachen University in May 2006.
Overview

The vision of our research is the development of flexible, scalable, resilient communication systems and the required models, methods and tools to realize this vision.

The scope of considered systems spans from complex and massively distributed Peer-to-Peer-systems, via traditional Internet-based communication systems to ubiquitous devices, embedded systems and tiny sensor nodes.

With flexibility, scalability and resilience as key challenges in mind, we identify three important research areas and mainly focus on them:

- Communication Systems Engineering:
  - Engineering of Resilient and Flexible Communication Systems
  - Models, Methods and Tools for Protocol and Communication Systems Development
  - Validation and Visualization of Protocols and (Embedded) Systems

- Self-Organization and Coordination in (Massively) Distributed Systems:
  - Scalability and Resilience in Massively Distributed Systems
  - Structured Peer-to-Peer-Systems, Distributed Hash-Tables (DHTs)
  - Self-Organization in Massively Distributed Systems
  - Load-Balancing and Resilience in Structured P2P-Systems
  - Security, Trust and Anonymity in Massively Distributed Systems

- Communication Support for (Massively) Distributed Systems:
  - Flexible and Scalable Communication Support in/for Distributed Systems
  - Support for Various Communication Forms
  - Mobility Support for Distributed Systems
  - Support for Services in the Network and their Composition
  - Bridging the Limitations/Heterogeneity of Today’s Internet
Research Projects

Legacy Applications Support for Overlay Networks
Klaus Wehrle, Dilip A. Joseph, Ion Stoica (joint work with UC Berkeley)

Researchers have recently proposed many new Internet architectures and overlay networks (e.g. RON, i3, HIP) in order to add new functionality to the Internet. However, users are often unwilling to switch from their favorite applications just for leveraging the new functionality offered. It is thus important to enable legacy applications (e.g. Internet Explorer, Firefox, SSH) to work on new architectures and overlays. Rewriting/recompiling all legacy applications for each new architecture is a tedious and often impossible task.

OCALA (Overlay Convergence Architecture for Legacy Applications) is an overlay convergence architecture that allows legacy applications to leverage the functionality of new architectures and overlays without any source code modification, recompilation or reconfiguration. OCALA allows a user to simultaneously access multiple overlays for different purposes, stitch together the varied functionality offered by different overlays, as well as communicate with hosts residing in overlays the user is not directly connected to. OCALA also factors out the common requirements for supporting legacy applications – researchers can concentrate on designing new network architectures, rather than getting legacy applications to work.

Extended Communication Primitives for UMIC Applications
Tobias Heer, Klaus Wehrle (joint work with MobNets research group)

Modern networking applications require extended communications primitives like multicast, anycast, service composition, and delegation. As a matter of fact, providing these communication primitives efficiently surpasses the capabilities of the traditional point-to-point communication paradigm prevalent in today’s Internet. As attempts to provide these primitives within the core network structure of the Internet have largely failed, several overlay networks like the Internet Indirection Infrastructure (i3) which enable these communication primitives have emerged. However, i3 has been designed and implemented for reliable infrastructure networks like the Internet. This makes it inapplicable in networks that exhibit a more dynamic network behavior, such as mixed ad-hoc and wireless mesh networks.
Ultra High-Speed Mobile Information and Communication (UMIC) is a cluster of excellence which focuses on providing high-speed communication in wireless networks beyond the limitations of today’s WiFi and wireless mesh networks. Figure 2 depicts an exemplary UMIC scenario and some challenges in UMIC. The Distributed Systems Group and Mobnets are working on a joint UMIC project which aims at realizing extended communication primitives in dynamic networks. The goal is to ease and accelerate the deployment of complex communication applications in mobile environments in general and for UMIC applications in particular. The integration of these extended primitives into UMIC yields a wide range of challenges. On the one hand, the indirection infrastructure must be tightly integrated into the network to avoid an overhead due to inefficient routing and unnecessary structure maintenance. On the other hand, the infrastructure must abstract from the actual network topology in order to provide a consistent and clear interface for applications. An important step in implementing the extended communication primitives is the design of a flexible namespace which allows for addressing and identifying hosts independent of their location in the multi-hop network.

**Briding the Heterogeneity of today’s Internet**

*Stefan Götz, Klaus Wehrle*

Today, Internet technology is extremely widespread and everyday business life cannot be imagined without it. However, in its basic functions, Internet technology increasingly shows its drawbacks, especially concerning communication patterns which differ from point-to-point communication, which was prevalent up until now. This has resulted in communication-related problems in numerous mobile situations, which
are becoming more and more important in everyday business life. These difficulties urgently require new software techniques for communication support. The need for new software solutions especially becomes obvious with examples of wireless mobile equipment, group communication as well as situations involving diverse equipment.

The Semobis project (funded by Baden-Württemberg State Foundation) aims to solve these problems with a new approach. Through a change of paradigms – from locally fixed contents and services to a content based access – a suitable method will be created to adequately resolve the problems of mobility, heterogeneity and the security of mobile systems. Through corresponding technological software interfaces, individual services are carried out and connected in varied ways.

On the whole, the research project will develop new innovative methods to create complex mobile software solutions for company purposes and facilitate a seamless integration of mobile information systems. The planned technological software framework will make it possible for application developers to create specially customized systems, whose service modules can be reused several times. These service modules are inconspicuous for the user as they are automatically integrated according to context and demands.

Lightweight Authentication for the Host Identity Protocol (LHIP)

Tobias Heer, Stefan Götz, Klaus Wehrle

The ubiquity of truly mobile appliances such as WiFi-enabled mobile phones, PDAs, and Internet web pads stands in stark contrast to the lack of mobility support in today’s communication protocols. Many of these devices are multihomed and use standard protocols like IP and TCP, which have been designed for non-mobile computers with a single network device. Therefore, they are not able to cope with mobility and multihoming appropriately. Several protocols and protocol extensions have been proposed in order to add mobility support to TCP/IP. One of the most promising among them is the Host Identity Protocol (HIP) which adds an additional protocol layer between TCP and IP to hide host mobility from the transport layer. However, especially mobile devices with few CPU resources are slowed down by HIP. The poor performance of HIP on these mobile devices results from the extensive use of public-key cryptography for securing the main HIP protocol functions.

Lightweight HIP is a protocol extension which enables HIP to offer mobility and multihoming support without the use of public key cryptography. The goal of LHIP is to speed up HIP in order to make it usable for weak mobile devices. To achieve this goal, LHIP utilizes and refines several alternative authentication mechanisms like interactive hash chain authentication and incorporates them seamlessly into the HIP protocol design. First results prove that LHIP is able to provide decentralized mobility
and multihoming support even to very resource-restricted devices. Thus, LHIP extends the scope of HIP to a wide range of truly mobile appliances.

The LHIP project is part of a long-term cooperation project between the Distributed Systems Group and the Helsinki Institute for Information Technology (HIIT). The collaboration is partly funded by the German Academic Exchange Service (DAAD).

---

**Peer-to-Peer-based Anonymous Communication in the Internet**

*Olaf Landsiedel, Klaus Wehrle*

Anonymous routing and forwarding enables private communication in today’s Internet. Its applications range from private web-browsing and online voting to anonymous email, chats and content distribution. The research community proposed Onion Routing as a substrate to enable anonymous communication. Using Onion Routing, a host can setup a route to a server through a set of relays and thereby hide its identity. Layered encryption ensures that each hop in the relay network can only decrypt the address of its successor. As this route remains the same until the communication between the two nodes has ended, the connection-based design of today’s Onion Routers enables practical pattern- and timing attacks against users’ anonymity.

In contrast to existing approaches, the MORE project introduced dynamic multipath Onion Routing to extend the static Onion Routing paradigm. This approach allows packets exchanged between two end points to travel along different paths. To provide anonymity the first half of the path is selected by the sender and the second half by the receiver of the packet. The benefits are manifold: (1) dynamic multipath Onion Routing increases the resilience against threats, especially pattern and timing based analysis attacks. (2) the dynamic paths reduce the impact of misbehaving and overloaded relays. (3) inspired by Internet routing, the forwarding nodes do not need to maintain any state about ongoing flows and so reduce the complexity of the router.

---

**Range Queries in Structured Peer-to-Peer Systems**

*Simon Rieche, Klaus Wehrle*

In very large distributed systems, the concept of Distributed Hash Tables is a preferred method for scalable storing and looking up data. Their simple, efficient, scalable, and self-organizing algorithms for data management and lookup offer crucial advantages compared to unstructured Peer-to-Peer- and Client-Server-like solutions. But a major weakness of DHTs is the missing support for unsharp search patterns. For data re-
trieval, the very nature of hash tables allows only exact matches, e.g., a file is stored under \( \text{Hash}(\text{filename}) \) and can only be found by knowing the exact name.

Cerco is a solution for the problem of range queries by employing a hierarchically structured P2P approach based on the principles of DHTs. We propose to use structures like rings of key-value-pairs for the organization of the content. It is similar to a classical DHT technique, however without relying on a regular hash function. Instead, a simple unicode representation of items, grouped and ordered, e.g. by name, will be applied. In high load regions, e.g. for some letter ranges, the system decides on demand to generate hierarchical subrings of a whole region with the same arrangement as in the above layer. We showed that a dynamic hierarchy of DHTs can positively influence the response time of range queries while maintaining lookup correctness.

**Mobility in Distributed Hash-Tables**

*Olaf Landsiedel, Klaus Wehrle*

For the use in the Internet domain, distributed hash tables (DHTs) have proven to be an efficient and scalable approach for distributed content storage and access. We explore how DHTs and mobile ad-hoc networks (MANETs) fit together as both share key characteristics in terms of self organization, decentralization, redundancy requirements, and limited infrastructure. However, node mobility and the continually changing physical topology pose a special challenge to scalability and the design of a DHT for mobile ad-hoc networks. We evaluated that – based on some local knowledge – one can build a scalable and mobile structured peer-to-peer network, called Mobile Hash Table (MHT). Furthermore, our work shows that with little global knowledge, e.g. a map of the city or the area the nodes are moving, one can even further improve the scalability and reduce DHT maintenance overhead significantly; allowing MHT to scale up to several ten thousands of nodes. Similar to Internet based peer-to-peer systems a deployed mobile hash table suffers from suddenly leaving nodes and the need to recover lost data items. We evaluated how redundancy and recovery techniques used in the Internet domain can be adapted to the needs of hash tables in a mobile environment.

**Peer-to-Peer-based Infrastructure Support for Massively Multiplayer Online Games**

*Simon Rieche, Klaus Wehrle* (joint work with Tübingen University)
Massively multiplayer online games (MMOGs) played via the Internet have become very popular in recent years, because they allow thousands of players to share a single game world. Because of consistency, such a world is usually run on a high-performance and high-availability server cluster. However, such infrastructure is inflexible and error-prone and downtimes of several hours are not uncommon. Also, MMOGs are an interesting challenge and chance for the future development of the Peer-to-Peer (P2P) paradigm. A wide variety of aspects are only theoretically solved or completely unsolved. E.g. security and trust problems appear as well as the need to prevent cheating. Consistent data storage is a problem, and decisions and transactions have to be performed in a decentralized way.

Our approach uses structured P2P technology for the infrastructure of MMOGs to improve their reliability and scalability. It can adapt to the current state of the game, handle uneven distributions of players in the map and has the ability to add supplementary nodes at runtime. The game world is split into disjunctive zones in different dimensions and distributed on nodes of a P2P network.

Modular and Platform-independent Communication Protocols

Olaf Landsiedel, Klaus Wehrle

New communication protocols, an increasing number of Internet standards (RFCs) and demanding user needs continuously change the Internet and its communication schemes. Implementing new protocols or just extensions and modifications to existing ones demands a careful evaluation to ensure functionality, scalability, and security. Especially highly embedded systems require flexible and extendable communication systems and paradigms, as from home appliances to airplanes all of them have data processing and communication capabilities. Demanding user expectations and new applications require protocols and networks stacks to provide a minimum of latency and a maximum of throughput and reliability in dynamic environments. To fulfill theses expectations, network stacks have to adapt flexibly and dynamically to changes in the context and new situations by reconfiguring and exchanging components and protocol building blocks. Furthermore, today’s communication protocols need to be implemented on each platform separately, requiring evaluation and maintenance for each implementation. This results in implementation overhead and increases the risk of security leaks. Additionally, the modification and extension of existing protocols is very challenging due to their limited flexibility. This results in long deployment times, high cost and risks as recent developments (IPv6, Multicast and Mobile IP) underline.

In the DFG project MoMenTum the research group develops communication protocols that are composable from functional protocol building blocks. This allows to dynamically reconfigure communication protocols to meet changing application and user
needs. Furthermore, we develop a platform independent abstraction layer, allowing building blocks to be used in various operating systems and network simulators.

**Evaluating Communication Protocols by Coupling and Synchronizing of Evaluation Tools**

*Simon Rieche, Klaus Wehrle*

An important task in the development process of communication protocols and systems is the evaluation of concepts, algorithms, and the final implementation. For the evaluation of communication protocols and systems different types of distinctly used methods exist. Mathematical analysis is used to determine the general behavior of protocols. Simulation attempts to model the participating systems and protocols to study how the system and communication protocols work. However, these models have a lower degree of detail than a operating system in an emulator.

The goal of this project is the design and analysis of a new methodology for analyzing and evaluating communication protocols and systems. By synchronizing the virtual time of various tools (like simulators or virtual machines running a real operating system), we combine the realistic analysis of real systems with the scalable analysis of large simulated systems. For communication, due to the different concepts for network packets pursued by simulations and emulations, a way to convey information between has been developed. So the approach of coupling and synchronizing different tools enables opportunities for studying and analyzing communication systems.

**Analysis of animal ecological and social networks with programmable sensor nodes**

*Jó Á. Bitsch Link, O. Landsiedel, K. Wehrle (joint work with Tübingen University)*

Natural behaviour of animals takes place in complex environments, allowing for a wealth of social and ecological interactions. While laboratory studies have been extremely useful to identify individual mechanisms of behaviour, the functioning of such behaviour in natural environments is still only poorly understood. Efficient means of animal monitoring in the wild as well as tools for modelling complex systems are required for a deeper understanding of phenomena such as spatial cognition, optimal foraging, social behaviour and learning, or multi-species interactions. Current telemetric approaches to animal monitoring are often limited by the range and bandwidth of radio-transmission, especially in large, subterranean, or under-water environments.
In this interdisciplinary project (in cooperation with the Department of Zoology at Tübingen University), we develop a novel system for animal surveillance in the wild, using tiny sensor node technology. Programmable sensor nodes with a multitude of sensing capabilities attached to the animals will record data such as motion, vocalizations, and body temperature of the carrier. Upon encounter of another animal, sensor nodes interact, exchange and aggregate data on the time and participants of the meeting. Stationary base nodes at occasionally visited, but easily accessible locations will be used to collect the animal data for further analysis, including trajectory reconstruction, daily activity profiles, and interaction graphs.

The challenges in terms of communication are the sporadic general connectivity and the lack of continuous end-to-end connections due to the subterranean environment and limited size and carrying capacities of the animals under research. Sophisticated delay tolerant networking schemes have to be devised to meet these challenges.

**Other Activities**

Klaus Wehrle is serving as elected member of the steering committee of the GI/ITG board on “Kommunikation und Verteilte Systeme (KuVS)”.

Klaus Wehrle is active reviewer for several journals, publishers, and boards. In 2006, he also served as a member of the program committees of the following conferences and workshops:

- Sixth IEEE International Conference on Peer-to-Peer Computing (P2P 2006)
- Multimedia Service Composition Workshop (MSC’06) at ACM Multimedia
- IEEE Local Computer Networks 2006 (LCN 2006)
- IEEE International Conference on Communication 2006 (ICC 2006)
- IEEE Consumer Communications and Networking Conference (CCNC 2006)
- International Workshop on Self-Organizing Systems (IWSOS 2006)

The DS Team organized the Dagstuhl Seminar 06131 on “Peer-to-Peer Systems and Applications” together with Prof. Ralf Steinmetz (TU Darmstadt), Prof. Anthony D. Joseph, and Prof. Ion Stoica (both UC Berkeley).

Stefan Götz was invited by Intel Research for a six-months internship in the Intel Research Lab Hillsboro near Portland (OR).

In August 2006, Dr. Andrei Gurтов and Dr. Dimitry Korzun from the Helsinki Institute on Information Technology and from Helsinki Technical University visited our group for some weeks.
In October, Prof. Anthony D. Joseph (UC Berkeley) visited our team for some days.
In November 2006, Klaus Wehrle and Tobias Heer spent a one week scientific visit at the Helsinki Institute of Information Technology.
The DS Team was asked by German Science Foundation (DFG) to represent DFG at the “Summer of Science 2006” (Wissenschaftssommer), one of the major events in the year of Computer Science (Informatikkjahr 2006). Please see a separate report on the event in this book.

** Talks and Publications **

** Talks **


**Publications**


Security Engineering Group

Staff

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

- Research Assistants:
  Dipl. Inform. Tina Kraußer
  Dipl. Inform. Alexander Reinhard
  Dipl. Math. Henning Sudbrock

- Student Assistants:
  Richard Gay
  Corinna Habets
  Ercan Yalvac
Overview

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

We approach this problem from several directions in our research:

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

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

Research Projects

Formal Methods for Security Engineering (FM-SecEng)

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

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

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

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

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

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

Mobius addresses the security problems accompanying the manifold possibilities that originate from increasing mobility and ubiquity. One goal is to guarantee that sensitive information used by a program is not released to untrusted communication partners. This complements traditional security mechanisms such as access control or sandboxing. The use of type systems and verification for the security analysis reduces the burden of checking the security of a downloaded, updated, or dynamically extended application on the mobile device. The Proof Carrying Code (PCC) paradigm imposes the responsibility of securing a program and of providing reliable evidence that security has been achieved onto the developer. The code producer provides not only the code, but also a certificate that helps the code consumer in checking the security of the program as illustrated in the figure below. Different notions of certificates are possible. For instance, certificates can have the form of proofs of the given security property, of tactics that generate such proofs, or of types that can be checked with a type system. This allows the code consumer to easily verify that the program indeed is secure. This is the advantage over using cryptographic certificates where the user needs to trust the developer’s claim about the security of the program.

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

Courses

Summer Term 2006

• Lecture: Formal Methods for Information Security

Winter Term 2006

• Seminar: Formal Methods for Information Security (Advanced Topics)
• Seminar: Quantitative Aspects of Security

PC and SC Memberships

H. Mantel was a PC member of the following conferences:

• European Symposium on Research in Computer Security (ESORICS’06)
• ACM Workshop on Formal Methods in Security Engineering: From Specifications to Code (FMSE’06)
• Information Security Conference (ISC’06)
• ACM Symposium on Applied Computing, Track on Computer Security (SAC’06)
• Verification Workshop (VERIFY’06)

H. Mantel was a member of the steering committee of

• the GI working group Formale Methoden und Software Engineering für sichere Systeme,
• and the VERIFY workshop series.

Talks and Publications

Talks


**Publications**


B. Köpf, H. Mantel: *Eliminating Implicit Information Leaks by Transformational Typing and Unification*, In Revised Selected Papers, Formal Aspects in Security and

A.Reinhard: Analyse nebenläufiger Programme unter intransitiven Sicherheitspoli-
tiken, Diploma Thesis, RWTH Aachen, 2006

S. Autexier and H. Mantel: Verify’06: Verification Workshop, In FLoC, 2006. Work-
shop in connection with Federated Logic Conference, FLoC’06

Study on Comparison Shopping, Journal of Applied Logic (in print)
Information Systems and Database Technology

Staff

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

- Secretary:
  Gabriele Hoeppermanns

  Tel: (0241) 80-21501, Fax: (0241) 80-22321
  E-mail: sekris@i5.informatik.rwth-aachen.de
  WWW: http://www-i5.informatik.rwth-aachen.de

- Researchers:
  Sebastian Brandt
  Yiwei Cao
  Mohamed Amine Chatti
  Aida Jertila (until 14.09.2006)
  David Kensche
  Dr. Ralf Klamma
  Dr. Erika Linz
  Dominik Lübbers
  Michael Miatidis
  Dr. Christoph Quix
  Marcus Raddatz
  Dr. Lemonia Ragia (until 01.06.2006)
  Dr. Marcus Schlüter
• Researchers continued:
  Dominik Schmitz (until 30.04.2006)
  Christian Seeling (until 30.06.2006)
  Marc Spaniol
  Satish Srirama

• Visiting Lecturers:
  Dr. Andreas Becks, Fraunhofer FIT
  Dr. Wolfgang Broll, Fraunhofer FIT
  Jessica Huster, Fraunhofer FIT
  Dominik Schmitz, Fraunhofer FIT (since 02.05.2006)
  Christian Seeling, Fraunhofer FIT (since 01.07.2006)
  Dr. Yehya Mohamad, Fraunhofer FIT

• Technical Staff:
  Tatiana Liberzon
  Reinhard Linde
  Eric Heder

• Student Researchers:
  Anamika Agrawal, Thomas Arzdorf, Martin Bachwerk, Michael Comanns, Dimitar Denev, Tian Gan, Adam Gasior, Marcus Gelderie, Anna Glukhova, Heike Haegert, Zille Huma, Muhammad Ikram, Iliyana Ivanova, Holger Janßen, Euelena Lapi, Yan Leng, Xiang Li, Xuan Li, Andrea Martini, Matthias Moers, Alberto Moyano Sánchez, Nanda Firdausi Muhammad, Negah Nabbi, Takhmina Namozova, Tim Niemüller, Tomas Novotny, Malek Obaid, Achim Passen, Zinayida Petrushyna, Manh Cuong Pham, Monika Pienkos, Johannes Renner, Dominik Renzel, Sebastian Rüschel, Patrick Selders, Leszek Seweryn, Irfan Simsek, Sabrina Steinfels, Bingfeng Wang, Sascha Witte, Onusa Yamcharoen, Edwin Yaqub, Peifang Zhang
Overview

Informatik 5 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 Learning, Database and Repository Technologies, and Requirements Engineering for Complex Systems.

Informatik 5 cooperates closely with the Fraunhofer Institute for Applied Information Technology (FIT) of which Prof. Jarke is Executive Director. Two FIT area managers, Prof. Wolfgang Prinz and Prof. Thomas Berlage, hold cross appointments as Associate Professors in Informatik 5. Prof. Jarke is also one of the Founding Directors of the Bonn-Aachen International Center for Information Technology (B-IT); within B-IT, a third joint professorship has been established and filled with Prof. Thomas Rose.

In September 2006, the Chair of Information Systems celebrated its 15th Anniversary with an international alumni meeting. Presentations by Dr. Matthias Nicola (IBM San Jose) and Dr. Markus Baumeister (Philips Labs Aachen) were followed by the traditional joint dinner at Vaalsbroek Castle.

Other joint activities with FIT include the European Network of Excellence in Technology-Assisted Learning (PROLEARN). Dr. Ralf Klamma of Informatik 5 chaired the highly successful second PROLEARN Summer School with over 45 doctoral students, held in Bled.
Slovenia. Moreover, the group co-organized the second International Symposium on Media Informatics at the B-IT in Bonn, a workshop on Information Systems for Science, Cultural Heritage Management, and e-Government in Afghanistan in Aachen, and a workshop on Mobile Services and Personalized Environments in Aachen.

Two major efforts characterized much of 2006 in Informatik 5. Firstly, as president of the German Computer Society GI, Prof. Jarke served as scientific coordinator of the Informatik-jahr - the Science Year 2006 dedicated to the field of Informatics by the German Ministry of Research. Secondly, Informatik 5 took leading roles in proposals for excellence clusters and graduate schools within the so-called Excellence Initiative of the German government. Prof. Jarke is Area Coordinator “Mobile Applications and Services” in the UMIC Excellence Cluster on Ultra-Highspeed Mobile Information and Communication approved in October 2006, and Coordinator of the BITGRAD Proposal for a Bonn-Aachen International Graduate School for Applied Informatics that has reached the final round for the decision in fall 2007.

33 diploma and master theses were also completed at Informatik 5 in 2006. Carla Valle defended her doctoral dissertation; she is now with the United Nations headquarters in New York. Aida Jertila joined the German Institute of Medical Documentation and Information in Köln. Dr. Ragia followed an offer for a visiting professorship at the University of Toronto and subsequently for a research position at the University of Geneva. Prof. Prinz turned down an offer from the University of Vienna.
Research Projects

Metadata and Cooperative Knowledge Management

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

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 2006, the group worked on the new release 7.0 of ConceptBase which includes several improvements of the user interface, query evaluator, query optimizer, and the active rule engine.

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

Metadata in Community Information Systems

M. Jarke, R. Klamma, Y. Cao, M.A. Chatti, A. Jertila, E. Linz, D. Lübbers,
M. Spaniol, S. Srirama, D. Denev, M. Bachwerk, H. Haegert, I. Ivanova,
H. Janßen, E. Lapi, X. Li, A. Martini, M. Moers, A. Moyano Sánchez,
N.F. Muhammad, N. Nabbi, M. Obaid, Z. Petrushyna, M.C. Pham, M. Pienkos,
D. Renzel, P. Selders, S. Steinfels, O. Yamcharoen

Community information systems are a combination of work practices, information, people, digital media theories organized in a way that they support the goals of the community. Metadata in community information systems stabilize the ongoing change management process in these systems. The research goal of the working group is a better understanding of the creation, use, and maintenance of metadata in the context of community systems. Metadata are based on international standards in different domains like Audio-visual Media, E-Learning, Cultural Heritage, Music Information Retrieval, and Geographical Information Systems. Central for our approach is the reflective conceptual architecture ATLAS which incorporates a set of (self-)monitoring tools for the community members and the repository/community middleware. Communities can assess their community needs and evolve...
the community through the development and change of the community information systems. The monitoring tools allow the measurement, analysis and simulation of community aspects with methods from the semantic web, information retrieval & visualization, data/text/media mining, geospatial database querying, social network analysis, transcripitive algorithms etc.

On the database/repository level we use and develop further scalable state-of-art database technologies for the management of mass data and metadata for community systems. On the middleware level we realize scalable community hosting services like single-login, variable and fine-granular access control, mobility support, multimedia management, multimedia annotation, interoperable search and retrieval, matching, data/text/media mining etc. The following projects have been worked on in the year 2006:

**SFB 427: Media and Cultural Communication: Agency in Digital Social Networks by Visualization of Multidimensional Patterns of Disturbance**

In 2006 the field of research primarily was community and social software. Together with the Chair of Urban History (Prof. M. Jansen) we researched on a community driven information system called ACIS to preserve the cultural heritage in Afghanistan. In order to understand the impact of media on intercultural learning better, the non-linear multimedia story-telling environment called MIST has been developed. Again, this project was developed in transdisciplinary cooperation together with Prof. Nalin Sharda (Victoria University Melbourne, Australia) and Prof. Jörg Schönert (Forscherguppe Narratologie, University of Hamburg). Recent research results were presented at international conferences such as I-Know, ICWL, ICALT, and EC-TEL. In parallel, we established an MPEG-7/21 community that brings together leading researchers from across Europe and industry partners (e.g. T-Systems and Siemens). We hosted and co-organized the Workshop on Information Systems for Science, Cultural Heritage Management & e-Government in Afghanistan (WSAF ’06) in February in Aachen and the 2nd International Symposium in Media Informatics “Cow Paths: Agency in Social Software” (MI2 ’06) in November in Bonn.

Further interdisciplinary research in the context of SFB 427 is dedicated to the effects of mobile communication technology and the internet on communicative behavior and interpersonal relationships. The research focuses on how wireless technology extends and reconfigures the individual peripersonal space and alters the patterns of personal interactions. In collaboration with linguists, neurolinguists and psychologists from the research project “Semiological agency” (A1) it explores media induced transformations of communication and social interaction order.

**SunSITE Central Europe**

Since 1995, Informatik 5 is active in the field of internet-based community support, both in terms of research on community and web service tools and in terms of providing infrastructures for scientific communities worldwide. For example, Informatik 5 hosted the first website for the city of Aachen in 1995 and, since the same year, manages one of the most successful public-domain internet servers in the German science net, SunSITE Central Europe. Supported by Sun Microsystems with powerful hardware and base software,
SunSITE Central Europe 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 around 10 million accesses per month.

**AdMIRE: Advanced Music Information Retrieval Environment**

In this project we investigate the use of metadata technology for the development of intelligent music information retrieval systems. Our goal is the integration of retrieval approaches for different kinds of media (like e.g. text retrieval algorithms for lyrics databases and customized similarity functions for signal processing-based audio features) with a user-friendly interface.

In 2006 we primarily concentrated on the further development of an exploration environment for personal music collections that allows the user to walk through a virtual environment of sounding music where the pieces are placed according to a Self-Organizing-Map that represents their audio-based similarity.

**Mobile Web Service Provisioning**

Intelligent phones as web service provider is the topic of a doctoral thesis in cooperation with Ericsson Eurolabs done in the context of the Graduate College “Software for Mobile Communication Systems”. A number of results concerning aspects of service discovery, mediation, security and testing strategies for mobile web service providers were published.

---

**UMIC: Ultra High-Speed Mobile Information and Communication**

*M. Jarke, C. Quix, R. Klamma, Y. Cao, D. Kensche, E. Lapi, M.C. Pham, M. Jansen (Sbg), G. Toubekis (Sbg)*

The “Ultra High-Speed Mobile Information and Communication (UMIC)” is a research cluster under the German Excellence Initiative promoted by the German Federal and State Government at German Universities. UMIC is the only Excellence Cluster fully dedicated to the field of information and communication technology approved in the first excellence competition in 2006.

More than 20 institutions at RWTH Aachen are participating in UMIC, aiming at interdisciplinary design of ultra high-speed mobile information and communication systems. Concepts and demonstrators for smart, mobile, broadband, low-cost systems will be developed with support the demanding applications of the next-decade mobile Internet.

Building on previous work in SFB 427 and in the GK “Software for Mobile Communication Systems”, Informatik 5 works closely together with many institutes of electrical engineering, mechanical engineering, architecture, and computer science in two subprojects in the research area of “Mobile Application and Services” which is coordinated by Prof. Jarke. This research area focuses on mobile multimedia processing and environmental information processing. Two subprojects have started in 2006.
Future Mobile Internet Services
The mobile communication and applications’ impacts in developing countries such as Afghanistan and Somalia will be paid special attention. The related scenarios as well as requirements will be analyzed.

The first scenario of Virtual Campfire as mobile social software has been proposed to bridge media and communities via mobile platforms. In Virtual Campfire cultural heritage information collected from developing countries is to be integrated into a multimedia non-linear digital storytelling system for communities. The concept was successfully demonstrated at the 5th UNESCO / ICOMOS Expert Working Group for the Preservation of the Bamiyan Site in Aachen in December. We also established a Bamiyan Community (http://www.bamiyan-development.org) that brings together international researchers and governmental and administrative officers who are involved in the conservation work in Bamiyan, Afghanistan. More activities of seminars and events are in plan, e.g. the UMIC will be presented at the CeBIT 2007.

Mobile and Wearable P2P Information Management in Health Net Applications
Informatik 5 cooperates with the institute for textile technology (ITA) and the Philips Chair for Medical Information Technology (MEDIT). The aim is to develop a P2P network in which patients, doctors, nursing staff, and emergency services have full access to information and services in their mobile work environment. Data about the health status of a patient is collected by a network of sensors integrated in the textile clothes. The data can be
reviewed by doctors to consult the patients online, or by the emergency service to improve the diagnosis in an emergency situation. The task of Informatik 5 is to model the data which is exchanged in this setting; thereby enabling the automatic integration and exchange of the data. For this purpose, techniques developed in the context of model management have to be adapted to multidimensional data and data streams.

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

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

In winter term 2004/2005 the first students were enrolled in this pan-European master programme jointly executed with the universities of Trento and Edinburgh. In three different areas of specialisations, Net-Centric Computing, Embedded Systems, and Lifescience Informatics, students are trained at two of the universities to get a double degree in computer science. The programme is accompanied by a scholar programme to bring world class lecturers from different parts of the world to Aachen. First students finalized their studies in 2006, in some cases with excellent master theses with refereed publications resulting from them.

**PROLEARN: EU Network of Excellence**

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

PROLEARN, started January 1, 2004, is dedicated to join research in the area of professional learning and training focusing on small and medium enterprises (SME). The NoE advances the state of the art in the key areas personalized adaptive learning and interactive media, with learning resources connected to real-world settings and reusable in different contexts. It investigates and advances issues especially relevant for professional training in SME’s and larger companies, including brokerage platforms and services, business models for specific markets, and advanced eLearning and knowledge work management arrangements.

Recent research results were presented at international conferences such as I-Know, ICALT, ICWL, and EC-TEL. The concept “Learning as a Service” was successfully demonstrated on IST Conference & Exhibition in Helsinki in November, 2006. The PROLEARN Academy Portal (http://www.prolearn-academy.org/) employs Web 2.0 technologies and serves a large user communities.
As a major event the chair co-organised the PROLEARN summerschool 2006 in Bled, Slovenia, from June 5-9. The summerschool brought together PhD students, teachers, academics and industry people for PhD training, entrepreneurial activities, and network events. More than 45 PhD students have successfully attended the summerschool in 2006.

In the ProLearn project, the concept “Learning as a Service” (LAS) was successfully demonstrated on IST Conference & Exhibition in Helsinki in November, 2006.

CUELCE: EU Tempus Cairo University E-Learning Centre

M. Jarke, R. Klamma, Y. Cao, M.A. Chatti, A. Jertila, D. Kensche, M. Spaniol, A. Moyano Sánchez, M. Obaid, M. Fayek (Cairo University), K. Maillet (INT Evry)

CUELCE aims to bridge the currently existing gap between the advanced, technology enhanced teaching and learning methods in Europe and Egypt. These advanced teaching methods should enhance the Cairo University teaching staff skills, provide better feedback facilities on students’ performance, and afford continuous fruitful monitoring. Moreover, the WBT environment allows interaction between students and makes student-student and student-teacher synchronous and asynchronous communication possible. Offering learning on demand, and life long learning possibilities to everybody is also an advanced goal of the centre. Besides, we plan to use the proposed
E-Learning centre with the already existing one in Aachen University of Technology to
design an intercultural virtual campus, thus bringing together students from different
cultures and giving them the opportunity to exchange their experiences in the area of
technology enhanced learning.

### MErKoFer

*Identification and Reuse of Experience Knowledge in Rubber Extrusion Processes*

*M. Jarke, M. Schlüter, M. Raddatz, S. Brandt, T. Namozova, I. Simsek, S. Witte*

Building on basic research results achieved in SFB 476, MErKoFer is a collaborative
project of Informatik 5 and aiXtrusion GmbH in cooperation with Meteor Gummiwerke K.H. Bädje GmbH & Co. KG. The project is supported by the Bundesministerium für Bildung und Forschung (BMBF). The project has been funded in its initial phase till September 2006, and has been extended until June 2007 to investigate additional aspects of integrated production process analyses.

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

After determining the most influential process parameters and applying explorative data mining methods to identify interrelations and temporal dependencies, we correlate product flaws and the according process states. By recording the operator’s actions and evaluating their efficiency, we are able to construct an experience knowledge base. When another problem occurs, we can provide decision support for operators by supplying a number of previously taken actions and an evaluation of their respective efficiency to correct anomalies in a similar context. Based on this additional information the chance to compensate interferences in the production process is significantly increased.

### SFB 476 IMPROVE

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

*M. Jarke, M. Miatidis, S. Brandt, M. Schlüter,
M. Comanns, M. Ikram, A. Passen, J. Renner*
The collaborative research center (CRC) SFB 476 IMPROVE was funded from July 1997 until June 2006 by the Deutsche Forschungsgemeinschaft (DFG), and aimed at improving the early design phases in chemical and plastics engineering. During the last phase of the CRC in 2006, the research focused on the aspects of cooperative work and synergetic interleaving. In this context, Informatik 5 conducted research in the context of two subprojects.

In the subproject “experience-based support for cooperative engineering processes” (B1), the research concentrated on the direct, experience-based support of developers during creative design processes. The followed approach was based on the key idea of a-posteriori process integration of tools that offers the potential for integrated method guidance and traceability. Moreover, further research was conducted towards fine-grained cooperative and reuse aspects of the design.

In the subproject “goal-oriented management of information flows in engineering design processes” (C1), a process data warehouse was contributed as an ontology-oriented infrastructure for semantic access to product and process experience data. The research focused on supporting interdisciplinary design processes that involve inter-organizational cooperation between the domains of chemical and plastics engineering.

---

**TROPOS and ZAMOMO – 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 Focused Research Programme on Socionics, jointly conducted with the KBS group of Prof. Lakemeyer and the network sociology group of Dr. Funken, and has been further expanded in the context of the DFG-funded Graduate School 643 “Software for mobile communication systems”. It aims at improving requirements engineering for such networks by not just representing their goals and dependencies statically, but also by studying the dynamic interactions between both (esp. trust) via agent-based simulation through our SNet prototype environment.

This work has been continued in the context of three diploma/master theses in 2006. Hakan Karanfil investigated the role of network rules and proposed modelling means to capture them explicitly in the i* formalism. Another important aspect, distrust-based monitoring, has been addressed by Andreas Kneifel and results in an extension of the modelling as well as an extension of the agents’ planning capabilities. Aristama Roesli has looked at the dynamic evolution of actors in such a network at run-time and proposed means to prescribe their paths of evolution in order to reflect real world
behaviour. Further research compared similarities and differences of our approach to other i* related analysis formalisms.

The experiences and results that have been gathered within these activities, especially with the i* modelling framework and the simulation capabilities, are now transferred to a new project, ZAMOMO, located with the Fraunhofer FIT and addressing the integration of model-based software and control engineering in the construction of automotive engines. i*/TROPOS serves here as a common platform for capturing software and control requirements considering an electronic engine control unit as the application example.

Zentrum für Softwarekonzepte

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

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

Informatik 5 works closely together with Fraunhofer FIT in this project. The main activities in 2006 included presentations at several events such as CeBIT, “Tag der Innovationen” in Berlin, and “Tag der Informatik” in Aachen. A website with documents on .NET technologies has been created. The website contains also the “Informatiklandkarte” on which the computer science research institutions in Germany and the events of the “Informatikjahr 2006” are geographically displayed. Furthermore, an outline of a seminar about the new features for online collaboration of the new Office system has been defined. In addition, Informatik 5 offered a lab course for the development of web services based on .NET.
Other Activities

Service

Prof. Jarke’s major administrative and service activities in 2006 included:

• Executive Director, Fraunhofer FIT, Birlinghoven
• Deputy Chairmen, Fraunhofer Group Information and Communication Technology
• Founding Director, Bonn-Aachen International Center for Information Technology (B-IT)
• Coordinator, BITGRAD Graduate School Proposal
• President, GI German Informatics Society (re-elected for 2006-2007)
• Scientific member, steering council Informatikjahr - Science Year 2006
• DFG elected reviewer for practical computer science
• member, Working Group “Hightech Strategy for the Information Society”, First Nationale IT Summit of Chancellor Merkel, Potsdam
• member, extended management board of FfR e.V. at RWTH Aachen
• Scientific advisory board, Faculty of Informatics, University of Vienna, Austria
• Scientific advisory board, Learning Lab Lower Saxony (L3S), Hannover
• Scientific Advisory board (Chairman-Elect), OFFIS, Oldenburg
• Scientific advisory board, Beta Research School, Eindhoven/Twente, Netherlands
• Scientific advisory board Computer Science, Free University of Bozen, Italy
• Scientific review board, CIS/IM Department, Tilburg University, Netherlands
• Scientific review board, Enterprise Software Initiative Baden-Württemberg
• Supervisory, curatory and scientific advisory board, IBFI, Schloss Dagstuhl
• Jury member, Wissenschaftspreis Stifterverband der Deutschen Wirtschaft
• External Reviewer, Habilitation Thesis Veronique Heiwy, Université Paris V René Descartes

Besides his role as scientific coordinator in the steering committee of Informatikjahr 2006, Prof. Jarke participated in about seventy public events and gave numerous interviews to TV and radio stations as well as almost all the leading newspapers and popular-science journals (iX, c’t, CHIP, Computer Zeitung, etc.) in the country.

Dr. Klamma is a substitute member of the PROLEARN executive board. Dr. Klamma served as advisor of the ERASMUS Mundus master programme European Master in Informatics (EuMI).

Y. Cao is member of DIN NI-32 “Data management and data exchange”.

Editorial Boards

M. Jarke served on the following editorial boards:

• Decision Support Systems
• Requirements Engineering Journal
• Organizational Computing and Electronic Commerce
· Intelligent Information Systems
· Group Decision and Negotiation
· International Journal of IT Standards and Standardization Research

W. Prinz served on editorial boards:
· CSCW Journal, Kluwer
· i-com Zeitschrift für Interaktive Medien, Oldenburg

Conference Organization


W. Prinz served as programme committee member for the following conferences and workshops: M&C 2006 - Mensch und Computer 2006; ICE 2006 - 12th International Conference on Concurrent Engineering; UMICS 2006 - Ubiquitous Mobile Information and Collaboration Systems; CollaborateCom 2006; CWE 07 - Collaborative Working Environments; COOP06 - 7th International Conference on the Design of Cooperative Systems; SemDesk 2006 - Semantic Desktop and Social Semantic Collaboration Workshop; Pragmatic Web 2006; MDM 2006 - The 7th International Conference on Mobile Data Management. He was also reviewer of CHI 2006 and CSCW 2006.

Y. Cao was co-organizer of the Workshop on “Information Systems for Science, Cultural Heritage Management & e-Government in Afghanistan”, Aachen, Germany, February 17, 2006.

R. Klamma was co-chair of the following events: workshop on “Information Systems for Science, Cultural Heritage Management & e-Government in Afghanistan”, Aachen, Germany, February 17, 2006; 2nd International Symposium in Media Informatics: “Cow Paths: Agency in Social Software”, B-IT, Bonn, Germany, November 16-17, 2006; 2nd PROLEARN Summer School 2006, Bled Slovenia, June 5-9, 2006; PROLEARN/ICAMP Workshop on Social Software for Professional Learning at the EDEN’06, Vienna, Austria, June 14, 2006; Future of e-learning track at PTF’06, Stuttgart, Germany, November 15, 2006; Doctoral Consortium of the First European
Conference on Technology Enhanced Learning (EC-TEL 2006), Crete, Greece, October 1-4, 2006. He serves as associate editor on IJASS, IJTEL, and IJHSC and for special issues of JUKM, JIME, JISG, and IJCHB. He served as programme committee member / reviewer for the following conferences and journals: EC-TEL’06, WBC’06, KVD’06, I-Know MPEG-7 Community Workshop 2006, TenComptence Workshop 2006, MDSGEO’06, PCEL’06, ICALT’06, CAMA’06, SITIS’06, Informatik’06 Workshop SNSSA, PTF’06, IMSA’07, WEBIST’07, C&T’07, BTW’07, BIT, CACM, IEEE Multimedia, IEEE TKDE, Electronic Commerce Journal, i-Com.

E. Linz was co-organizer of the 2nd International Symposium in Media Informatics: “Cow Paths: Agency in Social Software”, B-IT, Bonn, Germany, November 16-17, 2006. She co-chaired the international workshop “Free will and social cognition” hosted by the Kurt-Schumacher-Akademie, Friedrich-Ebert-Stiftung, Bad Münstereifel, Germany, June 12-14, 2006.

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

M. Spaniol was co-organizer of the 2nd International Symposium in Media Informatics: “Cow Paths: Agency in Social Software”, B-IT, Bonn, Germany, November 16-17, 2006 and the Workshop on “Information Systems for Science, Cultural Heritage Management & e-Government in Afghanistan”, Aachen, Germany, February 17, 2006. He was member of the programme committee of the JUKM Special Issue of the Multimedia Metadata Community, the 5th International Conference on Web-based Learning (ICWL 2006), Penang, Malaysia, July 19-21, 2006, the I-Know’06 Special Track on “Advanced Semantic Technologies” (AST’06), Graz, Austria, September 6, 2006 and the I-Know’06 “Multimedia Metadata Community Workshop” (MMC’06), Graz, Austria, September 7-8, 2006.

S. Srirama was co-organizer of the First International Workshop on Mobile Services and Personalized Environments (IWMSPE “06), Aachen, November 16-17, 2006.

**Software Demonstrations**

- LAS MPEG-7 Services in Community Engines, Graz, Austria, September 7, 2006.
- Virtual Campfire, IST Conference & Exhibition, Helsinki, Finland, November 21-23, 2006.
Talks and Publications

Talks

T. Berlage: *Life Science Informatik für die Systembiologie*, Kolloqium, Universität Düsseldorf, Klinik für Gastroenterologie, Hepatologie und Infektiologie, May 12, 2006

T. Berlage: *High Content Image Analysis*, High Content Analysis Europe, Vienna, Nov. 8, 2006

T. Berlage: *High Content Analysis for Systems Biology Research*, University Bonn, Life & Brain, Nov. 11, 2006


Y. Cao: *Spatiotemporal Thematic Maps for Sustainable Development of Heritage Site Tourism*, InterCarto - Inter GIS 12 International Conference on Geoinformation for Sustainable Development, Berlin, Germany, August 28-30, 2006


H. Janßen, D. Denev: *MPEG-7 Services in Community Engines provided by a Lightweight Application Server (LAS)*, 5th Multimedia Metadata Community Workshop, Graz, Austria, September 7, 2006


211

M. Jarke, P. Federer: *Informatikjahr 2006*, GI Fellows Meeting, Bonn, March 5, 2006


M. Jarke: *Deutschland - Land der Ideen*, Award Ceremony for Fraunhofer Center Birlinghoven Castle Open Day, March 17 and May 4, 2006


M. Jarke: *IT Research Perspectives in Germany*, Colloquium “IT: From New Economy to Catalyst of Old Economy” on the Occasion of the retirement of Dennis Tsichritzis, Birlinghoven Castle, May 16, 2006


M. Jarke: *Laudatio*, Colloquium on the Occasion of the 60th Birthday of Armin B. Cremer, Bonn, June 7, 2006

M. Jarke(chair), R. Laleau, R. Wilton, J. Mylopoulos, A. Sutcliffe, V. Kritis, L. Constantine: *The different facets of trust in information systems*, Panel Discussion at CAiSE 2006, Luxembourg, June 7, 2006


212
M. Jarke: *Grusswort des GI-Präsidenten*, Symposium 10 Jahre FH Bonn-Rhein-Sieg, October 24, 2006


M. Jarke: *Informatik als Innovationsmotor*, Opening Keynote, Tag der Informatik, University of Passau, November 17, 2006


M. Jarke: *Das Informatikjahr 2006 - Outsourcing und Offshoring in Deutschland*, IBM Outsourcing Conference, IBM Training Center Herrenberg, November 22, 2006

M. Jarke, A.B. Cremers, K.-U. Witt: *Director’s Report Bonn-Aachen International Center for Information Technology (B-IT)*, Scientific Advisory Board Meeting and B-IT Endowment Board Meetings, B-IT Bonn, November 22-23, 2006

M. Jarke: *Das Fraunhofer-Institut für Angewandte Informationstechnik FIT*, Presentation to MIWFT, Birlinghoven Castle, December 5, 2006

M. Jarke: *Informatik im Alltag - Droht die digitale Spalung der Gesellschaft?*, Seniorenstudium, RWTH Aachen, December 6, 2006


M. Jarke et al.: *Working Group Hightech-Strategie für die Informationsgesellschaft*, German IT Summit, Potsdam, December 18, 2006


M. Jarke: *Research at Fraunhofer FIT*, Presentation to Research Subcommittee, City of Bonn, Birlinghoven Castle, December 20, 2006


D. Kensche: *Mobile Web Services for Collaborative Learning*, 4th International Workshop on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE 2006), November 16-17, Athens, Greece, 2006


214
R. Klamma: PROLEARN Academy, PROLEARN Annual Review, Hannover, Germany, March 22, 2006


R. Klamma: Community and Organizational Content Creation: Semantic Zapping and Story Telling, PROLEARN Summer School 2006, Bled, Slovenia, June 8, 2006

R. Klamma: Social Software for Professional Training: Research and Development Perspectives, Keynote at PROLEARN/ICAMP Workshop on Social Software for Professional Training, TU Vienna, Vienna, Austria June 14, 2006

R. Klamma: Social Software und Community Informationssysteme, Invited Talk at Vienna University of Economics and Business Administration, Vienna, Austria, June 16, 2006

R. Klamma: Technology Enhanced Learning: Outreach to Industry and Academia, National College of Ireland, Dublin, August 18, 2006

R. Klamma: Virtual Entrepreneurship Lab 2.0: Sharing Entrepreneurial Knowledge by Non-Linear Story-Telling, I-Know 2006, Graz, Austria, September 7, 2006

R. Klamma: PALADIN: A Pattern Based Approach to Cross-Media Analysis in Digital Social Networks, I-Know 2006, Graz, Austria, September 7, 2006


R. Klamma: Pattern-Based Cross Media Social Network Analysis for Technology Enhanced Learning in Europe, EC-TEL’06, Crete, Greece, October 3, 2006

R. Klamma: Community Aware Content Adaptation for Mobile Technology Enhanced Learning, EC-TEL’06, Crete, Greece, October 4, 2006

R. Klamma: Social Software in Professional Training, PROLEARN General Assembly, Crete, Greece, October 5, 2006

R. Klamma: What is happening in the long tail? Reliable technologies for communities, Sixth Internet Next Generation Workshop: Web 2.0, Internet 2.0, online, October 18, 2006


E. Linz: Intentionality, International Workshop “Free will and social cognition” hosted by the Kurt-Schumacher-Akademie, Friedrich-Ebert-Stiftung, Bad Münstereifel, Germany, June 12-14, 2006

E. Linz: Mobilkultur. Das Handy als Cyborg-Technologie, Kolloquium des SFB/FK 427, Cologne, November 14, 2006

W. Prinz: Social Software - Eine neue Kategorie erobert das Internet, REGINA e.V. Management Treffen, Aachen, May 17, 2006


W. Prinz: Pervasive Games, IuK Summit “Mehr als Entertainment: Mit Technologie spielen”, Berlin, October 6, 2006


W. Prinz: Augmented Reality Anwendungen, Eröffnungsvortrag zur Innovationsausstellung der Bayer Business Services, Köln, November 9, 2006


C. Quix: Model Management using a Generic Metamodel, Invited Talk, Tilburg University, Netherlands, November 7, 2006

M. Raddatz: Identification and Reuse of Experience Knowledge in Continuous Production Processes, 9th IFAC Symposium on Automated Systems Based on Human Skill and Knowledge, Nancy, May 22-24, 2006


D. Schmitz: The TCD/SNet Approach: A Modeling and Simulation Environment for Trust-Based Inter-Organizational Networks, EXYSTENCE Topical Workshop: Trust-Based Networks and Robustness in Organisations, Zurich, Switzerland, March 15, 2006

D. Schmitz: Comparing TCD/SNet with two other formal analysis approaches based on i*: Formal Tropos and Secure Tropos, Workshop on Agent-Oriented Information Systems (AOIS), Luxembourg, June 6, 2006


M. Spaniol: PALADIN: A Pattern Based Approach to Knowledge Discovery in Digital Social Networks, Conference I-KNOW ’06, Graz, Austria, September 6, 2006

M. Spaniol: Community Hypermedia in Collaborative and Self-reflective E-learning Applications, Conference EC-TEL 2006, Hersonissou, Greece, October 1, 2006

S. Srirama: Mobile Web Service Provisioning, Graduiertenkolleg “Software für mobile Kommunikationssysteme”, April 26, 2006

S. Steinfels: Cross Media Social Network Analysis for Innovation Management, Informatik 2006 Workshop Social Networks in Social Software Applications, Dresden, Germany, October 6, 2006

Publications

Books and Edited Volumes


C. Valle: Decision Follow Up Using Task Management and Semi-Structured Messages, Dissertation, the Faculty of Mathematics, Informatics and Nature Science at RWTH Aachen University, Germany, 2006

Journal Articles


217


M. Spaniol, R. Klamma, L. Springer, M. Jarke: **Aphasic Communities of Learning on the Web**, International Journal of Distance Education Technologies (JDET), Vol. 4, No.1, 2006, R. Lau and F. Li (Eds.): Special Issue: Advances in Web-Based Learning, pp. 31-45


**Conference and Book Contributions**


218


M. A. Chatti, S. Srirama, D. Kensche, Y. Cao: Mobile Web Services for Collaborative Learning, in Proceedings of the 4th International Workshop on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE 2006), November 16-17, Athens, Greece, 2006


D. Schmitz, G. Lakemeyer, M. Jarke: *Comparing TCD/SNet with two other formal analysis approaches based on i*: Formal Tropos and Secure Tropos*, In Proceedings of the 8th Workshop on Agent-Oriented Information Systems, AOIS @ CAiSE, Luxembourg, June 2006


S. Srirama, M. Jarke, W. Prinz: *Mobile Host: A feasibility analysis of mobile Web Service provisioning*, 4th International Workshop on Ubiquitous Mobile Information and Collaboration Systems, UMICS 2006, a CAiSE’06 workshop, June 5-6, 2006


**Other Publications (Selection)**


M. Jarke: *Wir stehen am Anfang einer Innovationswelle (Interview)*, Der Spezialist, June 2006, pp.14-17


M. Jarke: *Informatik bleibt Innovationsmotor Nr. 1*, InnoVisions 4/2006, pp. 73

M. Jarke, R. Klamma, M. Spaniol: *Internet-Kooperation verändert die Kulturwissenschaften*, RWTH Themen, RWTH Aachen, Sommersemester, 2006, pp. 10-11

222
Knowledge-Based Systems & Cognitive Robotics Group

Staff

- Associate Professor:
  Univ.-Prof. Gerhard Lakemeyer, Ph. D.
e-mail: lakemeyer@informatik.rwth-aachen.de
www: http://kbsg.rwth-aachen.de/

- Secretaries:
  Gabriele Hoeppermanns
  Phone: +49 241 80 21501
  Fax: +49 241 80 22321
e-mail: sekris@i5.informatik.rwth-aachen.de

- Research Assistants:
  Dipl.-Inform. Daniel Beck
  (since October 2006)
  Dipl.-Inform. Laurent Calmes
  (funded by DFG)
  Dipl.-Inform. Jens Claßen
  (funded by DFG)
  Dipl.-Inform. Alexander Ferrein
  (funded by DFG)
  Dipl.-Inform. Stefan Schiffer
  (since February 2006, funded by DFG)

- Student Researcher:
  B. von Eicken, M. Liebenberg, C. Mies,
  T. Niemüller
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.

As part of our own research in Cognitive Robotics we are concerned with the development of logic-based languages suitable for the high-level control of mobile robots, and their embedding into robotic systems. 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. In a recent project funded by the German Science Foundation (DFG) and in collaboration with the University of Freiburg, we are investigating the integration of Golog with state-of-the-art planning systems. In another DFG-funded project, we are applying our techniques to the control of robots in highly dynamic domains like robotic soccer and, more recently, in home-robot scenarios, where the interaction with humans plays an increasing role. In this context, we are also working on methods for sound-source localization, in collaboration with Prof. Wagner from Biology and funded by DFG. Last but not least we are also actively engaged in designing and building robots, together with the necessary low-level control software.
Research Projects

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

Alexander Ferrein, Gerhard Lakemeyer

The goal of this project is to develop a deliberative component supporting coordinated actions of multi-robotic systems under real-time constraints, using robotic soccer as a benchmark application. This project is part of the research initiative “RoboCup” (SPP 1125) funded by the German Science Foundation. The basis for the deliberative component to be developed in this project is the logic-based action language Golog, which was initially conceived at the University of Toronto. Golog has been extended within our group in recent years and applied successfully to the control of mobile robots in office environments and museums.

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

To validate our approach in the framework of RoboCup, we apply it to both the simulation league and real robots in the so-called mid-size league, using our soccer robots which we built in 2002 with a grant of the NRW Ministry of Education and Research and in collaboration with the Department of Electrical Engineering (Prof. Kraiss). Moreover, we evaluated our approach not only in the soccer domain, but also showed its usefulness for the encoding of computer players (so-called game bots) in interactive computer games like UNREAL Tournament 2004.

In 2006, we participated at the European Championships “RoboLudens” in Eindhoven, The Netherlands, and at the RoboCup World Championships in Bremen, Germany. In Bremen we attended in the leagues 3D simulation, Middle-size, and RoboCup@Home, a new service robotics league. In this league we were able to win the 2006 World Championships. More information about our participation at RoboCup@Home are given in Section “Cognitive Service Robotic Systems and Applications”. For 2007 we started to develop a new soccer robot platform with a grant from the Bonn-Aachen Institute of Technology which is specialized for the soccer task. The mechanical development is undertaken in cooperation with the Institute for Engineering Design.
The research areas of the Knowledge-based Systems Group are Knowledge Representation, Reasoning, and as an application Cognitive Robotics. One of our aims is to develop intelligent mobile robot platforms. With a funding from the German National Science Foundation (DFG) in the Priority Program “Cooperative multi-robot teams in highly dynamic domains” and the Ministry for Science of North-Rhine Westphalia, Germany (MSWF) we developed five robots and participate in RoboCup Championships with these robots for several years now. RoboCup is an international research initiative to foster research and education in the field of artificial intelligence and robotics. The common problem is to develop autonomous soccer playing robots (www.robocup.org).

The scope of the RoboCup initiative has gotten much broader in recent years. It now also covers the design of robots to rescue people from urban disaster areas in the RoboCup-Rescue leagues or the development of service robots in the RoboCup@Home league. The task of robots in the latter domain is to help people in a home-like environment with fulfilling tasks of everyday life.

The “AllemaniACs” RoboCup Team participates in the soccer competitions for several years. We also participated in the first RoboCup@Home Challenge this year and we
won the World Championship in this league. Important tasks in the @Home domain are to localize oneself in the home environment, not to collide with anything in the apartment, and to interact with humans living in it (human-machine interaction). The specific tasks in this years competition were to safely navigate through the environment and visit several distinct places, to follow a human through the environment, and a so-called free challenge, where our robot sought a beer box and brought it to the referees sitting in the living room watching the FIFA world championship.

To be able to successfully participate in the RoboCup@Home league we adapted our robot system. The basic components of the robot system were designed in such a way that they could be used in the new scenario without substantial modifications. It was our laser-based localization following a Monte Carlo approach and a very robust collision avoidance and navigation module that provided us with a stable basis to move from the soccer field to the home-like environment. In fact, both these modules work even better in more structured environments and with lower speeds than in the soccer domain. A map building tool which allows for semantic annotations of maps used for localization and navigation was developed. The annotations are available throughout the whole system and especially for the human machine interface. By adapting our ball recognition to other shapes and colors we were also able to detect other objects in the home environment.

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

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

The aim of this work is to equip a mobile robot with a method of sound source localization by using biologically inspired algorithms. The Jeffress model has been a fruitful scheme for understanding the representation of inter-aural time difference as an azimuthal sound-localization cue. As an improvement over previous work, we used the complete three-dimensional coincidence map for determining the azimuth of a sound source. A first implementation of the algorithm on the mobile robot Carl has been completed with promising results. Localization of broadband sound sources could be achieved with excellent precision. Localization of low frequency, narrowband signals is less than satisfactory. This was initially ascribed to the acoustical characteristics of the microphone mount. With the help of acoustic room simulations conducted in 2006, we could show that the inferior performance for low-frequency, narrowband signals is not caused by the microphone mount and neither by the algorithm, but by room reverberations. We integrated a sound localizer based on inter-aural level differences as well as an attention module with the current system. Furthermore, a beamformer module was developed which allows spatial filtering, i.e., sounds coming from a given direction can be enhanced while all other directions are attenuated. A first attempt was made at combining laser-based object recognition and sound localization on one
of the RoboCup robots. We are currently working on more sophisticated methods for exploiting these two sensor modalities. Specifically, a Markov Chain Monte Carlo-based tracking algorithm is in the process of being implemented, which will make it possible for the robot to track dynamic objects emitting sounds (e.g. humans) over time. In combination with the beamformer, this system can act as a front end for speech recognition, by enhancing speech signals from the direction of a human, on which the robot’s attention is focused.

**PLATAS – Planning Techniques and Action Languages**

*J. Claßen, G. Lakemeyer, B. Nebel*, G. Roeger*

*(University of Freiburg)*

Although there is a common origin, research on automated planning on the one hand and action logics on the other hand developed rather independently over the last three decades. This is mainly due to the fact that work on action languages was concerned with formalisms of high expressiveness, whereas for planning methods, the focus had to lie on computational efficiency, yielding input languages with less expressive possibilities. However, one can observe that during the last few years, the two separate fields began to converge again. Exemplary for this trend is the development of the planning domain definition language PDDL, which extends simple STRIPS-based planning by features such as conditional effects, time, concurrency, plan constraints and preferences, and which virtually constitutes a standard in the field of planning.

This DFG-funded project is conducted in cooperation with the Research Group on the Foundations of Artificial Intelligence of Bernhard Nebel at the University of Freiburg. It aims at integrating latest results in the areas of both action languages (in particular, Golog) and planning techniques (in particular, PDDL-based planners like Hoffmann and Nebel’s FF) to acquire systems that are both expressive and efficient. For this purpose, we are on the one hand working on establishing a common semantical basis for both Golog and PDDL in the situation calculus. Results in this direction have been achieved for certain fragments of PDDL (including ADL, time and concurrency) and will be extended in the course of the project to eventually cover the full scope of the language. On the other hand, expressiveness is studied by means of compilation schemes; corresponding fragments of both formalisms with the same expressive power have thus already been identified. This work will provide the foundation for embedding state-of-the-art planning systems like FF in Golog (which is beneficial in terms of the system’s runtime, as first experiments have shown) and enhancing planners with Golog relevant features such as time, concurrency and continuous actions, yielding in both cases systems that are both efficient and expressive.
Other Activities

Best Paper Award
Gerhard Lakemeyer and Hector Levesque received a best paper award at the American National Conference on Artificial Intelligence for their paper “Towards an Axiom System for Default Logic.”

Program Committees
Gerhard Lakemeyer was Program co-Chair of the International Robocup Symposium and a PC member of the European Conference on Artificial Intelligence and the International Joint Conference on Artificial Intelligence, among others. He ended his term as Associate Editor of the Journal of Artificial Intelligence Research and became a member of the Advisory Board of this journal.

Research Visits
As part of his sabbatical, Gerhard Lakemeyer visited the University of New South Wales in Sydney (January–March), where he collaborated with Maurice Pagnucco. During his visit he gave invited talks in Sydney and Adelaide. In September he visited Prof. Hector Levesque at the University of Toronto, Canada, where they wrote a paper on a new variant of the situation calculus. In October he visited China at the invitation of China Aerospace with invited talks in Beijing and Xian.

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 $360^\circ$ 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.

RoboCup 2006
We participated with our team “AllemaniACs” at the Tenth RoboCup World Championships in Bremen in the leagues 3D Simulation, Middle-size, and RoboCup@Home. RoboCup@Home is newly established RoboCup league to foster service robotics applications. The robots had to show that they are able to safely maneuver in an apartment without colliding with the furniture, or to localize in the apartment. Of special
interest is the human machine interaction, that is the communication between man and machine in a natural way.

With the AllemaniACs@Home team we advanced to the finals. In the final round the AllemaniACs robot showed useful action especially at times of the FIFA soccer world championships with bringing a beer crate to the couch in the living room. With the overall sound performance of the team we made the first place and became the first RoboCup@Home World Champion.

Science and Trade Fairs

**Automatica 2006 in Munich.** We demonstrated our soccer robots at the “Mechatronische Spielwiese” at the Automatica in Munich in May 2006, one of the large international automation fairs. We demonstrated the robot’s abilities to autonomously navigate through its environment. With a previously generated map from the laser range finder the robot was able to localize itself on the fair and fulfill service robotics tasks.

**Participation at the Wissenschaftssommer 2006 in Munich.** Our freshly elected champion represented the RWTH Aachen at the fair booth of the DFG at the ‘Wissenschaftssommer’ in Munich in July. At the first weekend of the Wissenschaftssommer there was a special RoboCup exhibition with other teams from Germany, all funded by the SPP 1125. One of the highlights was the visit of the President of the Federal Republic of Germany, Dr. Horst Köhler, and the Minister of Science and Education, Dr. Anette Shavan.

**INSITE 2006 in South Africa.** The German Academic Exchange Service organized on behalf of the Ministry of Science and Education the second edition of largest science fair on the African continent, the INSITE 2006. Again, our world champion was invited to show its abilities on this fair, which took place from September 24 - 27 in Johannesburg, South Africa.

Development of new Middle-Size Robots

We are currently developing a new innovative robot platform for the RoboCup Middle-size league. Unlike our previous robots which were developed for both, soccer as well as service robotics applications, we now focus on soccer playing. This means that we also follow the main stream in the Middle-size community to use an omni-directional drive as well as an omni-directional camera. Further, we are going to use a stereo vision camera transmitting rectified images from which depth information of the objects in the image can be retrieved. While in 2006 we designed the robot platform we hope to get the new robots ready by mid of 2007 to be able to participate
with them at the RoboCup 2007 in Atlanta, USA. For building the robots and in many mechanical and engineering questions we are able rely on our colleagues of the Institute of Engineering Design. The development was made possible by a grant from the Bonn-Aachen Institute of Technology and support from the Chair of Computer Science 5.
Publications


Dominik Schmitz, Gerhard Lakemeyer and Matthias Jarke: *Comparing TCD/SNet with two other formal analysis approaches based on $i^*$: Formal Tropos and Secure Tropos*, In Proceedings of the 8th Workshop on Agent-Oriented Information Systems, AOIS @ CAiSE, Luxembourg, June 2006.


Staff

- Faculty:
  Professor Dr.-Ing. Hermann Ney
  email: ney@informatik.rwth-aachen.de
  http://www-i6.informatik.rwth-aachen.de

- Secretary:
  K. Bäcker
  G. Gillmann
  J. Kikum

- Academic and Research Staff:
  Dipl.–Inform. O. Bender
  Dipl.–Phys. M. Bisani
  Dipl.–Inform. J. Bungeroth
  Dipl.–Inform. T. Deselaers
  Dipl.–Inform. P. Dreuw
  Dipl.–Math. N. Ehling
  Dipl.–Inform. C. Gollan
  Dipl.–Inform. S. Hahn
  Dipl.–Inform. S. Hasan
  Dipl.–Phys. G. Heigold
  Dipl.–Inform. B. Hoffmeister
• Academic and Research Staff (cont.):

Dipl.–Inform. G. Leusch
J. Lööf, M. Sc. Engineering Physics
Dipl.–Inform. K. Macherey
Dipl.–Inform. W. Macherey
Dipl.–Inform. E. Matusov
Dipl.–Inform. A. Mauser
Dipl.–Inform. C. Plahl
Dipl.–Ing. M. Popović
Dipl.–Inform. D. Rybach
Dr. rer.nat. R. Schlüter
Dipl.–Inform. D. Stein
Dr. rer.nat. V. Steinbüß
Dipl.–Math. N. Ueffing
Dipl.–Ing. D. Vilar Torres
Dipl.–Inform. J. Xu
Dipl.–Inform. R. Zens
Y. Zhang, M. Comp. Sc. Tech.

• Technical Staff:

M. Kohns
S. Koltermann

• Visitors:

Dustin Hillard
University of Washington, Seattle, USA
March 2006 – July 2006

Daniel Ortiz
Universidad Politécnica de Valencia
May 2006 – July 2006
Overview

The Lehrstuhl für Informatik 6 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 6 cover the following applications:

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

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

**Selected Research Projects**

**Global Autonomous Language Exploitation (GALE)**

The goal of the GALE program is to develop automatic systems to extract information from a variety of sources, such as broadcast news, newswire text or Usenet newsgroup articles in the languages English, Chinese and Arabic. The Lehrstuhl für Informatik 6 will contribute to GALE with the transcription of audio data into text (automatic speech recognition) and the translation of foreign language material into English (machine translation). The systems will pass along pointers to relevant source language data that will be available to humans and downstream processes. The distillation engine integrates information of interest to its user from multiple sources and documents.

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

TC-STAR is a concentrated three year effort for advanced research in all core technologies for speech-to-speech translation: speech project targets at recognition, machine translation, and speech synthesis.

This EU integrated project is the first one world-wide that tackles the speech-to-speech translation of an unconstrained conversational speech domain, namely parliamentary debates in European English and European Spanish and broadcast news in Chinese, thus covering
a few languages relevant for Europe’s economy and society. The technical challenges and objectives of the project focus on the development of new algorithms and methods, integrating relevant human knowledge which is available at translation time into a data-driven framework. Examples of such new approaches are the integration of linguistic knowledge in the statistical approach of spoken language translation, the statistical modelling of pronunciation of unconstrained conversational speech in automatic speech recognition, and new acoustic and prosodic models for generating expressive speech in speech synthesis. This work is supported by the collection of language resources and the setup of an evaluation infrastructure. Systematic and objective evaluation is executed both within the project and with the external scientific community in order to monitor progress and to compare the performance of algorithms.

The Lehrstuhl für Informatik 6 is involved in several work packages of this project. We are building the European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation. The EPPS corpus consists of acoustic data, corresponding transcriptions, and parallel texts, i.e. translations of plenary sessions of the European Parliament in the languages English and Spanish. In the area of machine translation, we are involved in research on innovative translation methods, use of human-supplied knowledge, and on the integration of machine translation and speech recognition. We are work package leader and develop translation systems for Chinese-English, Spanish-English, and English-Spanish as well as automatic speech recognition systems for English and Spanish in the EPPS domain. Our work in the area of speech recognition covers lightly supervised transcription, new optimization criteria, and open vocabulary methods.

**EU Project TT2 (TransType2)**

The aim of TransType2 was to develop a computer-assisted translation system, which would help to meet the growing demand for high-quality translation. The innovative solution proposed by TransType2 was to embed a data-driven machine translation engine with an interactive translation environment. In this way, the system combined the best of two paradigms: the computer-assisted translation paradigm, in which the human translator ensured high-quality output; and the machine translation paradigm, in which the machine ensured significant productivity gains. Another innovative feature of the system was that it had two input modalities: text and speech. Six different versions of the system were developed for English, French, Spanish and German which were evaluated by two professional translation agencies. Lehrstuhl für Informatik 6 contributed to improving the translation technology; and systems were set up for all six language pairs. Additionally, we extended the system by a speech interface for German to make the system more convenient for human translators. The project was completed in February 2005.

**EU Project LC-STAR (Lexica and Corpora for Speech-to-Speech Translation Technologies)**

The objective of the LC-STAR project was to improve human-to-human and man-machine communication in multilingual environments. LC-STAR was a joint European project lasting
three years. It was completed in 2005. Within the project, lexica and corpora needed for speech-to-speech translation were created. A speech-to-speech translation demonstrator for the three languages English, Spanish and Catalan was developed. The Lehrstuhl für Informatik 6 concentrated on the investigation of speech centered translation technologies and on the creation of lexica for speech recognition in German. The research focused on the use of morpho-syntactically enriched language resources to improve speech translation.

**DFG Project Statistical Methods for Written Language Translation**

This project aims at the development and improvement of statistical machine translation. The following problems are tackled: large vocabulary translation, improvement of statistical alignment and lexicon models, integration of mono- and bilingual syntactic structures and morphological analysis, and adaption and improvement of training and search algorithms for statistical machine translation.

**DFG Project Statistical Modelling for Image Object Recognition**

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

**RWTH Project IRMA (Image Retrieval in Medical Applications)**

The RWTH IRMA project is a joint project of the Institute of Medical Informatics, the Department of Diagnostic Radiology, and Lehrstuhl für Informatik 6. 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 6, emphasis is put on the research in the domain of automatic image categorization and the evaluation of different features for medical image retrieval.

![Fig. 4: Examples from the IRMA Database](image)

**National and International Evaluation Campaigns**


  In 2006, we took part in the NIST machine translation evaluation for translation of Chinese and Arabic into English. Four input conditions were tackled in this year’s campaign: translation of text from the domains newswire, newsgroups, broadcast news
and broadcast conversation. Among leading research groups from all over the world, the RWTH system was ranked fourth of 25 systems for Chinese-to-English and fifth of 24 for Arabic-to-English. For the Arabic track, the RWTH system participated for the first time in this evaluation.

- **IWSLT 2006 (International Workshop on Spoken Language Translation)**
  
The C-STAR consortium organized the third annual evaluation campaign for speech translation. The task was translating spoken conversations from the touristic and travelling domain. Translations were done for spontaneous speech and read speech automatic speech recognition results as well as for the correct transcriptions.

  The Lehrstuhl für Informatik 6 competed with 11 other research groups in the translation directions Chinese to English and Japanese to English and was ranked first in translation quality in all input conditions and language pairs.

- **CLEF/ImageCLEF Image Retrieval Evaluation 2006**
  
  In 2006, we took part in the ImageCLEF content-based image retrieval evaluation for medical images. Among leading research groups from all over the world, our systems were ranked first and third in the medical automatic annotation task. In the medical retrieval task, we could strongly improve our results using a combination of text and image retrieval.

- **PASCAL Visual Object Classes Challenge 2006**

  In 2006, we participated in the PASCAL visual object classes challenge. Among leading research groups from all over the world, our part-based method obtained very good results over several of the different challenges.

- **Data Mining Cup 2006**

  In 2006, a practical course for students held by Lehrstuhl für Informatik 6 took part in the Data Mining Cup organized by the Chemnitz University of Technology, and prudsys AG.

### 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 5) 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.

Fig. 6: (a) Speech waveform of the utterance “Sollen wir am Sonntag nach Berlin fahren”, (b) the corresponding FFT spectrum

At Lehrstuhl für Informatik 6, the following research directions related to all main areas of automatic speech recognition were pursued in 2006:

- The generation of *European Parliament Plenary Session (EPPS) corpus* for speech-to-speech translation between English and Spanish was continued. This corpus consists of transcribed speech and parallel texts in the languages English and Spanish and is based on corresponding TV broadcasts and internet publications.

- Methods for *unsupervised training* were improved to take advantage of relatively small amounts of untranscribed speech data.

- Extraction methods for *novel acoustic features* were further developed and were shown to give competitive results. In a cooperation with the Dalle Molle Institute for Perceptual Artificial Intelligence (IDIAP), Martigny, Switzerland, data-driven methods to extract acoustic features using neural networks were investigated. Approaches to combine systems based on different acoustic features were carried out and gave significant improvements in word error rate.

- *Speaker adaptive training* were further developed by generalization to projection transforms and application of advanced training criteria.

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

241
• A number of system combination methods were investigated, including two word lattice based approaches.

• Methods for discriminative training were investigated. Specifically, phone error minimizing criteria were developed and compared to existing discriminative criteria.

• Transducer-based search architectures were investigated and compared to the standard search architecture.

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

• Refinements of Bayes decision rule using a word error based cost function were investigated with special focus on analytic simplifications and reduction of complexity.

---

**Machine Translation**

The goal of machine translation is the translation of a text given in some natural source language into a natural target language. The input can be either a written sentence or a spoken sentence that was recognized by a speech recognition system. At Lehrstuhl für Informatik 6, 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 7). The translation model is decomposed into the lexicon model which determines the translations of the words in the source language and the alignment model forming a mapping between the words in the source language string and the words in the target language string. These models are trained automatically on a corpus of bilingual source/target sentence pairs. In this approach, it is not necessary to manually design rules for the translation or the construction of sentences. A search algorithm determines the target language sentence that has the highest probability given the source language sentence.

The statistical approach to machine translation is particularly suitable for the translation of spontaneous speech, where the translation approach has to cope with colloquial language and speech recognition errors.
At Lehrstuhl für Informatik 6, the following research directions related to the main topics of machine translation were pursued in 2006:

- The phrase-based translation system (PBT) was improved and enhanced. The system is capable of translating text as well as lattices from automatic speech recognition systems. Constantly high translation quality was proven by top ranks in several international evaluations.
- Our method for system combination for statistical machine translation, inspired from methods in speech recognitions was improved leading to better translation quality.
- 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.
- New reranking methods and features for machine translation were developed, implemented, and tested. Among the features were improved language models, syntactic features like parsing and tagging, and alternative translation models. The methods improved translation quality and contributed to the good results in international evaluations.
- Research efforts were extended in the area of automatic translation between German written text and German Sign Language. Existing parallel corpora were augmented in order to improve existing statistical machine translation systems. Combined with speech input and a graphical output, the system aims at the support for deaf people.

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

## Natural Language Processing

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

The development of statistical approaches for these applications is one of the research activities at the Lehrstuhl für Informatik 6.

In natural language understanding, the objective is to extract the meaning of an input sentence or an input text. Usually, the meaning is represented in a suitable formal representation language so that it can be processed by a computer. Usually, hand-crafted grammars are used in order to parse input sentences and map them onto a formal representation. The language understanding systems developed at the Lehrstuhl für Informatik 6 are based on statistical machine translation and learn dependencies between source and target representations automatically from annotated texts. Because the usage of hand-crafted grammars is reduced, the systems can be easily ported to other domains.

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

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

In 2006, the maximum entropy framework developed for tagging was compared to standard machine translation approaches with respect to their performance in natural language understanding. The results showed that the discriminative maximum entropy approach clearly outperformed the source channel-based machine translation approach.
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 8 and 9). 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 2006, 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.

Fig. 8: Examples of single objects to be recognized (Caltech database)

Fig. 9: Examples from the USPS database
Automatic sign language and gesture recognition is similar to automatic speech recognition. Our aim is to build a robust, person independent system to recognize continuous sign language sentences. Additionally, our vision-based approach does not require special data acquisition devices, e.g. expensive data gloves which restrict the natural way of signing.

As a baseline system we propose to use appearance-based image features, i.e. thumbnails of video sequence frames. They serve as a good basic feature for many image recognition problems, and are already successfully used for gesture recognition. Further features, which are inspired by linguistic research in sign language, are extracted using hand- and head-tracking methods.

In 2006, we have furthermore shown that many of the principles from automatic speech recognition can be directly transferred to the new domain of continuous automatic sign language recognition and that great improvements are possible by adopting the experiences from automatic speech recognition to problems in video-analysis.

We achieved very promising results on publicly available benchmark databases (see Figures 10) by combining different data sources, suitable language modelling, temporal contexts, and model combination.

**Other Activities**

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

- Image Retrieval Engine FIRE (Flexible Image Retrieval Engine)
  http://www-i6.informatik.rwth-aachen.de/~deselaers/cgi_bin/fire.cgi
Publications

References


S. Khadivi, R. Zens, H. Ney. Integration of speech to computer-assisted translation using


H. Müller, P. Clough, W. Hersh, T. Deselaers, T. Lehmann, A. Geissbuhler. Using heterogeneous annotation and visual information for the benchmarking of image retrieval systems. In SPIE conference, Electronic Imaging, San Jose, CA, USA, Jan. 2006.


Dissertations

D. Keysers: *Modeling of Image Variability for Recognition*
Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr.-Ing. Hans Burkhardt
March 2006

H. Schramm: *Modeling Spontaneous Speech Variability for Large Vocabulary Continuous Speech Recognition*
Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr.-Ing. Reinhold Häb-Umbach
March 2006

Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr. Enrique Vidal
March 2006

A. Zolnay: *Acoustic Feature Combination for Speech Recognition*
Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr.-Ing. Reinhold Häb-Umbach
August 2006
Overview

Lehrstuhl für Informatik 6

TC-STAR is an EU funded integrated project and brings together partners from twelve different European research sites from both academia and industry. Its focus lies on advanced research in all core technologies for speech-to-speech translation: speech recognition, speech translation, and speech synthesis.

<table>
<thead>
<tr>
<th>TC-STAR</th>
<th>Participating companies:</th>
<th>Participants from academia:</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.tc-star.org">www.tc-star.org</a></td>
<td>ELDA</td>
<td>ITC-irst (Trento)</td>
</tr>
<tr>
<td>FP6 integrated</td>
<td>IBM</td>
<td>LIMSI-CNRS (Paris)</td>
</tr>
<tr>
<td>project</td>
<td>Nokia</td>
<td>RWTH Aachen University</td>
</tr>
<tr>
<td>starting April</td>
<td>Siemens</td>
<td>SPEX (Nijmegen)</td>
</tr>
<tr>
<td>2004</td>
<td>Sony</td>
<td>UKA Universität Karlsruhe</td>
</tr>
<tr>
<td>granted for 3</td>
<td></td>
<td>UPC (Barcelona)</td>
</tr>
<tr>
<td>years</td>
<td>total 18 million Euro</td>
<td></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 lies on the development of novel algorithms and methods, integrating relevant human knowledge which is available at translation time into a data-driven framework.

Examples of such new approaches are the integration of linguistic knowledge in the statistical approach of spoken language translation, the statistical modelling of pronunciation of unconstrained conversational speech in automatic speech recognition, and new acoustic and prosodic models for generating expressive speech in synthesis.

TC-STAR has been granted for three years with a total funding sum of 11 million Euro. It targets a selection of unconstrained conversational speech domains - i.e. broadcast news and parliamentary debates - and a few languages relevant for Europe’s society and economy: native and non native European English, European Spanish and Chinese.

This work is supported by the collection of language resources. While competition is fostered by the setup of an infrastructure for competitive evaluation, the project supports cooperation by a technological infrastructure (common language resources, workshops, formats, APIs) and strives for the effective dissemination of scientific results within the consortium and the research community.
Let us now focus on the contribution of Lehrstuhl für Informatik 6 to several of the work packages of the TC-STAR project.

**The Statistical Approach to Speech-to-Speech Translation**

The statistical approach to pattern recognition, highly developed especially in the field of speech recognition, has been successfully applied to the more general field of automatic processing of human language, including the translation of spoken and written language and the understanding of natural language and spoken dialogue systems.

The general framework for our research activities is based on statistical decision theory and problem specific modelling – acoustic–linguistic modelling for speech recognition and linguistic modelling for translation. The probabilistic framework and statistical decision theory have some characteristic advantages:

- The approach is able to model weak dependencies and vague knowledge at all levels of the system.
- Due to the statistical formulation of both the speech recognition and the translation problem, the combined problem of recognizing and translating speech can be described in a single, consistent mathematical framework.
- The free parameters of the models can be automatically learned from training data (or examples), and there exist powerful algorithms for this purpose.
- Using the Bayes decision rule, the final decision is made by taking all available context into account.

**Automatic Speech Recognition**

A speech recognition system can typically only recognize words that are part of its so-called recognition vocabulary. While this can be very large, new out-of-vocabulary words occur frequently – just think of proper names. We work on open vocabulary methods that target to overcome this restriction. Other improvements cover lightly supervised transcription where the system is trained using speech of which the text is not exactly known and new optimization criteria for automatic speech recognition systems. Within the speech recognition part of TC-STAR, we cover the languages English and Spanish.

**Spoken Language Translation**

Lehrstuhl für Informatik 6 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, the use of human-supplied knowledge, and on the integration of machine translation and speech recognition. One research activity focuses on improvement by combining the outputs of several individual systems.

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 6* makes a major effort in building the European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation. The EPPS corpus consists of acoustic data, corresponding transcriptions, and parallel texts/translations of plenary sessions of the European Parliament in the languages English and Spanish. We collect the acoustic recordings and transcribe recordings in English, either original parliamentary speeches (many of them by non-native speakers) or speech from simultaneous translation into English. Spanish transcriptions are produced by UPC. We also take care of the parallel text corpora - this technical term describes texts which consist of pairs, one sentence (sometimes more) in the source language and its translation in the target language. Although the exact correspondences between words or sub-phrases are not provided, it is possible for the machine translation systems to derive that information from the data in a statistical model estimation process called *training*.

The typical amount of data used in contemporary state-of-the-art systems and also generated in this project is in the range of over a hundred hours of acoustic recordings and of about one hundred million running words of text in the parallel texts.
Logic & Theory of Discrete Systems

Staff

- Faculty:
  
  Prof. Dr. Dr.h.c. Wolfgang Thomas
  
  Prof. (em.) Dr. Walter Oberschelp

- Secretary:

  Marianne Kuckertz

- Research Assistants:

  Dipl.-Inform. Jan Altenbernd
  Dr. Arnaud Carayol
  Dipl.-Inform. Florian Horn
  Dipl.-Inform. Wong Karianto
  Dr. Mikhail Kats
  Dr. Christof Löding
  Dr. Volker Penner
  Dr. Philipp Rohde
  Dipl.-Inform. Alexandra Spelten
  Dipl.-Inform. Nico Wallmeier

- Technical Staff:

  Rolf Eschmann
Overview

In the year 2006, teaching and research suffered a bit by the fact that the leader of the group was heavily involved in matters of administration (dean of the faculty of mathematics, computer science, and natural sciences). Due to a special effort of Dr. C. Löding, who took over major courses for the chair, the negative effect for students was minimized.

At the end of March 2006, Dr. Volker Penner left the chair for retirement. The chair and the whole department express their sincere thanks for his many contributions and unfailing service for over 35 years of office, to numerous areas in research, teaching, and administration.

Highlights

• Prof. W. Thomas was elected as member of Academia Europaea.

• On 1st July, the DFG Research Training Group AlgoSyn (DFG-Graduiertenkolleg 1298 “Algorithmische Synthese reaktiver und diskret-kontinuierlicher Systeme”) started with Prof. W. Thomas as speaker.

• On 1st November, the Excellence Research Cluster UMIC (“Ultra High-Speed Mobile Information and Communication”) within the federal Excellence Initiative started, including Prof. W. Thomas as one of the principal investigators.

• International cooperations were pursued on several levels:
  – via the DAAD Procope project Finitely Represented Infinite Graphs – Structure, Behaviour, Algorithmics with the University of Rennes, and via the EU Network of Training and Research GAMES.
  – by participation in the doctoral promotions of five external researchers (in Belgium, France, and Italy).
  – by the joint French-German dissertation project (F. Horn, Paris) and the employment of Dr. A. Carayol, Rennes, on a full assistant position at the chair (October 2006-October 2007).
  – by a meeting for students of ENS Cachan, who obtained information about possible internships in the CS Department of RWTH Aachen.

• Special efforts were devoted to the preparation of STACS 2007, the 24th International Symposium on Theoretical Aspects of Computer Science, e.g. for the organization of the program committee meeting in November 2006, which had to select 56 papers out of 400 submissions.
The research in this field was done in different cooperations and spans a rather broad spectrum:

- C. Löding’s contribution to a structural characterization of spatial database queries was published in the *Journal of the ACM* (cooperation with the data base group of the University of Limburg, Belgium, and with Th. Wilke, Kiel) [2].


- In a German-Israeli cooperation, A. Rabinovich and W. Thomas [13] characterized the sets of natural numbers that have a decidable monadic second-order theory (with <). For this, the new concept of uniformly homogeneous sets (in the context of the infinite Ramsey Theorem) was introduced.

- A cooperation between a dean (computer science), his predecessor as dean (mathematics), and a doctoral student resulted in a paper on number-theoretic decidability results [8].

- A comprehensive tutorial by W. Thomas was published in [16].

This research partly took place in the Procope project funded by DAAD with the University of Rennes.

- In [1], C. Löding studied the decidability of an extended notion of regularity (i.e. the intersection of regular word languages with sets of well-bracketed words) in
the case of visibly pushdown languages (cooperation with V. Bárány, a doctoral student at Mathematische Grundlagen der Informatik, RWTH Aachen, and O. Serre of LIAFA Paris).

- In his PhD Thesis [5], supervised by D. Caucal (Rennes, France) and finished on an assistant position in our group, A. Carayol introduced a notion of regularity for the so-called higher-order pushdown automata, extending Büchi’s results on reachable stack contents for pushdown automata.

- In [4], A. Carayol proposed an algebraic framework for studying notions of regularity arising in unary algebras (cooperation with D. Caucal in the scope of the DAAD Procope project).

---

**Tree Automata**

*W. Karianto, C. Löding, A. Spelten, W. Thomas*

*Funding: DFG*

The goal of this project, funded by the DFG (“German Research Foundation”), is to advance the theory of unranked tree automata. Unranked trees serve as a basic model for semi-structured data, e.g. XML documents, and unranked tree automata can thus be used to process such kind of data. The main contributions of our research can briefly be summarized as follows.

- **Automaton models that go beyond regularity:** In [10] a model of unranked tree automata is developed that allows to check equality of subtrees that are rooted below the same node. The comparison of subtrees in general can be helpful for processing data values in XML documents. These data values are usually abstracted away when modeling a document by an unranked tree. The goal of this research is to find a model that has good algorithmic properties and allows more general comparisons that are not restricted to subtrees rooted below the same node. Another extension of unranked tree automata is obtained by allowing (a restricted use of) counters. In an internship, supervised by W. Thomas and W. Karianto, a student from Cachan (France) compared different such extensions of unranked tree automata [17].

- **Rewriting for unranked trees:** In [10] the algorithmic properties of transition graphs of ground rewriting systems for ranked trees are studied in detail, giving a clear picture of the border between decidability and undecidability. In her diploma thesis [19], A. Spelten developed notions of rewriting systems for unranked trees and analyzed the classes of transition graphs obtained by these
systems, as well as their algorithmic properties such as reachability. The generalization to unranked trees yields a larger class of infinite transition graphs for which the reachability problem is still decidable.

**Infinite Games**

*F. Horn, Ph. Rohde, W. Thomas, N. Wallmeier*

*Funding: DFG (Graduiertenkolleg AlgoSyn)*

This research direction is tightly connected with the DFG Research Training Group AlgoSyn. Two publications report on work of previous years: In [14], a logic is developed over dynamically changing structures which can be analyzed with “sabotage games” (in which one player moves through a graph and the other deletes edges). In [15], an experimental analysis of two complex automata theoretic algorithms is given. Finally, the study [18] obtained progress in the problem of optimizing the synthesis of finite-state controllers, a research track which will be further continued within AlgoSyn.

**Other Activities**

W. Thomas

- Dean of the Faculty of Mathematics, Computer Science, and Natural Sciences of RWTH Aachen (until October 2006)
- Speaker of the DFG-Graduiertenkolleg 1298 “Algorithmische Synthese reaktiver und diskret-kontinuierlicher Systeme” (since July 2006)
- Member of Academia Europaea
- Member of the Editorial Board of the following journals:
  - ACM Transactions on Computational Logic
  - Logical Methods in Computer Science
  - RAIRO Theoretical Computer Science and Applications
  - Discrete Mathematics and Theoretical Computer Science
- Member of the Award Committee for the E.W. Beth Dissertation Prize of the European Association for Logic, Language, and Information
• Member of the Executive Committee of the Research Network AutoMathA (Automata Theory: From Mathematics to Applications) of the ESF (European Science Foundation)

• Member of the Council of EATCS (European Association of Theoretical Computer Science)

• Member of external commissions for doctoral promotions: G. Puppis* (Udine), I. Boneva* (Lille), W. Martens (Limburg), Th. Brihaye (Mons), A. Carayol* (Rennes) [*: with report]

• Program Committee Co-Chair of STACS 2006 (23rd International Symposium on Theoretical Aspects of Computer Science), Marseille

• Program Committee Member of the IFIP Conference on Theoretical Computer Science, Santiago (Chile)

• Member of Aachen Competence Center for History of Science

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)

• Member of Aachen Competence Center for History of Science

C. Löding, V. Penner, Ph. Rohde

• Student Advisors for Curricula of Minor Subjects and for Teachers’ Curricula

Talks and Publications

Talks


A. Carayol: *Automates Infinis, Logiques et Langages*, PhD Defense, Université de Rennes 1, December 2006


W. Karianto: *Unranked Tree Automata with Sibling Equalities and Disequalities*, Workshop of the Procope project Aachen-Rennes, Rennes, August 2006


C. Löding: *Automata for Unranked Trees*, ESF Workshop on Tree Automata, Bonn, June 2006

C. Löding: *Memory Reduction for Strategies in Infinite Games*, Workshop on Games in Design and Verification, GDV’06, Seattle, August 2006

W. Oberschelp: *Potentials and Limits of Computers (in German)*, Seniorenseninar, RWTH Aachen, April 2006

W. Oberschelp: *Reconstructing the Design Context of Historical Astronomical Objects (in German)*, Workshop of the Aachen Competence Center for History of Science, Aachen, October 2006

W. Oberschelp: *Cassini, Campani and the Ring of Saturn (in German)*, Workshop of the special interest group History of Astronomy, VDS, Potsdam, November 2006

W. Oberschelp: *Science and Engineering in Medieval Islam (in German)*, Forum Technik und Gesellschaft, RWTH Aachen, December 2006


W. Thomas: *Fundamentals on Logics over Trees*, ESF Workshop on Tree Automata, Bonn, June 2006

W. Thomas: *The Ordering of Natural Numbers with a Unary Predicate: Approaches to Show Decidability Results*, 11th Mons Days of Theoretical Computer Science, Rennes, August 2006


**Publications**


263


**Diploma Theses**


Mathematical Foundations of Computer Science

Staff

- Faculty:
  Prof. Dr. Erich Grädel

- Secretary:
  Marianne Kuckertz

- Research Assistants:
  Vince Bárány
  Dietmar Berwanger
  Tobias Ganzow
  Łukasz Kaiser
  Michael Ummels
Overview
The research group on Mathematical Foundations of Computer Science is part of the Department of Mathematics, but there is a very intensive collaboration, both in research and teaching, with the Department of Computer Science, most notably with the research group Computer Science VII (Prof. Wolfgang Thomas).

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

Research Projects

Games and Automata for Synthesis and Validation (GAMES)
www.games.rwth-aachen.de
E. Grädel, V. Bárány, D. Berwanger, T. Ganzow, Ł. Kaiser, M. Ummels
(and Research Group Computer Science VII of Prof. W. Thomas)

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

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

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

B. Reactive computation. We want to make progress in a so-far unexploited potential of infinite games, namely to develop them as a model of reactive computation. Our aim is to devise game-based methods for the automatic synthesis and testing of reactive controllers.
C. Verification: New Frontiers. Model checking techniques have been applied with great success to the verification of hardware. One of the big challenges for this network is to extend the verification methodology so as to deal with broader classes of systems, including important classes of software systems.

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

 Algorithms and Complexity for Logic Problems

E. Grädel, D. Berwanger

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

Recently, substantial progress has been made concerning the algorithmic properties of modal logics (in the broad sense, including temporal logics, dynamic logics, the modal μ-calculus etc.), two-variable logics, and guarded logics. A key issue in this context is the relationship of algorithmic and model-theoretic properties of logical systems and the use of automata-based methods.

 Computational Model Theory and Descriptive Complexity

E. Grädel, D. Berwanger, V. Bárány, T. Ganzow

Finite model theory studies the relationship between logical definability and computational complexity on finite structures. A particularly important aspect concerns logical descriptions of complexity classes. Our research group has made significant contributions to this area.

A newer development in this field is the extension of the approach and methodology of finite model theory to (particular classes of) infinite structures. Algorithmic issues on infinite structures are of increasing importance in several areas of computer science. In databases, the traditional model based on finite relational structures has turned out to
be inadequate for modern applications (like geographic data, constraint databases, data on the Web). Also in verification, infinite (but finitely presentable) transition systems become more and more important, in particular for applications to software.

We investigate several directions, for making the methodology developed in finite model theory applicable to infinite structures. Of particular importance are, again, the connections between algorithmic issues and logical definability.

We have developed a model theory of *metafinite structures* that combine finite structures with arithmetic operations on infinite numerical domains. Applications of metafinite model theory have been studied in the following domains: descriptive complexity on real numbers, approximation properties of optimization and counting problems, databases with uncertain or unreliable information, and database query languages with aggregates.

We study algorithmic and definability issues on various classes of infinite structures that are presentable by *automata* and *interpretations*. The work by A. Blumensath, V. Bárány, and E. Grädel on *automatic structures* has been very influential for the development of this field.

---

**Algorithmic Synthesis of Reactive and Discrete-Continuous Systems (AlgoSyn)**

www.algosyn.rwth-aachen.de

E. Grädel, D. Berwanger, Ł. Kaiser, M. Ummels

AlgoSyn is an interdisciplinary Research Training Group (Graduiertenkolleg) at RWTH Aachen University lead by a group of ten professors representing five different disciplines. Integrating approaches from computer and engineering sciences, the project aims at developing methods for the automatised design of soft- and hardware. AlgoSyn is funded by the German Science Foundation (DFG).

**Objectives.** While methods of software validation and verification based on adequate formal models are by now well established and tested in practical applications, the approach of automatic synthesis of software (and hardware) is as yet only developed in quite rudimentary form. On the other hand, in theoretical computer science as well as in engineering disciplines a rapidly increasing stock of techniques for the development of algorithmic synthesis procedures is emerging, triggered by the demand to decrease development costs by invoking algorithmics in formal modelling frameworks. However, the approach of program synthesis is only applicable in restricted scenarios, in particular in reactive (multi-agent-)systems with low data complexity and in control systems. Central issues in the area are the establishment of system models which allow an algorithmic solution of the synthesis problem, the combination of discrete
and continuous parameters in hybrid systems (as this is also familiar from verification), and the exploration of the potential of applications.

The aim of the Research Training Group is to unify the expertise from computer science, mathematics, and four engineering disciplines (processor architectures, automatic control, process control engineering, train traffic systems) and to push forward the desired integration of methods. The research will be carried out in four subject areas: Algorithmics for agent-based probabilistic and hybrid systems, formal methods of reactive systems and game-theoretic methods, software development and modelling languages, and finally applications and demonstrators.

Inside this Graduiertenkolleg, our research group mainly focusses on foundational projects on infinite games. In particular we aim at extending game-based methodologies from two-player games to multi-player games and to games that involve infinitary winning conditions.
Other Activities

Erich Grädel

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

• Organiser of the Newton Institute Workshop on Games and Verification, Cambridge, July 2006.

• 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 Editorial Board of the *Journal of Logic and Computation* (Corner Editor for Logic and Games).

• Member of the Programme Committee of LPAR 2006, LICS 2007, CSL 2007, and CSR 2007.

• Organiser of the Annual German Meeting on Algorithmic Model Theory, Aachen, 2006 and 2007.

Talks and Publications

Talks


E. Grädel: How to win infinite games?, Université de Bordeaux, November 2006.
Ł. Kaiser: Game Quantification and Hierarchical Model Checking Games, GAMES Meeting, Cambridge, July 2006.
M. Ummels: Game Tree Logic, LIAFA, Université Paris 7, April 2006.
M. Ummels: Game Tree Logic, Arbeitsgemeinschaft Logik und Automaten, Aachen, August 2006.

Publications

271


Computer Graphics and Multimedia

Staff

- Faculty:

  Prof. Dr. rer. nat. Leif Kobbelt
  kobbelt@cs.rwth-aachen.de
  http://www.rwth-graphics.de/

- Secretary:

  Silke van Betteraey
  Tel: +49-241-80-21801
  Fax: +49-241-80-22899

- Research Assistants:

  Dipl.-Inform. Stephan Bischoff
  Dipl.-Inform. David Bommes (funded by DFG)
  Dipl.-Inform. Martin Habbecke
  Dipl.-Inform. Alexander Hornung
  Martin Marinov, M. Sc.
  Dipl.-Inform. Darko Pavic (funded by Innovaris GmbH)
  Dipl.-Inform. Arne Schmitz (funded by DFG)
  Dipl. Inform. Dominik Sibbing (funded by DFG)
  Jianhua Wu, M. Sc. (funded by DFG)

- Artist in Residence:

  M.F.A. Matthew Sloly

- Student Researchers:

  Ellen Dekkers, Jan Möbius, Volker Schönefeld,
  Boyi Zeng, Zhou Zhang
Overview

The Computer Graphics and Multimedia group at RWTH Aachen is focusing on research projects in the areas of Geometry Processing, 3D Reconstruction, Computer Vision, and Interactive Visualization but it is also active in related areas such as High Quality Image Synthesis, Point-based Graphics and Multimedia Data Processing. Our research projects and collaborations are funded by the Deutsche Forschungsgemeinschaft (DFG), the Federal Ministry of Education and Research (BMBF), the German-Israelian Foundation (GIF), and the European Union (EU). Moreover, we are cooperating with various companies in the automotive and automatization industry as well as with academic research groups around the world (North America, Europe, Asia). We consider our research field as applied basic research since even if the methods and techniques that we are developing often address fundamental and abstract problems we are nevertheless aiming at the application and evaluation of our solutions in real world scenarios.

A fully automatic Geometry Processing Pipeline is one of the long term goals on our research agenda. This requires methods for capturing the shape and texture of real objects, turning them into efficient computer models and enhancing the quality of the raw data with respect to surface roughness, sharp feature preservation and topological consistency. More sophisticated algorithms are able to even detect and extract structural information (e.g. in technical objects composed by shape primitives such as cylinders and spheres). Eventually we also need algorithms for the interactive visualization of the potentially massive datasets. To achieve this goal we are investigating new techniques to measure three dimensional data with digital cameras and laser range scanners. Once this data is obtained we have to integrate measurements from several sources into a single 3D computer model and thereby remove erroneous and redundant data. Recently, hybrid geometry representations (which combine surface and volume representations) have attracted our interest since they allow for more robust and more efficient algorithms in various geometry processing tasks. In the area of mesh generation we made significant advances in quad-dominant meshing for arbitrary input geometries.

In the past year we have started to look more closely into graphics applications in the context of mobile and distributed information and communication systems. This is part of our activities within the DFG research cluster UMIC (Ultra High-Speed Mobile Information and Communication Systems). The other line of research that receives increasing attention is visual simulation and pre-processing of complex geometric models for more sophisticated numerical simulations. Here we hope to be able to establish new collaborations within the DFG graduate school AICES (Aachen Institute for Advanced Study in Computational Engineering Science).

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 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. We are exploring these applications in the context of the DFG international research training group on “Schizophrenia and Autism” in collaboration with the RWTH Aachen University Hospital and the University of Pennsylvania. In all these applications the cost efficient generation and modification of complex 3D models is essential for the successful use of computers.

To promote this fresh and highly relevant research area we have started an international symposium series on Geometry Processing which after its successful start in Aachen in 2003 has now established as the major international forum specialized to this field. On the national level, we founded a “Geometry Processing” section as a sub-organization of the national Gesellschaft für Informatik. As the speaker of this section, Leif Kobbelt’s goal is to join the forces of the various research groups in industry and academia.

Our teaching curriculum currently comprises the sequel Computer Graphics I/II and the sequel Geometric Modeling I/II. Both curricula are taught in parallel with their first parts in the winter term and their second parts in the following summer term respectively. In the Computer Graphics courses we cover the basic as well as the advanced techniques for image synthesis and lighting simulation, image based rendering techniques, and polygon mesh processing. The Geometric Modeling courses are more 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 Low Cost 3D Scanners. Our goal in this project is to develop system for 3D shape capture by using a camera and projector setup. On the undergraduate level we offer an introductory seminar and practical exercises on topics in Computer Graphics.

As a special event in this year we hosted the Vision, Modeling, and Visualization Conference VMV2006. This is the major international conference in graphics in Germany (“German Open”) with about 150 participants from all over the world.

On the following pages, we are going to give a brief overview of our current research projects. These range from sophisticated 2D image processing tools and VR applications to computer vision, mesh optimization and interactive shape modeling. This year our group was again able to publish innovative research papers on many internationally recognized conferences and journals in Computer Graphics.
Research Projects

Extracting consistent and manifold interfaces from multi-valued volume data sets

Stephan Bischoff, Leif Kobbelt

In recent years the visualization and processing of structural magnetic resonance imaging data sets of human organs like the heart has become an important tool for anatomists and scientists alike. Extracting the interfaces between different tissue types of such datasets is not only important for indirect volume visualization but in particular is an integral part of many downstream applications, like e.g. segmentation or tracing of anatomical structures by active contour models. Typically these interfaces are represented as triangle meshes that have to satisfy certain quality criteria: Each triangle mesh should be a 2-manifold with boundary. The boundaries of the triangle meshes should consistently fit together, i.e. no gaps, T-junctions or other artifacts should occur. Furthermore, the triangles should be well-shaped in order to facilitate robust numerical evaluation. Finally, the triangle meshes should reflect user-specified a-priori knowledge about the anatomical structure. In this project we develop algorithms to automatically construct such a set of interfaces from a multi-valued volume dataset. While each single interface is a manifold triangle mesh, two or more interfaces may join consistently along their common boundaries, i.e. there are no T-junctions or gaps. In contrast to previous work, our algorithm classifies and removes the topological ambiguities from the volume before extracting the interfaces. This not only allows for a simple and stable extraction algorithm, but also makes it possible to include user constraints. Hence our algorithms are also able to compensate for noise that might be present in the input data.
The availability of increased bandwidth and processing capabilities for mobile applications will enable the creation of significantly enriched multimedia content. With cameras now being available in every mobile phone, image-, sound-, and video-processing is routinely used already in many applications. However, with the steadily growing importance of 3D graphics such as in virtual collaboration environments or games, one of the next important technical challenges for future multimedia applications are efficient algorithms for 3D content creation and processing. The aim of this UMIC project is the development of techniques to support compact geometry representations, efficient and progressive transmission and visualization, and the seamless integration of 3D geometry data with other existing types of multimedia data for an interactive and high quality 3D experience on mobile platforms.

To optimize the performance of interactive graphics applications, it is inevitable to reduce the polygonal complexity of 3D objects while preserving their high quality. In this project we will develop new methods for anisotropic remeshing, addressing the specific requirements of mobile applications. In client-server application scenarios with restricted data transfer, one needs extremely compact geometry representations to achieve robust and reliable real-time performance. A powerful technique to achieve these goals are surface approximations based on subdivision surfaces. For this purpose we research and implement algorithms to automatically extract subdivision control meshes from arbitrary polygonal approximations. These representations enable the use of hierarchical data structures which are essential for progressive data transfer to mobile phones. So all in all we aim at an universal representation for multi-resolution models, which flexibly integrates into mobile interactive applications.

In the above image the original unprocessed geometry (left) is remeshed with locally aligned isotropic triangles (middle) and globally aligned anisotropic quads (right). This last representation captures the structure of the original geometry while using less memory and making a high efficient multi-resolution data structure possible.
Physically based Segmentation of 3D Objects

David Bommes, Leif Kobbelt

A fundamental geometric problem is the decomposition of complex 3D objects into simpler parts. Many algorithms perform better or do even require simple geometric structures, making this decomposition an essential preprocessing step. Examples are parameterization, remeshing, data compression, morphing, matching, collision detection and shape editing. There are two different classes of segmentations with different decomposition structures. Patch segmentations divide the object into preferably flat, disc like structures while part segmentations identify the meaningful parts of the object which a human would recognize as sub-parts.

In this project we used a physical definition to derive part segmentations of objects. The meaningful parts are characterized based on their salience with respect to the whole object. These are usually parts which are bounded by concave regions and stick out of the object. In construction design these regions also play an important role, because they contain the stress maxima and make the object vulnerable to cracks. Starting with this observation we developed a physically based segmentation technique which uses finite element methods to identify fracture susceptible regions and consequently leads to boundaries between meaningful parts. Exploiting this connection between physical and geometrical properties we ended up with a robust algorithm savely identifying the desired segmentations. A thorough analysis of the non-linear optimization problem for stress maximization enabled us to formulate an algorithm which efficiently solves a set of linear systems and makes the method computationally feasible.

The image above shows a dino model (left), its fracture susceptibility (middle) and its corresponding part segmentation (right).
A Surface-Growing Approach to Multi-View Stereo Reconstruction

Martin Habbecke, Leif Kobbelt

We have developed a new approach to reconstruct the shape of a 3D object or scene from a set of calibrated images. The central idea of our method is to combine the topological flexibility of a point-based geometry representation with the robust reconstruction properties of scene-aligned planar primitives. This can be achieved by approximating the shape with a set of surface elements (surfels) in the form of planar disks which are independently fitted such that their footprint in the input images matches. Instead of using an artificial energy functional to promote the smoothness of the recovered surface during fitting, we use the smoothness assumption only to initialize planar primitives and to check the feasibility of the fitting result.

The algorithm employs a greedy strategy: After an initial disk has been found, the recovered region is iteratively expanded by growing further disks in tangent direction. The expansion stops when a disk rotates by more than a given threshold during the fitting step. A global sampling strategy guarantees that eventually the whole surface is covered.

The main advantages of our technique are that it does not depend on a shape prior or silhouette information for the initialization and that it can automatically and simultaneously recover the geometry, topology, and visibility information which makes it superior to other state-of-the-art techniques. Our algorithm performs highly robustly and is tolerant to a wide range of image capture modalities. Below two high-quality reconstruction results are shown.
In recent years, research on two-dimensional image manipulation has received a huge amount of interest. Very powerful solutions for problems such as matting, image completion, texture synthesis, or rigid image manipulation have been presented. Based on these and similar methods it has now become possible to explore interesting new ideas to re-animate still pictures, e.g., the animation of passive elements such as water and trees that are subject to natural forces like wind. In this project we wanted to take the idea of creating animations directly in image space one step further by making photographed persons move.

We present a new method to animate photos of 2D characters using 3D motion capture data. Given a single image of a person or essentially human-like subject, our method transfers the motion of a 3D skeleton onto the subject’s 2D shape in image space, generating the impression of a realistic movement. We present robust solutions to reconstruct a projective camera model and a 3D model pose which matches best to the given 2D image. Depending on the reconstructed view, a 2D shape template is selected which enables the proper handling of occlusions. After fitting the template to the character in the input image, it is deformed as-rigid-as-possible by taking the projected 3D motion data into account.

Our method works for images from arbitrary views and requires only a small amount of user interaction. We can generate animations of a diverse set of human (and non-human) characters with different types of motions such as walking, jumping, or dancing.

In the above image pairs, the left image shows the input image, while the right image shows a frame of the corresponding animation generated with our system.
The faithful reconstruction of three dimensional real world objects remains a great challenge in computer graphics and computer vision. Although established technologies such as laser scanning are able to produce high quality 3D reconstructions, they still lack flexibility with respect to material and lighting conditions and are relatively expensive. Hence the idea of reconstructing 3D objects from photos or video is not only of scientific importance but would also be an economically relevant alternative to specialized 3D scanning devices.

In this project we developed a new volumetric stereo algorithm to reconstruct the 3D shape of an arbitrary object. Our method is based on finding the minimum cut in an octahedral graph structure embedded into the volumetric grid, which establishes a well defined relationship between the integrated photo-consistency function of a region in space and the corresponding edge weights of the embedded graph. In contrast to previous methods, this new graph structure allows for a highly efficient hierarchical implementation supporting high volumetric resolutions and large numbers of input images. Furthermore we will show how the resulting cut surface can be directly converted into a consistent, closed and manifold mesh. Hence this work provides a complete multi-view stereo reconstruction pipeline. We demonstrate the robustness and efficiency of our technique by a number of high quality reconstructions of real objects.

The above images show image-based reconstructions of a geometrically complex Dragon model and of the Bahkauv-statue in the city of Aachen using our volumetric reconstruction technique.
The high quality reconstruction of a proper, watertight surface mesh from scattered point samples remains a difficult problem in many areas of computer graphics, including laser-scanning or image-based surface reconstruction techniques as well as repairing non-manifold or topologically noisy meshes.

In this project we developed a new volumetric method for reconstructing watertight triangle meshes from arbitrary, unoriented point clouds. While previous techniques usually reconstruct surfaces as the zero level-set of a signed distance function, our method uses an unsigned distance function and hence does not require any information about the local surface orientation.

Our algorithm estimates local surface confidence values within a dilated crust around the input samples. The surface which maximizes the global confidence is then extracted by computing the minimum cut of a weighted spatial graph structure. This cut can be efficiently converted into a closed, manifold triangle mesh. The use of an unsigned distance function avoids the topological noise artifacts caused by misalignment of 3D scans, which are common to most volumetric reconstruction techniques. Due to a hierarchical approach we can efficiently produce solid models of low genus even for noisy and highly irregular data containing large holes. Our method can handle input point clouds from a diverse set of different application settings such as model generation from raw laser-scanned data, image-based 3D reconstruction, and mesh repair.

The images show several input point clouds and the corresponding reconstructions generated by our algorithm.
Fragment-based image completion techniques are a very powerful tool to fill in missing pixel information, e.g., when removing a foreground object from a digital photo. The conceptual idea is to fill a hole in the image by copying small source fragments from known regions of the image such that they eventually completely cover the undefined region. The mutual overlap of the target fragments and the overlap between target fragments and the boundary of the hole is used to compute a similarity measure which controls the selection of the best source fragment candidate in order to guarantee a seamless appearance of the completed image.

The fundamental assumption, which justifies the fragment-based image completion approach, is that for a small enough image fragment, we can assume the scene, which is visible in this fragment, to be planar. However, the restriction to affine transforms of the fragments, as it has been done in the previous work, mathematically corresponds to the even more strict and somewhat unrealistic assumption that these planar scene fragments are aligned to the image plane.

We have developed a new system for interactive image completion which applies perspective corrections when copying fragments. Through a simple interaction metaphor the user can define a set of projective transforms. Based on this information the system rectifies the corresponding image regions and then performs the image completion in rectified image space. An intuitive extension of this user interface allows the system to handle even more complex scene geometries such as moderately curved surfaces (see example below). An automatic snapping mechanism for the points selected by the user guarantees continuity at the boundaries of adjacent rectified regions. User-defined feature information is taken into account by encoding feature proximity as an additional color channel to the image.
Toolpath Generation for Layered Manufacturing

Darko Pavic, Leif Kobbelt

Computer Numerically Controlled (CNC) milling is the process of machining physical objects usually from 3D digital model data provided by a CAD software. After generating such a model the next step in the processing pipeline is to generate toolpaths which are to be traced by a CNC mill in order to carve the model from a raw block of material.

We develop methods for three-axis and five-axis CNC milling for milling machines able to use arbitrary slugs which are created in the typical layered manufacturing manner, e.g., as done during a rapid prototyping process. For the toolpath generation we exploit the GPU computing power and for a given contour we compute a distance field on the graphics card and extract the offset curves robustly using the well-known Marching Squares algorithm. Our method interconnects singular offset curves properly in the sense that the (in practice usually preferred) down-milling is favoured over the up-milling. Besides the pure generation of the toolpaths we develop also framework simulation which visualizes the layered manufacturing as well as the milling process and allows early error detection.

A raw block of material to be used should be as small as possible in order not to waste material during the machining process. In our layered manufacturing setting we use a simple, yet effective method for generating volume minimizing raw material blocks. For a given orientation of the 3D model we simply draw its shadow and extrude it along the milling axis, so that the whole part is included in so created volume. The orientation is optimized in the sense that the corresponding “shadow volume” is minimized. The domain for computing the toolpaths can now be reduced to the intersection part between the current milling plane and the computed minimal slug of material.
The simulation of the propagation of radio waves is important in many aspects of mobile communications. Both in cellular phone networks and in personal wireless networks the knowledge of radio propagation behavior is essential. Therefore we have previously implemented a radio wave propagation algorithm based on photon tracing. However computation could not be done in real-time, which would be necessary for interactive analysis of radio networks, antenna placement or usage in a packet-level network simulator.

Thus we have now developed a solution to use the radio wave propagation simulation at interactive rates. The input of the algorithm is the scene geometry and a sampling of possible radio transmitter positions in the scene. We then compute a simulation of the radio waves for each of the possible positions. This step will take a few minutes but is only necessary once for each scene.

The result will be a set of up to a few hundred 3D images containing the field strength for each transmitter position. These results can now be viewed with our interactive transmitter placement tool which allows moving the transmitter around. This is achieved by interpolating the results of the precomputed simulations. This is done using programmable graphics hardware allowing for up to 150 frames per second in outdoor (a) and indoor (b) simulations. Note that all the simulations run in 3D, as opposed to other works, which only do 2D simulations on maps. The fact that the geometry can be arbitrary is especially important for indoor simulations, where wireless connections between different floors have to be simulated. Also note that complex shadowing effects due to buildings or walls obstructing the transmitter are simulated.

This same approach is also used to get more accurate results when simulating wireless networks in the ns-2 simulation toolkit. We allowed this widely used network simulator to use the precomputed radio wave simulations in order to use a more accurate physical layer model. Before this, radio wave simulations based on photon or ray-tracing techniques were simply too slow to be used in network simulators and less accurate models were used instead.
Global Illumination describes the problem of how light propagates through a scene and how to synthesize an image that looks like a photo, given some light sources and objects. When we turn on a light, some objects are lit, some lie in the shadows. The shadows themselves are never pitch black, but they too receive some indirect lighting. Also objects made of glass can transmit and refract light, which gives rise to effects like distortions and caustics. Objects made of metal can act as mirrors and also produce different visual effects. The phenomenon of global light transport is very complex and can be described by the general Rendering Equation. This equation is very hard to solve and our goal is to find efficient and good algorithms to approximate and conquer this problem.

To know the lighting of a scene is of importance not only for engineering, designing and architectural purposes (a), (b), but Global Illumination is also used in movies, advertisement, video games, art and many other areas. In fact every computer generated photorealistic picture uses Global Illumination in some way.

In order to evaluate our algorithms we want to be able to take a photo (c) and generate an image that is as similar as possible (d) to the original. Since the effects involved are so complex, the task of doing all this at interactive rates is a particular challenge. We are working on methods to allow the rendering of complex illuminated dynamic scenes as fast as possible, allowing interactive walkthroughs or manipulation of the objects in the scene.

There are different approaches of doing this, either by precomputing parts of the lighting situation or by simplification and parallelization. The first approach allows for great rendering speeds, but affords quite some time for the precomputation of each scene. It also needs great amounts of memory, which can be reduced by advanced compression techniques. The second approach is more flexible, since it does not depend on the specific scene geometry.
Fast Interactive Region of Interest Selection for Volume Visualization
Dominik Sibbing, Leif Kobbelt

To understand anatomical structures or for making diagnoses the generation of 2D images from volumetric datasets like MRI or CT scans is an important visualization task in medicine. Modern graphics cards can produce those images at interactive frame rates. Unfortunately pure MRI/CT scans contain a lot of information which one does not want to see all at once. Using common direct and indirect volume rendering methods the region of interest (ROI) often is occluded by non interesting parts of the scan.

In this project we describe a new method to support the segmentation of a volumetric MRI- or CT-dataset such that only the components selected by the user are displayed by a volume renderer for visual inspection. The goal is to combine the advantages of direct volume rendering (high efficiency and semi-transparent display of internal structures) and indirect volume rendering (well defined surface geometry and topology). Our approach is based on a re-labeling of the input volume’s set of isosurfaces which allows the user to peel off the outer layers and to distinguish unconnected voxel components which happen to have the same voxel values. Therefore we store a sparse representation of the connected components of a set of isosurfaces in a tree data structure. With a depth first traversal of the tree we determine the new labels of each component. For memory and time efficiency, isosurfaces are never generated explicitly in the rendering process. Instead a second voxel grid is computed which stores a discretization of the new isosurface labels. Storing these labels in the graphics card memory we implemented the masking of unwanted regions as well as the direct volume rendering of the ROI on the GPU. This enables interactive frame rates even while the user changes the selection of the ROI.

For a better 3D visualization quality we enhanced the volume renderer by integrating lighting and shadows.
Other Activities

Committees and Organization:

- Member of the SIGGRAPH 2006 Paper Committee
- Member of the international Program Committee: Eurographics 2006, Vienna, Austria
- Program Chair of the international Program Committee of the ACM Symposium on Solid and Physical Modeling 2006, Cardiff, U.K.
- Chair of the international Program Committee: Pacific Graphics 2006, Taipei, Taiwan
- Conference Chair, Vision, Modeling, and Visualization Conference VMV 2006, Aachen, Germany
- Member of the international Program Committee: Symposium on Geometry Processing 2006, Cagliari, Italy
- Member of the international Program Committee: SIBGRAPI 2006, Brazilian Symposium on Computer Graphics and Image Processing, Manaus, Brazil
- Member of the Program Committee 3rd GI workshop on Augmented and Virtual Reality, 2006
- Member of the international Program Committee: Geometric Modeling and Processing 2006, Carnegie Mellon, Pittsburgh, USA
- Member of the international Program Committee of the 14th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision, WSCG 2006, Pilzn, Czech Republic
- Member of the international Program Committee of the ACM/Eurographics Symposium on Point-Based Graphics 2006, Boston, USA
- Member of the international Program Committee: Shape Modeling International 2006, Sendai, Japan
- Member of the international Program Committee: Computer Graphics International Conference 2006, Hangzhou, China
- Member of the international Scientific Committee of the 6th SMAI-AFA conference on Curves and Surfaces 2006, Avignon, France
- Member of the international Program Committee: 3rd International Symposium on 3D Data Processing, Visualization, and Transmission 3DPVT 2006; UNC, Chapel Hill, USA, June 14-16, 2006

Offices:

- Chair of the Computer Science Department
- Head of the Bachelor/Master Commission
- Deputy of the Examination Commission
- Speaker of the GI section “Geometry Processing”
- Scientific Advisor, German-Israeli Foundation for Scientific Research and Development
• Member of the scientific board, Virtual-Reality Center Aachen (VRCA)
• Member of the regional industry club REGINA e.V.
• Director of the Steinbeis Transfer Center “Geometry Processing”
• Organizational Member of the Eurographics Association
• Reviewer:
  – DFG
  – Humboldt-Stiftung
  – German-Israelian Foundation
  – Studienstiftung des Deutschen Volkes
  – Deutscher akademischer Austauschdienst
  – Norwegian Research Council
  – Various tenure procedures
  – Various ACM, IEEE, SIAM and other journals
  – Most international top conferences
• Stephan Bischoff: Student Advisor, main study period computer science

Talks and Publications

Invited talks
Leif Kobbelt: The Reconstruction and Optimization Pipeline for 3D Meshes, Microsoft Research Asia, October 2006, Beijing, China
Leif Kobbelt: The Reconstruction and Optimization Pipeline for 3D Meshes, National Taiwan University, October 2006, Taipei, Taiwan
Leif Kobbelt: Structure Preserving Quad Re-Meshing, Tsinghua University, October 2006, Beijing, China
Leif Kobbelt: Augmentation and Pre-Processing of 3D models, CAD/CG2006 conference, October 2006, Jinan, China
Leif Kobbelt: Automatic mesh repair and optimization for rapid prototyping and simulation, Tallinn, aim@shape EU summer school, July 2006
Conference presentations

M. Botsch, M. Pauly, S. Bischoff, C. Rssl, L. Kobbelt: *Geometric Modeling Based on Triangle Meshes*, Eurographics 2006 tutorial, full day

M. Botsch, M. Pauly, S. Bischoff, C. Rssl, L. Kobbelt: *Geometric Modeling Based on Triangle Meshes*, SIGGRAPH 2006 course, full day


Martin Habbecke: *Iterative Multi-View Plane Fitting*, VMV Konferenz, Aachen, November 2006


Darko Pavic: *Interactive Image Completion with Perspective Correction*, Pacific Graphics, Taipei, Taiwan, October 2006

Publications


M. Habbecke, L. Kobbelt: *Iterative Multi-View Plane Fitting*, Vision, Modeling, and Visualization 2006, pp. 73-80


290
M. Botsch, M. Pauly, M. Gross, L. Kobbelt: PriMo: Coupled Prisms for Intuitive Surface Modeling, ACM and Eurographics Symposium on Geometry Processing, 11-20, Best Paper Award, 2006

M. Botsch, M. Pauly, S. Bischoff, C. Rössl, L. Kobbelt: Geometric Modeling Based on Triangle Meshes, Eurographics 2006 tutorial

M. Botsch, M. Pauly, L. Kobbelt, S. Bischoff, C. Rössl: Geometric Modeling Based on Triangle Meshes, SIGGRAPH Course Notes, 2006


L. Kobbelt: Computergraphik und Geometrieverarbeitung, RWTH Themen, 1/2006, ISSN 0179-079X


S. Bischoff, L. Kobbelt: Extracting consistent and manifold interfaces from multi-valued volume data sets, Bildverarbeitung für die Medizin (2006)


291
Staff

- Faculty:
  Univ.-Prof. Dr. rer. nat. Thomas Seidl
  E-mail: seidl@informatik.rwth-aachen.de
  http://www-i9.informatik.rwth-aachen.de

- Secretary:
  Hedi Klee

- Academic and Research Staff:
  Dipl.-Inform. Ira Assent
  Dipl.-Inform. Christoph Brochhaus
  Dipl.-Inform. Jost Enderle
  Dipl.-Inform. Ralph Krieger
  Dipl.-Inform. Emmanuel Müller
  Dipl.-Inform. Marc Wichterich

- Technical Staff:
  Detlef Wetzeler

- Student Research and Teaching Assistants:
  Farzad Afschari, Ismet Aktas, Sebastian Bitzen, Huy Do,
  Alexander Lachmann, Jan Lutter, Kilic Mahir, Michael
  Nett, Thomas Novotny, Haidi Yue, Linlin Xu
Overview

Research at Computer Science 9 focuses on the aspects of data management and data exploration. In our modern world, more and more digital information is stored and processed. Telecommunication data, medical diagnostic data, environmental data, gene pools, structures of proteins and digital multimedia data are only a few of many examples for large databases storing complex objects. Concerning the aspect of data management, we investigate the problem of storing large sets of complex objects in a way that the data can be searched and retrieved very efficiently. One of our research interests 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 required to represent the complex objects. Depending on the chosen data model it is possible to develop effective data management techniques while simultaneously achieving interactive response times for queries.

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

Similarity search in database systems is becoming an increasingly important task in modern application domains such as multimedia, molecular biology, medical imaging, computer-aided engineering and many others. The major reasons to research efficient algorithms for knowledge discovery in large databases are the huge amount of data and the need to turn such massive data into useful information and knowledge.

Our goals of data exploration include the development and study of 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 may be combined. For example, multi-dimensional indexing structures like R-trees or X-trees are very useful for the retrieval of the required information.

Efficient techniques for similarity search are the basics for many algorithms in the field of Data Mining. Classification and clustering, for instance, are two tasks out of the wide range of various data mining problems. Developing new algorithms for these purposes is especially necessary to meet the various requirements of different applications. Marketing, electronic commerce, fraud detection, astronomy, biomolecular and other multimedia data to name only a few of many application areas which need special data exploration algorithms.
Research Projects

Index Support for CFD Data Post-Processing

Christoph Brochhaus

High performance computing clusters similar to the one installed at the RWTH Center for Computing and Communication are utilized to execute complex simulations (e.g. from the field of computational fluid dynamics, CFD) delivering enormous amounts of data, often covering the range of many gigabytes of hard disc space. In order to produce significant visualizations and meaningful results, a post-processing step is inevitable to extract the desired knowledge from the raw data and to transform this information to the format required by the visualization engines of the virtual reality environment. This post-processing is mainly done by standard PC hardware due to their low cost. Current methods hold the raw data in main memory completely, thus limiting the size of the raw data and therefore restricting the level of detail of the simulation depending on the size of available main memory.

To overcome this restriction, we develop out-of-core techniques to enable efficient access to the data which is held on secondary storage. Research on these techniques include customizing and streamlining existing geometric index structures as well as developing new methods to store and access the data in real-time virtual reality environments. These index structures enable a variety of access and query methods, e.g. view-dependent isosurface or cutplane extraction (cf. figure 11). This allows for the use of a very high level of detail of the simulation combined with real time user interaction in virtual reality environments, e.g. the CAVE or HoloBench installed at the VRCA (Virtual Reality Center Aachen).

Figure 11: Isosurface extraction (left) and cutplane extraction (right)

294
UMIC (Ultra High-Speed Mobile Information and Communication) is a research cluster established under the excellence initiative of the German government. The goal of this cluster is the interdisciplinary design of communication systems providing an order of magnitude improvement of the perceived quality of service for the next-decade mobile Internet. We are participating in the research area Cross Disciplinary Methods and Tools (D).

While bandwidth of mobile networks and processing power of mobile devices are enhanced continuously, the energy capacity of mobile clients remains a bottleneck of mobile applications. To overcome the limitation, energy efficiency has to be considered through all layers of mobile communication. We focus our research on the energy awareness of applications especially for transmitting large volumes of data through broadcast channels.

Figure 12: Energy efficient data dissemination by using new indexing techniques

For energy efficient data retrieval from large databases over a wireless network, several models have been proposed where data is pushed from a server to mobile clients by repeatedly sending data streams without explicit requests from the clients. Mobile client devices are enabled to restrict their listening activities to transmissions they are interested in while being switched off in the remaining time and thus battery power can be saved significantly. Their
decision when to listen is based on index information which is sent as redundant information within the database. We propose new techniques for data dissemination in broadcast scenarios where we also consider the quality of the transmission channel. Furthermore the underlying layers are also considered so that the index information allows an energy efficient transmission but also the access latency can be optimized.

Interval Joins in relational databases

Jost Enderle, Christoph Brochhaus

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

Figure 13: Query using a relational interval tree

Intervals represent a fundamental data type for temporal, scientific, and spatial databases where time stamps and point data are extended to time spans and range data, respectively. For database applications on large amounts of data, not only intersection queries have to be processed efficiently but also general interval relationships including before, meets, overlaps, starts, finishes, contains, equals, during, startedBy, finishedBy, overlappedBy, metBy and after. Our new algorithms use the Relational Interval Tree, a purely SQL-based and object-relationally wrapped index structure for managing interval data. This technique therefore preserves the industrial strength of the underlying RDBMS including stability, transactions, and performance. The efficiency of our approach has been demonstrated by experimental evaluations on large sets of generated as well as real-life data. In order to support broader ranges of data with our approach, we will extend our algorithms to support intervals with floating-point valued endpoints. Furthermore, we plan to adapt the newly developed methods to similarity search as well as to various application domains.

296
Figure 14: 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. Furthermore, we enhanced our algorithms to support additional selection predicates on scalar and temporal attributes as well as additional join predicates on scalar attributes. We also investigated the applicability of our join algorithms to scenarios where one of the joining relations is provided by a stream.

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

Subspace Clustering & Classification

Ralph Krieger, Ira Assent, Emmanuel Müller

Many environmental, scientific, technical or medical database applications require effective and efficient mining of high dimensional data or time series of measurements taken at different time points. Particularly the analysis of concurrent and multidimensional sequences poses new challenges in finding clusters of arbitrary length and varying number of attributes. We developed a novel algorithm capable of finding parallel clusters in different subspaces. In one application the structural quality of rivers is analyzed. The resulting clusters are used by hydrologists to develop measures for river quality improvements.

Fast Nearest Neighbor Search

Marc Wichterich, Christoph Brochhaus

Utilizing spatial index structures on secondary memory for nearest neighbor search in high-dimensional data spaces has been the subject of much research. With the potential to host larger indexes in main memory, applications demanding a high query throughput stand to benefit from index structures tailored for that environment. “Index once, query at very high frequency” scenarios on semi-static data require particularly fast responses while allowing for more extensive precalculations. One such precalculation consists of indexing the solution space for nearest neighbor queries as used by the approximate Voronoi cell-based method. We research methods to overcome the difficulties faced (support of dimensionality...
reduction, indexability) and aim at significantly improving response times through limiting the dimensionality of both the data and the Voronoi cell approximations. The latter allows for fast Nearest Neighbor retrieval without any further loss of accuracy. Our prototype system shows speedup factors of up to five compared to other indexing structures for real world data sets.

**Fast EMD Search**

*Ira Assent, Marc Wichterich*

In virtually any scientific or commercial application such as medical and biological imaging or music archives users deal with tremendous quantities of images, videos or audio files stored in large multimedia databases. For content-based data mining and retrieval purposes suitable similarity models are crucial. The Earth Mover’s Distance (EMD) was introduced in Computer Vision to better approach human perceptual similarities. Its computation, however, is too complex for usage in interactive multimedia database scenarios. In order to enable efficient query processing in large databases, we propose an index-supported multistep algorithm. We therefore develop new lower bounding approximation techniques for the Earth Mover’s Distance which satisfy high quality criteria including completeness (no false drops), index-suitability and fast computation.

![Multistep filter concept with low-dimensional index on high efficiency filter, followed by high selectivity filter; thus avoiding most expensive EMD computations](image-url)

Figure 17: Multistep filter concept with low-dimensional index on high efficiency filter, followed by high selectivity filter; thus avoiding most expensive EMD computations
Other Activities

Teaching

During the summer term, Prof. Seidl was on sabbatical.

Lectures:

- Index Structures for Databases (winter 05/06)
- Models for Data Exploration (winter 06/07)
- Interdisciplinary team-taught lecture series for Medical Image Processing (with Priv.-Doz. Dr.rer.nat. Thomas Lehmann et al., winter 05/06 and winter 06/07)
- Interdisciplinary team-taught lecture series for Bionics (with Priv.-Doz. Dr.rer.nat. Harald Luksch et al., winter 05/06 and winter 06/07)
- Interdisciplinary team-taught lecture series for “Faszination Technik” (with Lehrerbildungszentrum Dr. Boelhauve, Meier et al., winter 05/06)
- Programming (winter 05/06, undergraduate service)

Seminars:

- Algorithms for Data Mining B-IT IPEC (winter 05/06)
- Complex Objects in Databases (summer 06)
- Medical Image Processing (with Priv.-Doz. Dr.rer.nat. Thomas Lehmann et al., summer 06)
- Methods and Tools (winter 05/06 and winter 06/07, undergraduate)
- Research Seminar Datamanagement and Data Exploration

Lab courses:

- Data Mining Algorithms (winter 06/07)

Other teaching activities:

- Contribution of a unit on “searching and sorting” to the support program for young talents “Helle Köpfe”
Diploma Theses

Finished diploma theses:

- Farzad Afschari: Index support for Warping Distance-based similarity search in sequence databases
- Halil Ibrahim Gülež: Intervals and interval predicates: efficient extension in relational indexing
- Christian Klaus: Index support for the postprocessing of CFD-datasets
- Philipp Kranen: Dimensionality reduction for the Earth Mover's Distance for fast multimedia-retrieval
- Philipp Meisen: Data mining techniques for the planning and organisation of truck convoys
- Emmanuel Müller: Efficient density-based subspace clustering
- Torsten Seitz: Interval Data and temporal aspects in change management databases
- Petra Welter: Local selective classification with subspace clusters
- Afzal Zubair: Retrieval of Spoken Documents Using Fuzzy Keyword Search in Syllable Transcript

Diploma theses in progress (working titles):

- Christian Beecks: Relevance feedback for EMD-based similarity search
- Dennis Meichsner: Time-based index support for interactive CFD-postprocessing
- Tobias Meisen: Efficient EMD-based similarity search using vector quantization
- Till Schulte-Coerne: Structure-oriented analysis of internet streams
- Haobo Song: Video-based recognition of train signals
- Andreas Steffens: Risk analysis of customer behavior via subspace outlier mining
Industrial and Academic Collaboration

- Ericsson GmbH: Efficient management of key figure time series in data warehouses
- GEVAS GmbH: Interval Management for Traffic Monitoring
- QSC AG: Data Mining Methods for network traffic analysis
- CIM-Aachen GmbH: Data Mining for databases in manufacturing
- ExaConsult: Data Mining Applications
- INFORM GmbH: Data Mining concepts for the prediction of delays in flight traffic
- RWTH Faculty of Civil Engineering, Section of Engineering Hydrology (Prof. Dr. Heribert Nacken): Data Mining for decision support in hydrology
- RWTH Faculty of Medicine, Department of Medical Informatics (PD Dr. Thomas Deserno, geb. Lehmann): Similarity Search in medical image databases
- RWTH Faculty of Medicine, Institute for Biomedical Engineering - Cell Biology (Prof. Dr. Martin Zenke): Data Mining in Gene Expression Databases
- RWTH Faculty of Medicine, Institute for Human Genetics (Dr. Michael Baudis): Subspace Clustering in Gene Expression Databases
- RWTH Faculty of Mechanical Engineering, Department of Rail Vehicles and Materials-Handling Technology (Prof. Dr. Torsten Dellmann): Video Mining
- Virtual Reality Center Aachen (Prof. Christian Bischof, Ph.D.): Index support for a graphics data server
- Research Cluster Ultra high-speed Mobile Information and Communication (UMIC) (coordinated by Prof. Dr. Gerd Ascheid): Wearable and environmental computing; Energy efficiency
- EU Project NiSIS (coordinated by ELITE Foundation): Taskforce on Nature inspired Methods for Local Pattern Detection
Reviewing Activities

Membership in program committee:

- ACM International Conference on Management of Data (SIGMOD 2006)
- IEEE International Conference on Data Engineering (ICDE 2006)
- International Conference on Very Large Data Bases (VLDB 2006)
- International Conference on Database Systems for Advanced Applications (DASFAA 2006)

Journals:

- IEEE Transactions on Knowledge and Data Engineering (TKDE)
- International Journal of Geographical Information Science (IJGIS)
- Information Processing Letters (IPL)

Publications


Assent I., Seidl T.: *Efficient Multi-Step Query Processing for EMD-based Similarity*, T. Crawford, R. Veltkamp (eds.): Content-Based Retrieval. Dagstuhl Seminar 06171


Seidl T., Enderle J.: *Binäre Suche, Algorithmus der Woche*, www-i1.informatik.rwth-aachen.de/~algorithmus/


Assent I., Wenning A., Seidl T.: *Approximation Techniques for Indexing the Earth Mover’s Distance in Multimedia Databases*, Proc. IEEE 22nd Internat. Conf. on Data Engineering (ICDE 2006), Atlanta, GA, USA.


Computer-supported Learning

Staff

- Head:
  Univ.-Prof. Dr.-Ing. Ulrik Schroeder
  E-mail: schroeder@informatik.rwth-aachen.de
  http://lufgi9.informatik.rwth-aachen.de

- Secretary:
  Adriana Stasch (June – December)
  Birgit Teguer (January – May)
  Phone: +49-241-80-21931
  Fax: +49-241-80-22930

- Research Assistants:
  Dipl.-Inform. Eva Giani
  Dipl.-Gyml. Nils van den Boom
  (funded by regio iT aachen)

- Technical Staff:
  Detlef Wetzeler

- Student Researchers:
  C. Habets, T. Holtermann, M. Lukas, A. Molitor,
  Z. Petrushyna
Overview

The group’s focus in research and teaching covers various topics in computer-supported learning and the didactics of computer science, among them:

- instructional design of content and eLearning functions:
  - software engineering methods and tools for the analysis, specification, design and implementation of eLearning scenarios, and contents;
  - innovative instructional theories and their realization with methods of computer science;

- systematic construction of eLearning components and systems:
  - analysis, design and implementation of eLearning systems;
  - frameworks for the implementation of innovative instructional theories and development of sophisticated learning and authoring tools;

- informative, individualized and semi-automatic feedback in (self-)assessments;

- didactics of computer science:
  - teaching computer science in school, university, vocational training, and further education;
  - the role of IT and media competencies in teachers’ education.

Furthermore, this year’s activities were dominated by establishing the center for integrative teaching and learning concepts (CiL) being responsible for the sustainable introduction of eLearning elements into the university’s study programs. The CiL designs the technological, instructional and administrative framework for blended learning at RWTH Aachen University. The main focus of 2006 activities were the design, development, and deployment of the central eTeaching & eLearning portal L²P in cooperation with the computer and communication center. The pilot phase successfully started this winter term with 30 lectures in 8 of the 9 RWTH faculties and about 4.000 students being active in the prototype eLearning system.

Christian Spannagel concluded his dissertation on “Benutzungsprozesse beim Lernen und Lehren mit Computern” at the Pädagogische Hochschule Ludwigsburg. In his dissertation, he designed, developed and evaluated a tool which allows to capture and symbolically represent user-software-interaction processes in order to support learning and teaching processes, which utilize software tools. The interaction processes can be automatically analyzed and structured and evaluated statistically. The requirements and design guideline were derived from various cognitive theories about human-computer interaction and multimedia learning as well as instructional theories and models. The tool and exemplary didactic scenarios were utilized in an empirical study in integrated natural science lessons in undergraduate school (8th grade).
Research Projects

L²P – eTeaching/eLearning portal of RWTH Aachen University

Ulrik Schroeder, CiL and CCC of the RWTH Aachen University in cooperation with Microsoft Deutschland GmbH and imc AG Saarbrücken

The learning platform that is developed and maintained by the CiL and the CCC of the RWTH Aachen University enables all professors and lecturers to enhance their lectures with eLearning in an easy way. For each course created in CAMPUS they can automatically generate an associated “virtual learning room”. For this, all necessary data and information is obtained automatically from CAMPUS, and students are registered automatically according to the CAMPUS sign-on.

L²P supports lectures by innovative instructional methods by providing digital content and learning materials, communication and collaboration functionalities, and established learning applications. The goal is to support extensively face-to-face teaching at RWTH Aachen University, to enrich it by eLearning and blended learning, and to support and simplify the administrative process involved for tutors, learners, and administration.

L²P offers an easy access to the electronically supported teaching for those who have little or no experience with eLearning, as well as to facilitate more complex and sophisticated eLearning.

eSWES (eLearning Systems for Water and Environmental Studies)

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

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

**BLEND-XL - Finding a Balance in Blended Learning with eXtra Large Student Groups**

*Ulrik Schroeder, Eva Giani – with partners from Delft University of Technology, University of Northumbria at Newcastle, University of Zilina, RWTH Aachen University, and Academy of Humanities and Economics in Lodz*

Teaching large groups of students is an increasingly common phenomenon in higher education, especially in the first year of study, when many students follow introductory courses or core modules. These courses are often taught in large groups in big lecture theaters, which is found de-motivating by both students and teachers because of the lack of communication. As a consequence, there is a higher attrition rate and a lower success rate on the exams than in small-scale education, especially in technical studies where a high dropout rate is common and is leading to a shortage of engineers at a European level.

This three year EU-project started in October 2005 and is coordinated by the Centre for Education and Technology of Delft University. The idea behind this project is that large-scale education can be made more motivating and more personal through the effective use of ICT. This project focuses on the design of useful pedagogical models for learning situations in which face-to-face activities are mixed with online activities, often referred to as “blended learning”.

**Ali – Aachener eLeitprogramme der Informatik**

*Ulrik Schroeder, Nils van den Boom – with regio iT aachen and computer science teachers of Aachen high schools*

The intention of the ALI project is to develop high quality digital teaching and learning content for computer science education at high schools. Partners of the project included regio iT aachen, operating the eLearning platform to share the digital learning units among schools, as well as a number of computer science teachers of six Aachen high schools. The instructional concept chosen for the project are so called “Leitprogramme”, which are best suited for education with eLearning units, especially if the content has been designed by a different author than the teacher of the class. The purpose of this method is to allow pupils to learn at their individual pace in a relaxed
environment.

The basic concept of Leitprogramme, which were developed at the ETH Zürich, consists in completely elaborated classes in written form. As far as content is concerned, they consist of chapters, each with a motivation of the topic and the objectives of the chapter, short explanatory sections with detailed examples and exercises with solutions for self assessment, and a concluding examination concerning the chapter allowing the teacher to assess the students’ learning progress. To allow for an individual learning pace, students with a fast learning pace are provided with additional material (“Additum”) which covers further interesting aspects that are not part of the regular curriculum. An essential factor of the empirical proven success of the Leitprogramm method is the mastery principle: learners can only tackle the next chapter after mastering the previous one. The average result of 36 studies shows that students of classes employing this method can learn about 25% more or easier than with regular and good instruction.

The Computer-supported Learning Research Group advanced this method in this project to the blended learning method of “eLeitprogramme”. For this, the basic structure and properties of the Leitprogramme were adopted and enriched by advantages of eLearning, comprising multi-media elements as well as interactive tests which allow for automatic feedback concerning the exercises and the teacher’s control of the students’ learning progress.

### Jacareto

*Ulrik Schroeder, Christian Spannagel (PH Ludwigsburg)*

*Jacareto* is a framework that offers the functionality necessary for capturing user-program interaction on graphical user interfaces written in Java. It can be used

- to realize executable specifications of interactive systems using GUI-prototypes;
- to integrate self-explanatory tutorials in help systems of software;
- to implement instructional scenarios focussing on the learning process;
- to realize usability studies of interactive systems.

In contrast to other capture & replay tools, Jacareto replays recorded interactions between a user and a software system on instances of the observed software itself. Consequently, the replay puts the software system in the state that the user reached before. The protocol of the interactions is represented symbolically. Thus it can be automatically analyzed and structured, and to some extent also interpreted and statistically evaluated.
Other Activities

U. Schroeder

- Scientific leader of the eLearning Center of RWTH Aachen University: Center for integrative eTeaching and eLearning Concepts (CiL) (see http://www.cil.rwth-aachen.de);

- Member of the committee for the education of secondary school teachers of RWTH faculty 1, which defined new curricula and regulations for teachers education in computer science (see http://lehramt.informatik.rwth-aachen.de);

- Member of the committee for studies in Computer Science, developing the Bachelor/Master structure and regulations and its accreditation by ASIIN;

- Program Committee Member of the Conference “4. e-Learning Fachtagung Informatik der Gesellschaft für Informatik (DeLFI)”, Darmstadt, September 2006;

- Program Committee Member of the Conference “6th IEEE International Conference on Advanced Learning Technologies (ICALT)”, Kerkrade, The Netherlands, July 2006;

- Organizer of the workshop “Lernwelten 1: Informatik zum Anfassen für Schülerinnen” of the Aachen event in the computer science year 2006;

E. Giani

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

Finished Diploma Theses

- Tobias Schierge: Entwicklung eines Planspiel-Rahmenwerks zur generischen Erstellung von Entscheidungs simulationen

- Thomas Michel: Analyse kognitiv komplexer Systeme mittels automatisierter Interaktionsaufzeichnung

- Katharina Georgantopoulos: Modellierung und Implementierung eines Rahmenwerks zur systematischen Entwicklung situierter Lernumgebungen für die Einführung in die OO-Programmierung

- Dagmar Rostek: Möglichkeiten der softwarebasierten Unterstützung in der Moderation

- Lilian Sunadi: Definition und Implementierung von Aufgabenklassen für komplexe Mathematikaufgaben in eLearning Systemen
Finished State Examination Theses


Courses

Our group offered the following lectures, seminars and lab courses focusing on eLearning and “Fachdidaktik Informatik”:

- Lecture Web Engineering in WS 05/06
- Lecture Fachdidaktik Informatik 1 in SS 06
- Fachdidaktisches Seminar zur Schulpraxis in WS 05/06 and SS 06
- eLearning Engineering lab course in WS 05/06 and SS 06
- Fachdidaktisches Blockpraktikum in WS 05/06 and SS 06

Talks and Publications

Talks

U. Schroeder: Design der integrierten Lernplattform der RWTH, Workshop eLearning Plattformen, Darmstadt, Germany, April 21, 2006
U. Schroeder and P. Rohde: CiL – die eLearning-Strategie der RWTH Aachen, Workshop mit eLearning Center der TUM, München, Germany, May 12, 2006
U. Schroeder and P. Rohde: Anforderungen an ein Lehr- und Lernportal an der RWTH Aachen, iTeach AG, Aachen, Germany, May 19, 2006
P. Rohde: Das CiL der RWTH Aachen: eLearning aus einer Hand, eUniversity Workshop, Duisburg, Germany, July 7, 2006
U. Schroeder: Elektronische Leitprogramme in der Informatik, Kick-off Workshop des ALI Projekts, Aachen, Germany, September 6, 2006
U. Schroeder: L²P: Lehr- und Lernportal der RWTH Aachen, Tag der Innovation, Berlin, Germany, September 19, 2006
N. van den Boom: Konzepte der Lehramtsausbildung in Informatik, BWINF 2006, Rahmenprogramm des Finale des Bundeswettbewerbs Informatik, Aachen, Germany, September 2006

U. Schroeder: Introducing Blended Learning on a Large Scale, EECS Seminar, International University Bremen, Bremen, Germany, September 29, 2006

U. Schroeder: Centrum für integrative Lehr- und Lernkonzepte der RWTH Aachen, AG eLearning der Medizin: Informationsveranstaltung eLearning, Aachen, Germany, November 8, 2006


U. Schroeder and P. Rohde: \(L^2P\) als integriertes Lehr- und Lernportal auf der Basis von Microsoft Sharepoint, regio iT aachen, Aachen, Germany, November 8, 2006

P. Rohde: Integration von CAMPUS Management und eLearning, Strategie-Workshop der Uni Karlsruhe, TU München und RWTH Aachen, Karlsruhe, Germany, Dezember 8, 2006


Publications

U. Schroeder, Nils J. van den Boom: ali Aachener Leitprogramme der Informatik, accepted for INFOS 2007, 12. GI-Fachtagung Informatik und Schule

Martina Ziefle, Ulrik Schroeder, Judith Strenk and Thomas Michel: How younger and older adults master the usage of hyperlinks in small screen devices, Computer/Human Interaction Conference, CHI 2007, accepted for publication

Michael Gebhardt, Philipp Rohde, and Ulrik Schroeder: Effizientes und nachhaltiges eLearning an der RWTH Aachen durch das integrierte Lehr- und Lernportal \(L^2P\) und das CAMPUS-Informationssystem, Integriertes Informationsmanagement an Hochschulen - Quo Vadis Universität 2.0?, 8. Internationale Tagung Wirtschaftsinformatik, accepted for publication


Media Computing

Staff

• Faculty:
  Prof. Dr. rer. nat. Jan Borchers
  borchers@cs.rwth-aachen.de
  http://media.informatik.rwth-aachen.de/

• Secretary:
  Clarissa de Gavarelli
  Tel.: +49-241-80-21051
  Fax: +49-241-80-22050

• Visiting Researchers:
  Elaine M. Huang, Ph.D.

• Research Assistants:
  Rafael Ballagas, M. Sc.
  Eric Lee, M. Sc.
  David Holman, M. Sc.
  Dipl.-Inform. Daniel Spelmezan
  Dipl.-Inform. Thorsten Karrer

• Student Researchers:
  Eugen Yu, Sven Kratz,
  Yvonne Jansen, Anna Koster,
  Henning Kiel, Sarah Mennicken,
  Christian Mattar, André Kuntze

• Technical Staff:
  Eric Lee, Yvonne Jansen
Overview

The Media Computing Group at RWTH Aachen University conducts research in Media Computing and Human-Computer Interaction (HCI) that goes beyond today’s graphical user interface and desktop metaphor. Grounded in computer science, we develop and study new interaction theories, techniques, and systems in the areas of interaction with multimedia, ubiquitous computing environments, tangible user interfaces, and HCI design patterns. Our goal is to make the Brave New World of ubiquitous multimedia technologies useful by making it usable.

New media technologies, such as interactive TV or electronic books, often distinguish themselves through their capability for interaction. Their user interface, however, lags far behind its technological potential: today’s “media players” still largely resemble a 1950’s tape recorder. Multimedia interaction is stuck in the 30-year-old desktop metaphor—perfect for document work, but not for media processing. This bottleneck is giving HCI a significance push similar to the explosion of Computer Graphics in the 1990’s. It enables, but also requires us to rethink some central paradigms of interacting with information, especially time-based media.

New interaction techniques can re-enable established routines from the pre-digital world, or create new ones unique to the interactive medium. Our interactive exhibits, for example, enable users to interact with the rich structure of musical data streams—to find a piece in a musical database by humming it, improvise to a piece with computer support, or conduct an actual audio and video recording of the Vienna Philharmonic. This inevitably leads to fundamental research questions in computer science, such as real-time time stretching of A/V streams, conducting gesture recognition, and cognitive modeling of the human conducting process.

Beyond such individual systems lies the realm of media spaces, entire environments in which several key dimensions of complexity increase—multiple users interact with multiple media, using multiple systems, devices, and applications. History has shown that, as technology matures, it fades into the background of a newly augmented reality, instead of leading to virtual realities. But which devices and interaction modalities, if any, will be playing an equally dominant role in this post-desktop scenario as mouse, keyboard, and monitor in today’s desktop-centered systems? We have built the Aachen Media Space at our department, a next-generation interactive environment, to further explore this exciting new area of research.

Trying to prototype new, physical post-desktop user interfaces for such interactive spaces has led us to the development of the iStuff toolkit. As a result, questions such as how to handle inevitable latency in a decentralized user interface, new forms of feedback, and preferred modalities when interacting with media in such environments, have become better understood.

The increasing momentum in this field also calls for new, more efficient ways to capture, structure, discuss, and ultimately formalize and standardize the rapidly growing body of knowledge and experience in interaction technologies and techniques.
with multimedia. One way to express and distribute this kind of knowledge are our Interaction Design Patterns, combining the advantages of existing widely used formats such as general design guidelines, design rationale, and specific style guides.

Our group builds upon these results and continues to chart new territory in interactive multimedia research, in collaboration with international partners in research and industry, including Stanford University, KTH Stockholm, ETH Zürich, UCSD, and others. We are a member of the international RUFAE network that conducts research on user-friendly augmented environments, and of the DFG-funded UMIC Excellence Cluster in Ultra-Highspeed Mobile Information and Communication. We also offer courses and research opportunities within the Media Informatics Master’s Programme at the Bonn-Aachen International Center for Information Technology (B-IT). This center, established in 2002 and located in Bonn, offers highly selective International Master’s Programmes in Applied Information Technology as well as summer/winter schools to qualified Computer Science students.

**Research Projects**

### The Aachen Media Space

*Jan Borchers, Eric Lee, Rafael Ballagas, Daniel Spelmezan, David Holman, Thorsten Karrer*

The Aachen Media Space is a new interactive room, a computer-augmented environment for collaborative media-based activities, that our group is currently creating as part of our infrastructure. It features a notable non-presence of computers in their traditional form. Instead, it has the general atmosphere of a relaxed environment that invites collaborative activities. Its primary users are the research group members and senior students working on projects in the group. Typical tasks include interaction with multiple media, but also brainstorming, meeting, and presentation activities.

The space serves several functions: It provides an everyday social space to meet, discuss, and present work. It also serves as a test bed for new developments in multimedia computing done by students and researchers. Finally, it houses a gallery of outstanding projects (such as various interactive exhibits) that can be demonstrated directly in the Media Space, or moved out to external venues (conferences, etc.)

This makes the Media Space not only a crucial “melting pot” providing an integrating theme and focus for the work of the group, but also turns it into an excellent environment to demonstrate our research projects (and possibly those of other interested CS groups) to visiting academic peers and current and future industrial partners. Experience from working at several prior universities has shown that, as project artifacts, these running systems frequently become highly sought after by the institution in order
to serve as a showcase during public-relations events and on similar occasions, helping to attract prospective students, researchers, and support from funding agencies and industry, and even to give the institution a more interesting profile among the local community.

The room design is centered around eight mobile 40” high-contrast, high-resolution interactive wall displays distributed around the room that can be read conveniently despite daylight conditions, several group tables with built-in displays that can be joined into a large structure, and informal seating in a corner. Research shows that having these amounts of display real estate fundamentally changes how people interact with information.

A video conferencing unit links the space to research institutions around the world, fostering the continuation of existing international collaborations with institutions such as the Royal Institute of Technology Stockholm and Stanford University, and the establishment of new research contacts. Several untethered tablets are available for sketching, browsing, and interacting with multimedia data streams within the Media Space.

A speaker array allows for localizable audio signals at high quality. The array is handled by a room-wide audio server that any machine in the room can access to route its acoustic output to the array. This is achieved using our Audiospace middleware.

The room features raised floor and ceiling cable trays to facilitate cabling, installing sensors, cameras, microphones, and other technology necessary for a multimedia environment. It distinguishes itself from our Laboratory through the tasks it is designed for. Basic everyday development is not an activity to happen in the Media Space since by definition it hides that technology (no access to multiple keyboards, mice, monitors, CPUs, etc.). In the final setup the two rooms will be adjacent to each other to ensure that the development-oriented work in the Laboratory and the activities in the Media Space evolve in tight coupling with each other. Students can also go to the Laboratory in order to access a Media Space machine for administrative tasks. Media Space and Laboratory are based on Apple hardware.
During the last year, the Media Space has been used for regular group meetings, presentations, video conferences and student projects.

**Large Displays and Multi-Display Environments**

*Elaine M. Huang*

Elaine M. Huang, PhD, of Motorola Labs has received a fellowship from the Alexander von Humboldt Foundation to conduct research at the Media Computing Group on the topic of large displays and multi-display environments. From January 2007 until December 2007, Elaine will be conducting qualitative studies of large electronic displays in public deployments to understand how they are perceived, used, and accepted by people in non-research settings. The findings of this work will be conveyed to the research community to inform the design and deployment of future large display applications. The work will incorporate several methods for data collection and analysis, including contextual inquiry and grounded theory affinity analysis.

*Large displays in our Media Space*

**iStuff & iStuff Mobile**

*Rafael Ballagas, Jan Borchers*

iStuff is a toolkit of physical input and output devices, such as buttons, sliders, and sensors, that can be used to quickly prototype tangible user interfaces (TUIs). This can dramatically improve the quality of tangible interface design by allowing for many iterations in the design process, similar to the way graphical user interface (GUI) toolkits have improved the development lifecycles of application GUI development. The iStuff toolkit is designed specifically to support prototyping multi-modal, multi-user interaction in ubiquitous computing (ubicomp) environments. It leverages
a proven ubicomp infrastructure known as the Event Heap. Another strength of the iStuff project lies in its facilities for interoperability and reconfiguration provided by the Patch Panel middleware. The Patch Panel allows users to map devices to actions in the room, and thereby to incrementally integrate physical interfaces into a larger interactive system without changing any code. We are continuing to research and improve different aspects of the toolkit. Our goals are to understand and deal with the latency inherent in distributed ubicomp user interfaces, to help bridge the gap between the crossover from tangible prototype to final product, and to understand how important desktop interface concepts like focus and selection translate to the ubiquitous computing domain. The toolkit also helps us and our students to explore novel post-desktop user interfaces.

iStuff Mobile is an extension to the iStuff toolkit. It is a rapid prototyping platform that helps explore novel interactions with mobile phones. It combines sensor network platforms, mobile phone software with the existing iStuff framework. Interaction designers can use the framework to quickly create and test novel sensor-based interactions without making internal hardware modifications to the mobile phone handset. Our goal is to use this extension to explore novel interactions that combine mobile phones and ubiquitous computing, as well as to provide a design tool for ubiquitous computing research.
Central to the question of rapid prototyping is how designers specify the different interactions and their intended results. We are experimenting with a new Patch Panel GUI that extends Apple’s Quartz Composer as an intuitive visual interface to establish relationships between user actions and application feedback. We are researching how these visual programming environments compare to other programming environments such as scripting languages and how these different approaches effect the design process. iStuff and iStuff Mobile are available as open source from our website.

**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.

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 has been integrated into the third Personal Orchestra system, *Maestro!*, and was installed in the Betty Brinn Children’s Museum in Milwaukee, USA on March 11, 2006.
DiMaß is a technique for direct manipulation of an audio timeline, with continuous, high-fidelity audio feedback.

DiMaß consists of three parts (see Figure). A motion estimator receives position events $p(t)$ from an input device such as a mouse and calculates the desired audio position $x(t)$, and velocity $v(t)$. These parameters are fed into an input tracker that computes an adjusted audio play rate $r(t)$. Finally, the audio is processed using PhaVoRIT, a time-stretching algorithm that preserves the original audio pitch with high-fidelity. Unlike similar, existing time-stretching modules, PhaVoRIT supports arbitrary, including backwards, rates. After time-stretching, an updated audio position $a(t)$ is fed back to the input tracker to maintain precise audio to input synchronization.

The improved synchronization algorithm is the key contribution of this work, and together with PhaVoRIT, enables the unique combination of position control together with time-stretching feedback. Our current implementation offers a “viscosity” parameter that allows for smoother playback at the expense of decreased responsiveness (for example, maximum responsiveness would result in choppy playback, similar to skipping).

We implemented DiMaß in an audio editor prototype. In addition to the audio feedback while selecting an area on the waveform, a “toss” quasi-mode can be activated to allow the user to jump to distant parts of the waveform; such an interaction works especially well with a pen-and-tablet device and/or touchscreen.

STF: The Semantic Time Framework

Semantic Time is a theory for representing time and temporal transformations in interactive media systems. Traditional research in human-computer interaction is divided
into the domains of *user* and *computer*. In interactive media systems, we extend this classification to include a third domain, the *medium*.

Semantic time is a solution to the problem of mapping time from one domain to another. It is based on an interval structure tied to the semantics of multimedia, and is defined according to the needs of a particular application. In a computer music system such as Personal Orchestra, these intervals could be defined as the beats of the music; in a speech system, they could be phonemes or words.

The mapping between semantic time and presentation time results in a time function. These time functions can then be used to specify *synchronization* as a set of constraints on different timebases; for example, when synchronizing audio to video, synchronizing beats of a musical recording to conducting gestures. These time functions can also be used to form a temporal algebra for manipulation of beat microtiming.

Semantic Time is implemented as part of the Semantic Time Framework, an open source software library for building interactive multimedia systems (http://styme.org). The Semantic Time Framework forms the foundation for both DiMaß and Personal Orchestra.

### The Regensburg Experience

*Rafael Ballagas, Eric Lee, David Holman, Jan Borchers*

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

**REXplorer**: With REXplorer, we want to offer an alternative to people who find standard tourist offerings a little boring. REXplorer immerses tourists in a world of magic and spirits that they explore to learn about different periods and people of Regensburg’s past. It is a game that is played in the city streets, extending the Regensburg Experience outside of the museum. The basic premise of the game is that certain landmarked buildings have locked magical spirits, secrets, and treasures inside of them, all of which can be unleashed and interacted with by the way of the proper magical spell gesture. Game players can rent a “magic wand”, a gesture sensing and location tracking smartphone running custom software and data necessary for the game. REXplorer is a unique blend of fantasy and reality, fiction and historical fact that gives tourist an entertaining perspective on the cities historical treasures.
REXplorer uses the camera-based gesture recognition to allow players to cast spells by waving the phone through the air.

REXplorer is a very exciting project for us as a research team because it breaks new ground in how people can use the mobile phone, a device that they carry with them everyday, to interact the environment around them. The project is also exciting because it makes contributions in the emerging field of serious games by applying a game approach to the serious topics of tourism and education. In addition, the project explores novel uses of mobile social software allowing tourists to interact with each other as well as with their friends and family at home through a specially designed travel journal weblog that reflects the events happening in the game. It also deploys our mobile gesture recognition framework.

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.

REXband: 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 consisted 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. We explored the value of this assistance on the harmonic (pitch) scale and on the temporal scale.

*REXband Drehleier*

### Multitouch Gaze-Aware Tabletops

*David Holman, Jan Borchers*

We are interested in gaze interaction and its applications to multi-touch tabletop displays. We are actively developing GazeTop, a multi-camera system that tracks multi-user eye movement, with no calibration, in a co-located setting. Knowledge of eye movement is highly relevant to tabletop interaction: eyes can point to distant targets on large tables, address usability issues imposed by rotation sensitive objects, such as menu and text, and facilitate new types of multi-modal interactions.

### Table Lemmings

*David Holman, Christian Mattar, Jan Borchers*

We are also exploring collaborative tabletop play via Table Lemmings, a game one player cannot win alone. Groups can use cooperative gestures, like tossing a ball that the other player catches, or accomplish complex interactions, like moving a game character through a dark treacherous dungeon. Supporting rich and complex gestures performed in parallel means players will experience game play that is similar to and more engaging than traditional board games. The system is an exhibition in the Industriom Museum in Kerkrade.
Children playing Table Lemmings

We have developed both the software and hardware for three multi-touch tables, the largest being 120cm by 90cm.

Mobile Interaction Support for UMIC

Thorsten Karrer, Jan Borchers

Our chair is part of the Ultra High-Speed Mobile Information and Communication research cluster (UMIC) that has been established under the Excellence Initiative of the German government. For UMIC, we are developing future applications and new human-computer interaction paradigms for next-generation mobile platforms. To this end, we have formed an interdisciplinary research group that also includes the Chair for Computer Graphics & Multimedia (i8, Prof. Dr. Kobbelt), the Institute of Communication Systems and Data Processing (IND, Prof. Dr. Vary), and the Institute for Communications Engineering (INT, Prof. Dr. Ohm). An initial round of several half-day presentations, one at each institute, gave the participating researchers an insight into the work and key competences of each group, and regular meetings have established additional links to other UMIC groups that work on communication protocols and theoretical aspects of the cluster.

Organic Interfaces

Thorsten Karrer, Jan Borchers

Organic Interfaces are an attempt to carry over the ideas of the Organic Computing initiative into the user interface. Nature-inspired properties of artificial systems like self-healing, self-organization, self-configuration, etc. are not only desirable for the system itself but also for the UI. This is closely related to Mark Weiser’s ubicomp vision of the computer as a ‘calm’ device: smooth and fluent change of states and
graceful degradation in case of errors allow for a non-distracting and productive user experience. Information representations that are modeled after human learning strategies and thought patterns facilitate the understanding of and the communication about complex data.

The idea has been explored in two subprojects so far, which will be continued to expand our concept of Organic Interfaces: Fly is an organic presentation software that moves from the current linear and slide-based presentation style to dynamic concept maps. We believe that this approach is more suitable for humans to understand complex topics. The associative PDA is a mobile device that completely relies on associations to enter, retrieve and store data. We believe that this semantic network representation of data can, though it will be highly individual, reduce the mental load for the user and speed up data entry and retrieval.

Fly and aPDA prototypes

Wearable Snowboard Assistant

Daniel Spelmezan, Jan Borchers

In this project we want to investigate how wearable computing can help trainees learn a new sports techniques and keep them motivated. We use sensors to detect wrong body movements and give immediate tactile feedback through actuators to indicate how to correct these wrong movements.

Learning new sports techniques, such as snowboarding, is often difficult, time consuming, and expensive. The success greatly depends on the feedback that trainees receive from their instructors. In a typical snowboarding lesson on the slope the instructor first explains how to perform a certain movement and demonstrates an appropriate exercise. The trainee then tries to repeat this exercise. He receives feedback from the instructor only when they can talk to each other, i.e., after the student performed the exercise.
Instead of waiting until the instructor can talk to the trainee, the trainee should get immediate feedback on his technique to better differentiate between correct and wrong movements. Sensors placed in clothing, attached to the human body or to the snowboard, can collect data on body rotation, knee bending, pressure and weight distribution. A wearable assistant could analyze this life sensor data and give tactile signals to key body parts in order to indicate mistakes and how to correct a wrongly performed movement. Results from this project can be applied to other sports techniques and to healthcare in unsupervised situations.

**HCI Design Patterns: Capturing User Interface Design Guidelines for Interactive Multimedia Systems and Environments**

*Jan Borchers*

HCI Design Patterns are a format to capture golden rules, design guidelines, and design rationale when building interactive systems. Building on our past work in this area, we have established a collaborative web site for the growing international community of researchers working on this topic (http://www.hcipatterns.org/) which we host as heads of the IFIP task group on this topic.

In 2003, we worked with international partners both at the CHI 2003 Patterns Workshop and online, to create a structural specification for HCI Design Patterns. The result, PLML (the Pattern Language Markup Language, pronounced pell-mell), is expressed as a Document Type Definition (DTD) in XML, and can be found on our web site.

Several pattern languages, including our own HCI Design Patterns for Interactive Exhibits, have been converted by their authors into PLML and been made available online for general use.

Together with partners in the RUFAE network, we are currently working on a new pattern language for interactive environments such as the Aachen Media Space. It will capture the lessons we learned by designing this and other similar spaces (at
Stanford and elsewhere), and should be of help to others planning to create similar environments.

Other Activities

We hosted the first World Usability Day at RWTH Aachen University in November 2006. The main purpose of the event was to provide an introduction to the topic and create an awareness of the problem of inadequate usability. We covered the fundamentals of designing for usability including an introduction to cognitive psychology, the historical development, the user-centered design process, and methods of prototyping and evaluation.

Our infrastructure consists of 3 XServe G5 servers with a 2TB XServe RAID, around 15 Dual-2GHz G5 desktop machines with 23” Cinema Displays and iSight cameras for the student Laboratory, and several G4 PowerBooks and MacBook Pros with similar periphery for our staff. The Media Space contains eight 40” mobile interactive LCD screens, 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 2006, examples of our work were on permanent display at the HOUSE OF MUSIC VIENNA, the Children’s Museum in Boston, at the Betty Brinn Children’s Museum in Milwaukee, and were also exhibited at the Tag der Informatik at RWTH Aachen on December 1st.

In 2006, we worked as reviewers for CHI, UIST, Ubicomp, TOCHI, and various other conferences and journals in Media Computing and HCI. We also host the hicpatterns.org home page as heads of the IFIP task group on this topic.
Talks and Publications

Talks

Jan Borchers:  *How To Make Sure Nobody Can Figure Out Your Interactive Art*, Digital Art Weeks ’06, ETH Zürich, Switzerland, July 13, 2006


Jan Borchers:  *The Aachen Media Space: Multiple Displays in Collaborative Interactive Environments*, CHI 2006 workshop on Information Visualization and Interaction Techniques for Collaboration across Multiple Displays, Montreal, Canada, April 22, 2006


Tico Ballagas and Jan Borchers:  *REXplorer*, Convention for Federal Computer Science Competition (Bundeswettbewerb Informatik), RWTH Aachen, Germany, September 20, 2006

Tico Ballagas:  *REXplorer: Making Learning Fun through Serious Games*, Learn Festival (Lernfest), Kerkrade, Netherlands, September 30, 2006

Tico Ballagas and Steffen P. Walz:  *REXplorer: a Serious Game in Regensburg*, Akademie Regensburg Private Art College, Regensburg, Germany, October 4, 2006

Tico Ballagas:  *iStuff Mobile: Rapidly Prototyping New Mobile Phone Interfaces for Ubiquitous Computing*, RWTH Aachen University, Aachen, Germany, Computer Science Dept. Open House (Tag der Informatik 2006), December 1st, 2006

Tico Ballagas and Steffen P. Walz:  *REXplorer: a game for tourists in a UNESCO world heritage protected city*, Italian National Research Council Workshop on Culture for the MassesVenice International University, Venice, Italy, December 6, 2006

Publications


Eric Lee and Jan Borchers: *DiMaß: Audio Scrubbing and Skimming with Continuous, High-Fidelity Feedback*, In WWDC 2006 Apple Worldwide Developers Conference (Scientific Poster Session), San Francisco, USA, August 2006


Rafael Ballagas, Steffen Walz, and Jan Borchers: *REXplorer: A Pervasive Spell-Casting Game for Tourists as Social Software*, In CHI 2006 Workshop on Mobile Social Software (MoSoSo), April 2006

Staff

- Faculty:
  Prof. Dr.-Ing. Stefan Kowalewski

- Secretaries:
  Marina Herkenrath
  Karin Vonderstein
  Telefon +49 241 80-21151 / -21152
  Email ixi@informatik.rwth-aachen.de
  Internet www-i11.informatik.rwth-aachen.de

- Technical Staff:
  Herwig Linß

- Research Assistants:
  Dipl.-Ing. Gerlind Herberich
  Dipl.-Ing. Daniel Klünder
  Dipl.-Inform. Jianmin Li
  Dipl.-Inform. Ralf Mitsching
  Dipl.-Inform. Jacob Palczynski
  Dipl.-Inform. Andreas Polzer
  Dipl.-Ing. Falk Salewski
  Dipl.-Inform. Bastian Schlich
  Dipl.-Inform. Dirk Wilking
Overview

Informatik 11 represents the field of embedded software at RWTH Aachen University. The chair was established in November 2003. Our research is focused on design methodology and software technology for software-intensive embedded systems. Based on the experiences with the current practice in industry, our aim is to develop methods and technologies for embedded software which help software engineers to meet today's increasing quality demands. Our approaches are built on a model-based engineering paradigm. Analyzable models shall be employed early and continuously during the development process and not only for functional but also for quality requirements. The methodological issues of interest include aspects as diverse as safety and reliability of software-controlled systems, quality evaluation of architectures, process organization by agile methods, and the application of formal methods to safety-critical systems, and many more.

With respect to teaching, we further elaborated our lectures for the specialization area Embedded Software. The curriculum is currently divided into the lectures Introduction to Embedded Systems, Embedded Software Engineering, Dynamic Systems for Software Engineers, Formal Methods for Embedded Systems and Safety and Reliability Engineering. In all lectures we try to create a sensitivity to real-world requirements in the embedded systems industries and enable computer science students to communicate properly with control engineers. The same spirit of cross-disciplinary thinking is driving the preparation of a new Masters program in Control Engineering Science scheduled to begin in the winter term 2007. It will be offered by three faculties – computer science, mechanical engineering, and materials engineering – and be open to graduates from all of these and comparable disciplines.

In 2006, the number of research assistants at the chair doubled. We successfully acquired funding for a collaborative research project from the German Federal Ministry for Education and Research in the program “Software Engineering 2006” and we are involved in the DFG Research Training Group Algorithmic synthesis of reactive and discrete-continuous systems and the Excellence Cluster Ultra High Speed Mobile Information and Communication Systems. One of our secretaries, Maria Witte, left for a permanent position, and we welcomed our new secretary, Karin Vonderstein.

Life at Informatik 11 in 2006 was very much shaped by our involvement in administration and basic teaching. As the head of the examination board, Prof. Kowalewski was actively taking part in the preparation, accrediting and implementation of the new Bachelor and Master programs in Computer Science. We were also responsible for the first semester Bachelor courses Technical Computer Science and Electrical Engineering Fundamentals of Computer Science, and we are currently building up two laboratory courses for the second and third semester. Finally, the chair organized the “Tag der Informatik” in 2006. All this would not have been possible without the extraordinary commitment of all the people at Informatik 11.
Research Projects

Algorithmic Synthesis of Hybrid Control Systems

Gerlind Herberich, Stefan Kowalewski

Within the DFG Research Training Group “Algorithmic synthesis of reactive and discrete-continuous systems” (AlgoSyn) we focus on the synthesis of hybrid control systems. Methods for the synthesis of control systems have been developed for purely continuous and for purely discrete systems. However, real control systems are often hybrid, that is to say that discrete as well as continuous dynamics have to be considered. In many cases, the modeling of such hybrid systems can be realized by combining discrete transition systems with piecewise linear continuous transfer elements. Yet, algorithms for the synthesis of this class of systems only exist in quite rudimentary form. Therefore, we aim at developing a synthesis approach for hybrid systems and exploring its application potential. This work started in February 2007.

Automotive Software Engineering

Daniel Klünder, Stefan Kowalewski

The dramatically increasing amount and importance of software in automotive electronic systems poses new challenges to the engineering of such systems. Today’s cars host nearly 1 GByte of code distributed over up to 70 electronic control units 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 architecture. Therefore we are interested in design and analysis methods for system and software architecture which support the achievement of predefined quality goals and, in particular, meet current requirements like composability and exchangeability of software components from different sources and over the complete vehicle network.

The Abstract State Machines (ASM) method offers a practical and scientifically well-founded approach to high-level system design and analysis by guiding the developer seamlessly from requirements capture to implementation. So called ground models are used for a sufficiently precise, unambiguous, consistent, complete and minimal system description resulting from requirements elicitation. The formal semantics of ASMs enable high-level validation and verification through the execution of abstract models. They can be refined down to the implementation level by accurately linking models.
at successive stages of the system development cycle in an organic and effectively maintainable chain of coherent system views.

We are working towards an application of the ASM method for an automotive use case, exploiting their formal semantics for the description of component behaviour as well as component interaction for hard- and software. The composition and integration of several components is supposed to allow the consideration of non-functional features as early as possible.

Scalable Software Architectures for Massively Distributed Systems

Jianmin Li, Stefan Kowalewski

The involvement of Informatik 11 in the research cluster “Ultra high-speed Mobile Information and Communication systems” (UMIC) of the Excellence Initiative of the German government is in the field of software architecture design and evaluation. In the development of software-intensive mobile systems, software architectures decide whether a design fulfills the business-related non-functional requirements like reliability, maintainability etc. Several approaches have been developed, e.g. model-based software development, scenario-based architecture evaluation techniques etc. However, none of these approaches are sufficiently mature to be applicable to software development for large scale, distributed and dynamically changing mobile systems.

The goals of our research project are the application of state-of-the-art software architecture design methods to mobile systems, the evaluation of non-functional properties, in particular scalability, and the conceptual preparation of a model-based development for UMIC systems based on formal descriptions. As a modelling framework, we are focussing on Abstract State Machines as a general representation including functional behavior as well as selected non-functional properties.

Hybrid Control and Variability in Automotive Applications

Ralf Mitsching, Stefan Kowalewski

The increasing complexity of automotive control systems calls for more powerful design approaches. Successful designs approaches, in which costly and time consuming re-design cycles are avoided, can only be achieved using efficient design methodologies that allow for component re-use and evaluation of platform requirements at the early stages of the design flow. The high variability of powertrain and engine types as well as of sensors, actuators, control strategies and implementation platforms result in a high variability of the embedded software, which need to be handle efficiently.
Our approach is to introduce variability management in the model based development of embedded software with a focus on hybrid systems modelling. The Goal is to enable developers of automotive systems to systematically re-use hybrid models and other design artifacts.

In addition, the literature on Hybrid Systems is spread over different engineering fields such as control engineering, mathematical systems theory and computer science. In the context of the EU Network of Excellence Hybrid Control (HYCON) we are involved in creating a common reference archive. Our task is to assist in retrieving knowledge efficiently from the reference archive with advanced services.

Integration of model–based software engineering with model–based controller design (ZAMOMO)

Jacob Palczynski, Andreas Polzer, Stefan Kowalewski

ZAMOMO is a BMBF-funded project dealing with the “integration of model–based software engineering with model–based controller design”. The project goal is to bring together the different views, methodologies, models, tools and processes of the two disciplines of control engineering and computer science. The project is focused on the examplary application of automotive engine control systems.

Our main tasks are the design of an architecture for a rapid control prototyping (RCP) system, and the development of new methods of modelling controlled systems.

A RCP System has the task to support the validation of modelled controller by automatic code generation and conveniently hardware. Thus we first analysed constraints, functional and non-functional requirements for the RCP system. Based on these facts we developed an architecture which is able to deal with different hardware and different modelling tools.

The new methods of modelling controlled systems should generalize the existing modelling methods so that we can use it in very early phases of the developing process. Our approach is to look on the controlled system’s behaviour in a qualitative way. Since the behaviour is represented by the dependency of input and output signals, we generalise the behaviour by describing signals by sequences and dependencies of the characteristics.

The consortium consists of the Institut für Regelungstechnik of RWTH Aachen University, Fraunhofer Institute for Applied Information Technology (FIT), St. Augustin, VEMAC GmbH & Co. KG, Aachen, AVL Deutschland GmbH, Mainz-Kastel, and the Embedded Software Lab (Informatik 11).
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.

Embedded systems can be realized on basis of many different hardware platforms ranging from CPU based systems as microcontrollers (MCU) and digital signal processors (DSP) to Programmable Logic Devices (PLD) as Complex Programmable Logic Devices (CPLD) and Field Programmable Logic Arrays (FPGA). One of our interests is the influence of the decision for a certain hardware platform on the safety and reliability of the corresponding software. It is possible to improve safety and reliability of a system by finding the optimal combination of hardware and software.

In this context, we conducted empirical studies, which took place within graduate lab exercises, in order to get the necessary basic data. In these experiments different hardware structures were compared, e.g. MCU vs. CPLD and MCU vs. FPGA. The results show differences, but also similarities in the failure behavior with respect to systematic failures. Further analysis is done to investigate the specific potentials of MCUs and FPGAs with respect to safety related properties like encapsulation, testability, and reviewability.

In order to make our results available for other designers of safety-critical systems we plan to include them in a pattern catalogue using appropriate building codes.

Experimental Vehicle for Automotive Software Design
Falk Salewski, Andreas Polzer

The growing complexity of current automotive electronics and the lack of standards in this field lead to problems concerning non-functional properties of the software involved like discussed in the section Automotive Software Engineering. New approaches like drive-by-wire require adapted architectures and methods to deal with the according safety and reliability requirements.

In order to support our theoretical research we see a need for an experimental platform. This platform should be realistic on the one hand, but easy to handle in an academic context.
setting on the other hand. For this reason we chose a platform based on off-the-shelf model cars with a scale of 1:5.

These cars are usually equipped with hydraulic brakes and combustion engines. We replaced the original engines with electrical versions, powered by batteries. The original remote control had to be replaced in order to transmit data readable for computational units. All four wheels are equipped with optical speed sensors for speed measurement. In order to perform environment recognition ultrasonic and infrared sensors have been used (see figure 18).

![Figure 18: Experimental vehicle](image)

So far these cars have been used mostly in diploma and master thesis concerning safety and reliability properties (e.g. applying IEC61508, drive by wire). Other diploma theses are dealing with, e.g., applying design patterns on safety critical embedded systems and automatic parking concerning safety requirements.

---

**Model Checking Assembly Code for Microcontrollers**

*Bastian Schlich, Stefan Kowalewski*

The Embedded Software Laboratory has developed a model checker called [mc]square. The acronym stands for *Model Checking MicroControllers*. The tool is able to model check assembly code written for specific microcontrollers (ATMEL ATmega16, 32, 128L and Infineon XC 167). Currently a global and a local CTL model checking algorithm (on-the-fly) are both implemented in [mc]square.

The process followed by [mc]square is shown in Fig. 19. First, the user provides the specification given as a CTL formula and the program given as an Executable and Linking Format (ELF) file. The formula is used by the static analyzer and the model
checker component. The elf file is preprocessed and translated into human readable assembly code. Then, the static analyzer adds annotations to the assembly code, which are used by the simulator to limit the size of the state space.

After these preprocessing steps, model checking is started. The model checker fetches the first state from the state space and checks it for particular parts of the formula. Depending on the result of this check, it requests successors of this state from the state space. If these successors are not created yet, the state space uses the simulator component to create the needed states on-the-fly. This simulator component is not an ordinary simulator. It natively supports nondeterminism induced by, e.g., timers, interrupts, and input from the environment. Then, the successor states are returned to the model checker component and inspected. This process continues until a target state (proving or disproving the truth of the formula) is found or the complete state space is built. The result of the model checking process is given to the counterexample generator.

The generated counterexample is presented in assembly and in C code, as well as in the control flow graph of the assembly code, and also as a state space graph. The user can step through the counterexample and observe the contents of registers, variables, etc.
language, programming viscosity and commitment must be measured. These aspects belong rather to human sciences and thus a measurement principle from psychology, the Rasch model, has been borrowed. A first test involving the C language has been done with 140 participants from Heise-, RWTH-, and microcontroller.net-forums. Analysis of this data is currently done and results are soon to be published.

The other aspect that needs a strong control during experimentation is the product. In this case, the software developed by the experiment participants has to be tested in detail. In order to achieve this, a just-in-time compiler with an appropriate testing environment was developed on our Atmel microcontrollers. The resulting experimentation task allows measurement of single compiler features (taken as project progress) and allows to count the number of failures using a predefined test set.

These two aspects will be incorporated into an experiment to be executed in the fall of 2007. The aim here is to assess the influence of different length planning times on software projects. The controlled variable is the number of preplanned artifacts of the software projects together with a detailed time based planning for each participant. By altering the length and the level of detail, the optimal planning time shall be identified, e. g. the longest time period having the lowest number of changes.

Other Activities

Stefan Kowalewski:

Editing:

- Member of the Editorial Board (Herausgeberbeirat) of at-Automatisierungstechnik, Oldenbourg-Verlag, Munich
- Associate Editor, Journal on Discrete Event Dynamic Systems: Theory and Applications, Springer Verlag

Program committees:

- 2nd IFAC Conf. on the Analysis and Design of Hybrid Systems (ADHS), Alghero, Italy, June 2006.
- Int. Workshop on Discrete Event Systems (WODES), Ann Arbor, USA, July 2006.

• IEEE Int. *Conference on Control Applications (CCA)*, Munich, October 2006.


• 2nd International Symposium on Leveraging Applications of Formal Methods, Verification and Validation (ISOLA), Paphos, Cyprus, November 2006

Falk Salewski:
Program committees:

• 2nd International Workshop on Reconfigurable Computing Education, May 12, 2007, Porto Allegre, Brasil

## Talks and Publications

### Papers


**Talks**


342
Scientific Computing

Staff

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

- Secretary:
  Gabriele Meessen

- Lecturer:
  PD Dr.-Ing. H. Martin Bürker
  Dr. Torsten Kuhlen (Computing and Communication Center)

- Research Assistants:
  
  Dipl.-Math. Oliver Fortmeier *(funded by DFG within SFB 540)*
  Dipl.-Inform. Michael Lülfsmann *(since 11/2006, funded by DFG within SPP 1253)*
  Dipl.-Ing. Monika Petera *(funded by DFG within SFB 540)*
  Dipl.-Inform. Arno Rasch *(funded by DFG within SFB 401)*
  Dipl.-Inform. Jakob T. Valvoda
  Dipl.-Inform. Andre Vehreschild
  Dipl.-Inform. Andreas Wolf *(funded by GEOPHYSICA Beratungsgesellschaft mbH)*
Overview

A recurring theme of the research activities at the Institute for Scientific Computing is the interplay of methods from computer science with mathematics and engineering or natural sciences. Problems occurring in practice are often too complex to be solved with techniques from a single discipline. The enormous requirements with respect to data handling and computational power can be accommodated only with an interdisciplinary approach. Here, the central roles of computer science are to keep the complexity at a manageable level by making use of problem-inherent structure, and to provide appropriate software tools that allow users from technical or scientific disciplines to easily benefit from algorithms derived this way.

Our research addresses various topics of high-performance computing, including computational differentiation, parallel computing, and efficient numerical methods. Computational differentiation comprises the ensemble of techniques that, given an arbitrarily complex program computing some function $f$ (a large simulation code, say), yields another program that computes the derivative $f'$ along with $f$. These techniques rely on Automatic Differentiation (AD), which in turn is based on the fact that any program is built up from elementary operations, such as addition or multiplication, for which the derivatives are known. Starting with these “elementary” derivatives, the chain rule of differentiation is applied over and over again to obtain the derivative of the whole program. The associativity of the chain rule allows the elementary derivatives to be combined in many different ways, all leading to the same final result, but at widely differing costs. Finding the program that computes $f''$ at minimum cost is conjectured to be an NP-hard problem.

One particular area of research at our institute is the development or refinement of heuristics for reducing the cost of derivative computations with AD. In addition to optimized application of the chain rule, mathematical knowledge can be used to make the evaluation of the derivatives more efficient in terms of memory and operations. We also strive to transfer the AD theory into tools that enable practitioners to differentiate large programs involving complex control structures. Examples for such tools include the ADIFOR, ADIC, and ADiMat systems that are able to augment Fortran 77, C, and MATLAB 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

- \textit{Parallele Algorithmen zur Vorkonditionierung linearer Systeme} (Parallel Preconditioning Techniques for Linear Systems),

- \textit{Parallele Algorithmen und Software für iterative Methoden} (Parallel Algorithms and Software for Iterative Methods),

- \textit{Semantische Transformationen} (Semantical Transformations),

- Computational Differentiation,

- Automatic Differentiation in MATLAB,

- \textit{Virtuelle Realität} (Virtual Reality) offered in cooperation with the Computing and Communication Center.

In addition, seminars and practical courses are offered, giving a deeper understanding of HPC-related issues. More information on our teaching activities is available at \url{http://www.sc.rwth-aachen.de}.

**Research Projects**

Over the past years, the Institute for Scientific Computing has been fortunate to receive support from the Deutsche Forschungsgemeinschaft (DFG) within the Excellence Initiative, two Collaborative Research Centres (SFB), a Research Training Group (GRK), and a Priority Programme (SPP).

The Excellence Initiative aims to both promote top-level research and improve the quality of German universities and research institutions, thereby making a significant contribution to strengthening science and research in Germany in the long term, improving its international competitiveness and raising the profile of the top performers in academia and research. This national initiative involves three lines of funding: (a) graduate schools to promote young researchers, (b) clusters of excellence to promote world-class research, and (c) institutional strategies to promote top-level university research. The Institute for Scientific Computing is involved in the graduate school “Aachen Institute for Advanced Study in Computational Engineering Science” (AICES) and the cluster of excellence “Integrative Production Technology for High-Wage Countries”
Virtual Production Systems
C. Bischof, T. Kuhlen

This project is part of the cluster of excellence “Integrative Production Technology for High-Wage Countries” at RWTH. Virtual production systems are an important research topic in production technology. Simulation is a fundamental tool in the analysis and prediction of complex phenomena, especially for planning oriented questions in production process chains. The fields of material science and manufacturing technology have a degree of complexity that requires several simulation models to be completely understood. “The Ontology and Design Methodology of Virtual Production Systems” is the research area of the cluster of excellence that focuses on building an interconnected network of distributed simulations. Here, we are going to develop a scientific workbench for the analysis and steering of virtual production systems, making use of advanced real-time visualization and interaction methods. Based on GRID technologies, we will build an integrated platform for coupled soft- and hardware resources. Further information is available at http://wzl-lotus3.wzl.rwth-aachen.de/cms/exzellenzcluster/de/projekt.html

Computational Differentiation in Numerical Flow Analysis
A. Rasch, C. Bischof, M. Bucker

This subproject of the Collaborative Research Centre (SFB) 401, “Modulation of flow and fluid–structure interaction at airplane wings”, is aimed at developing efficient techniques for computing partial derivatives for Navier–Stokes Computational Fluid Dynamics (CFD) solvers. Such partial derivatives are needed, for instance, in sensitivity analysis and in design optimization. Due to strong non-linearities of the solution, as well as very high memory and runtime requirements of the simulation software, the traditional approach of approximating the derivatives with divided differences is not appropriate in these applications, in particular in three dimensions.

Therefore we rely on Automatic Differentiation (AD) tools for obtaining the derivatives along with the simulation results. Using the ADIFOR tool, we augment the TFS CFD solver, developed at the Aerodynamics Institute (AIA) of the RWTH, with code for computing partial derivatives, in particular the derivatives of the computed velocity or pressure fields with respect to fluid and geometrical parameters. The availability of such accurate derivative information is crucial if the TFS code is used within some optimization framework, e.g., for the estimation of turbulence parameters and wing shape optimization.
Furthermore, Automatic Differentiation is employed to obtain the analytic flux Jacobian for an implicit Newton-Krylov method which is used in the recent flow solver QUADFLOW currently under development within SFB 401. In contrast to numerical approximation of the Jacobian, the use of AD-generated code for the Jacobian calculation generally leads to increased performance and robustness of the overall computational method. Since in principle, only Jacobian-vector-products are needed by the iterative method implemented in QUADFLOW, we plan to avoid the explicit assembly of the whole Jacobian and generate code for computing Jacobian-vector products, yielding significant savings in memory consumption. This will also allow the transition from the currently used first-order-discretization in space to a second-order discretization scheme with improved convergence behavior.

An Environment for Parameter Identification and Sensitivity Analysis

M. Petera, 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 goal of this project is the design and implementation of an automatic differentiation tool for MATLAB. The ADiMat tool allows augmenting MATLAB programs with additional statements such that derivatives are computed along with the original function. ADiMat implements a hybrid approach combining source transformation and operator overloading techniques in order to achieve high performance while allowing for MATLAB’s dynamic type system.

**Reliable Parameter Estimation for Reactive Flows in Hot Aquifers**

A. Wolf, C. Bischof, M. Bücker

This project deals with the numerical simulation of reactive transport in porous media using the simulation package SHEMA T (Simulator for HEat and MAss Transport). SHEMA T is an easy-to-use, general-purpose reactive transport simulation code for a wide variety of thermal and hydrogeological problems in two or three dimensions. The goal of this project is to develop a parallelization of SHEMA T based on the OpenMP standard for shared memory computers as well as to establish a methodology to reliably estimate model parameters using automatic differentiation. This project is funded by GEOPHYSICA Beratungsgesellschaft mbH and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

**Parallel Simulation of Reactive Multiphase Fluid Flow Models**

O. Fortmeier, C. Bischof, M. Bücker

This project which is a joint work with the Chair for Numerical Mathematics is part of the Collaborative Research Centre (SFB) 540, “Model-based experimental analysis of kinetic phenomena in fluid multi-phase reactive systems”. The main topic of this project is the development of a parallel solver (DROPS) for the incompressible Navier-Stokes equations that can be used for the numerical simulation of certain two-phase fluid flow models which are considered in this SFB. The focus of our work is on the development of a hybrid parallelization strategy combining the advantages of OpenMP and MPI. Research topics include parallel grid refinement, load balancing, and parallel iterative algorithms to solve sparse systems of linear equations.
Robust Shape Optimization for Artificial Blood Pumps: Hematological Design, Large-scale Transient Simulations, and Influence of Constitutive Models, Sensitivity Analysis

M. Lälfesmann, C. Bischof, M. Bücker

This project is part of the Priority Programme 1253 “Optimization with Partial Differential Equations” financed by the DFG since July 2006. It is a joint work with the Chair for Computational Analysis of Technical Systems. In the context of shape optimization of blood pumps, we propose to address the issue of objective functions which can be correlated with the accumulation of blood damage and the influence of constitutive model on the optimal shapes. The entire optimization tool chain, based on analytically-derived sensitivities and adjoints, will be subjected to sensitivity analysis with the help of automatic differentiation. It is expected that criteria for detecting inadequacies in constitutive modeling will be exemplified, e.g., by extreme sensitivity of the optimal shapes to model parameters.

Rhinomodel—Airflow Analysis inside the Human Nasal Cavity

T. Kuhlen, C. Bischof

Impaired nasal respiration can lead to a significant loss of life quality. Surgical procedures targeting such impairments are performed quite frequently. Unfortunately, long-term success rates are not satisfactory. Therefore, an interdisciplinary team of physicians from the University Hospitals Aachen and Cologne, the Institute of Aerodynamics, and the Institute for Scientific Computing investigates the fundamentals of nasal airflow. Within this project, Virtual Reality technology is used for the visualization and analysis of medical and fluid mechanical data. In particular, new visualization methods for the interactive analysis and comparison of complex CFD simulation results are being developed. The project has been funded by the DFG from 2003 through 2005 and has been extended for another term ranging from 2006 through 2009.

RASim—Regional Anaesthesia Simulation

T. Kuhlen, C. Bischof

In order to minimize risks for patients and to improve the training of medical residents,
a Virtual Reality (VR)-based simulator for regional anaesthesia is being developed. One essential requirement is a set of anatomical plausible virtual patients. Advanced segmentation algorithms are researched because current technology of medical image acquisition does not capture nerve tissue sufficiently. Simulation algorithms are separated from subject-based anatomical data by novel functional anatomical systems. The two most important systems are the nervous system and the muscular system. These are used to simulate electric stimulation and motor response. Multimodal VR techniques like six degrees of freedom input and haptics force feedback are combined with stereoscopic visualization for virtual palpation and needle interaction.

This DFG-funded research project is an interdisciplinary collaboration of anaesthetists, anatomists and computer scientists from the RWTH Aachen University and the University Hospital Aachen. Further information can be found at http://www.rasim.info.

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:

- Barbara Chapman, University of Houston, USA, January 17, 2006
- Rüdiger Westermann, TU München, January 20, 2006
- Stever Ashby, Lawrence Livermore National Laboratory, USA, February 10, 2006
- Paul Hovland, Argonne National Laboratory, USA, April 3, 2006
- Jack Dongarra University of Tennessee, USA, June 22/23, 2006
- Serge Petiton, CNRS/LIFL, INRIA/Futurs and Polytech Lille, France, July 12, 2006
- Ursula van Rienen, Uni Rostock, November 27, 2006
- Bill Gropp, Argonne National Laboratory, USA, December 4, 2006
- Jens-Dominik Müller, Queen Mary, University of London, UK, December 6, 2006

Christian Bischof is speaker of the Working Group “Parallelism” within the Forum Informatik and organizes — jointly with Th. Lippert (Forschungszentrum Jülich GmbH), E. Speckenmeyer (University of Cologne) and U. Trottenberg (Fraunhofer Institute for Algorithms and Scientific Computing) — the Kolloquium über Parallelverarbeitung in technisch-naturwissenschaftlichen Anwendungen, a series of symposia concerned with
parallel processing in engineering and scientific applications. This series, initiated in 1993 under participation of K. Indermark and F. Hoßfeld, has since then established itself as a forum for discussion and information exchange among the Northrhine-Westphalian institutions concerned with parallel processing.

The following workshops were co-organized by our institute:

- Forth European Workshop on Automatic Differentiation held at Aachen, Germany, December 7–8, 2006. (Co-organized by Martin Bücker.)
- Sommerschule “Automatisches Differenzieren” held at Universitätskolleg Bommerholz, Germany, August 14–18, 2006. (Co-organized by Christian Bischof and Martin Bücker for the Research Training Group 775 “Hierarchy and Symmetry in Mathematical Models.”)
- Third European Workshop on Automatic Differentiation held at Oxford, UK, June 1, 2006. (Co-organized by Martin Bücker.)
- Kolloquium über Parallelverarbeitung in technisch-naturwissenschaftlichen Anwendungen held at Forschungszentrum Jülich, Germany, May 15, 2006. (Co-organized by Christian Bischof.)

In addition, Martin Bücker served on the program committee for:

- 8th International Workshop on High Performance Scientific and Engineering Computing (HPSEC–06), Columbus, Ohio, USA, August 18, 2006.
- Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC–06) held in conjunction with the 20th IEEE International Parallel & Distributed Processing Symposium (IPDPS–06), Rhodes Island, Greece, April 25–29, 2006.

Talks and Publications

Talks

C. H. Bischof: *Simulation Science at RWTH Aachen University*, Forth European Workshop on Automatic Differentiation, Aachen, Germany, December 8, 2006

C. H. Bischof: *Simulation Science at RWTH Aachen*, VRCA Workshop Aachen, November 21, 2006


C. H. Bischof: *Automatic Differentiation and Beyond*, Department of Computer Science, Carleton University, Ottawa, Canada, July 19, 2006
C. H. Bischof: *OpenMP Gathering Steam*, High-Performance Virtual Laboratory, Queens University, Kingston, Ontario, Canada, July 18, 2006

A. Rasch: *Effiziente Ableitungsberechnung für Optimal Experimental Design*, Institut für Informatik, Universität zu Köln, July 6, 2006


C. H. Bischof: *High-Performance Computing, State of the Art and its Limitations*, Sixth International Conference on Computational Electromagnetics, Aachen, Germany, April 6, 2006


C. H. Bischof: *Automatic Differentiation and Beyond*, Cornell University, Ithaca, USA, March 6, 2006


**Publications**


LuFG Informatik 12

Staff

- Faculty:
  Uwe Naumann

- Research Assistant:
  Ebadollah Varnik

- Secretary:
  Gabriele Meessen

- Long-Term Visitors:
  Jan Riehme, Dmitrij Gendler
  (University of Hertfordshire, UK)

- Student Researcher:
  Michael Maier
Overview

The focus of our research and development efforts is on adjoint compiler technology and combinatorial problems in derivative accumulation by automatic differentiation. Adjoint compilers transform numerical code that implements multivariate vector functions \( y = F(x) \), \( F: \mathbb{R}^n \rightarrow \mathbb{R}^m \), into code for computing products of the transposed Jacobian matrix \( F' = F'(x) \) with a vector \( \vec{y} \in \mathbb{R}^m \). The underlying technique is known as Automatic Differentiation (AD). Large gradients can thus be accumulated at a (hopefully small) constant multiple of the computational cost of \( F \). A factor between three and four is highly desirable for large-scale numerical simulation codes running at the limits of modern high-performance computers. The minimization of the constant overhead is the major motivation of our research that combines elements from graph theory, combinatorial optimization, compiler construction, and software engineering with applications from various areas in science and engineering.

Research Projects

Adjoints Compilers

Maier, Riehme, Gendler, Naumann

Adjoints compilers are one of the corner stones of the numerical solution of inverse problems via discrete adjoints. The application of such techniques to a large number of broadly defined inverse problems in computational engineering is the main theme of the Aachen Institute for Advanced Study in Computational Engineering Science that has been established within the framework of the Excellence Initiative of the German federal and state governments in November 2006. See

http://www.aices.rwth-aachen.de

for details.

In collaboration with The Numerical Algorithms Group Ltd. in Oxford and the University of Hertfordshire in Hatfield, UK, we are extending the NAGWare Fortran compiler with adjoint code generation capabilities. See

http://www.nag.co.uk/nagware/research/ad_overview.asp

for details.

The multi-language AD platform OpenAD has been developed as part of a collaboration with Argonne National Laboratory, Colorado State University, MIT, and Rice University, USA. See
We are interested in various combinatorial and graph problems arising in the context of AD. For example, we have shown only recently that the problem of accumulating a Jacobian matrix with a minimum number of arithmetic operations is in fact NP-complete (see publications). Another NP-complete problem arises in the context of adjoint code optimization regarded as the efficient reversal of a directed acyclic graph. Heuristics for finding approximate solutions to these highly relevant problems are under development.

We are associate members of the CSCAPES (“Combinatorial Scientific Computing and Petascale Simulations”) established by the US Department of Energy under its SciDAC program. See

\[ \text{http://www.cscapes.org} \]

for details.

Further information on ongoing research and development projects can be found under

\[ \text{http://www.stce.rwth-aachen.de} \]


**Talks and Publications**

**Talks**


**Publications**


358


Performance Analysis of Parallel Programs

Staff

- Faculty:
  - Prof. Dr. Felix Wolf

- Scientific Staff:
  - Dr. Markus Geimer
  - Dr. Brian Wylie

- Doctoral Researchers:
  - Dipl.-Ing. Daniel Becker

- Student Researchers:
  - Björn Kuhlmann

- Guests:
  - Farzona Pulatova
Overview

The Helmholtz University Young Investigators Group Performance Analysis of Parallel Programs is located at the Central Institute for Applied Mathematics of Forschungszentrum Jülich. Felix Wolf, the head of the group, is at the same time Juniorprofessor at the Computer Science Department of RWTH Aachen University.

Our objective is to make the optimization of parallel applications both more effective and more efficient. Facing increasing power dissipation, little instruction-level parallelism left to exploit, and almost unchanged memory latency, computer architects are realizing further performance gains by placing multiple “slower” processor cores on a chip rather than by building faster uniprocessors. As a consequence, numerical simulations are being required to harness higher degrees of parallelism in order to satisfy their growing demand for computing power. However, writing codes that run efficiently on large numbers of processors and cores is extraordinarily challenging and requires adequate tool support for performance analysis. Unfortunately, tools that normally assist developers in the optimization process often cease to work in a satisfactory manner when deployed on large processor counts. To improve the efficiency of large-scale applications and, thus, to expand their potential, our group develops scalable tools that collect relevant data on code performance and identify the causes of performance problems.

A key method we apply in our projects is event tracing, which is a well-accepted technique for post-mortem performance analysis of parallel applications. Time-stamped events, such as entering a function or sending a message, are recorded at runtime and analyzed afterwards with the help of software tools. Because event traces preserve the spatial and temporal relationships of individual runtime events, they are especially well suited for detailed inter-process analysis.

In addition to mastering parallelism inside a single machine, further challenges for achieving high application performance arise in Grid environments, which allow the coordinated use of multiple computing resources from different organizations. Therefore, a second goal of our group is developing new solutions to study the performance characteristics of Grid applications reaching beyond the limits of a single computer.

With scalable and Grid-enabled performance tools at hand, we believe that domain experts will become able to solve major scientific problems with increased efficiency by saving time during both the development of scientific codes and their later execution, thus, opening the way to even more complex computer simulations.
Scalable Performance Analysis of Large-Scale Applications

D. Becker, M. Geimer, B. Kuhlmann, F. Pulatova, F. Wolf, B. Wylie
together with contributors from FZ Jülich and U of Tennessee
(funded by the Helmholtz Association)

Automatic off-line trace analysis can provide the user with high-level information on application performance by automatically searching traces for complex patterns of inefficient behavior and quantifying their significance. Unfortunately, the traditional approach of sequentially analyzing a single trace file does not scale to applications running on thousands of processors.

In this project, we are developing a scalable trace-analysis tool called SCALASCA that achieves a very high degree of scalability by analyzing the trace data in parallel using as many CPUs as have been used for the target application itself. Exploiting distributed memory and processing capabilities available on the target system, the entire trace data is kept in main memory and analyzed using a parallel replay approach. Instead of operating sequentially on a single global trace file, all analysis processes traverse their local trace data independently and exchange information at synchronization points. To improve writing large amounts of trace data, trace files are compressed on the fly. The current prototype is restricted to MPI-1 applications, but support for alternate programming models, such as OpenMP, is envisaged. The scalability of SCALASCA was validated for up to 16,384 processes on the local Blue Gene/L system using two benchmark programs. In addition, SCALASCA was able to highlight performance problems in two real applications, the plasma physics code PEPC-B developed at the Central Institute for Applied Mathematics in Jülich and the fluid dynamics application XNS developed at the Chair for Computational Analysis of Technical Systems in Aachen. A prototype version was released under an open-source license available at www.scalasca.org.

In addition, SCALASCA was enabled to run on a metacomputer consisting of multiple geographically dispersed hosts. The main challenges addressed include the synchronization of time stamps in a hierarchical network with different latency levels, the absence of a global file system, and the detection of metacomputing-specific performance problems.

Finally, to improve analysis report exploration in the case of remote installation, work on a client-server architecture separating report storage and calculation of views from the actual presentation was started.
In 2006, we successfully applied for the foundation of the Virtual Institute High-Productivity Supercomputing (VI-HPS), a collaboration between Forschungszentrum Jülich, RWTH Aachen University, TU Dresden, and the University of Tennessee. The mission of VI-HPS will be devoted to the development and deployment of advanced performance-analysis and error detection tools for high-performance computing applications. A significant portion of our resources will also be assigned to training and support activities.

As a member of the Aachen Institute for Advanced Study in Computational Engineering Science (AICES), this group already established an interdisciplinary collaboration with the Chair for Computational Analysis of Technical Systems in Aachen, which resulted in the successful optimization of the XNS fluid dynamics code during the Blue Gene/L Scaling Workshop at Forschungszentrum Jülich in December 2006. After eliminating redundant message traffic diagnosed using mpiP and SCALASCA, the code, which initially did not scale beyond 900 processors, now runs efficiently on up to 4096 processors.

Typical application development and tuning scenarios involve the manual and separate use of compilers and performance tools, and program modifications based upon insights laboriously gleaned from their output. In this project, we are creating an integrated environment for program optimization that reduces the manual labor and guesswork of existing approaches.
We are developing strategies and the corresponding interfaces that enable the application developer, compiler and performance tools to collaborate to generate optimized code based upon a variety of sources of feedback. This year, a profiling interface for the OpenUH compiler that supports fine-grained instrumentation at the function, loop, and branch level was implemented and matched by a corresponding event adapter for KOJAK, an automatic trace analysis tool. Now application programmers who use OpenUH are able to track performance problems down to loops and branches.

**Other Activities**

This group is part of the consortium that successfully applied for the foundation of the Graduate School Aachen Institute for Advanced Study in Computational Engineering Science (AICES) within the framework of the Excellence Initiative of the German federal and state governments. Felix Wolf was elected to join the steering committee of AICES.

Moreover, we organized the Minisymposium Tools for Parallel Performance Analysis at the Workshop on State-of-the-Art in Scientific and and Parallel Computing (PARA) in Umeå, Sweden, in June 2006.

Members of this group served on the program committees of the International Conference on High Performance Computing and Communications (HPCC 2006) and of the European PVM/MPI Users’ Group Meeting Conference (EuroPVM/MPI 2006).

**Courses**

- Grid Computing (SS 2006)

**Conference Tutorials**


**Software Demonstrations**

Demonstration of SCALASCA at the exhibition of the Supercomputing Conference (SC’06), Tampa Florida, November 2006.
Talks and Publications

Talks


F. Wolf: Leistungsanalyse paralleler Programme, Tag der Informatik, RWTH Aachen University, December 1 2006.

F. Wolf: Scalable Trace-Based Performance Analysis of Parallel Applications, RWTH Aachen University, Chair for Computational Analysis of Technical Systems Seminar, November 20 2006.


B. Wylie: Scalable Trace-Based Performance Analysis of Parallel Applications, Workshop on Performance & Productivity of Extreme-Scale Parallel Systems, 7th Symposium of the Los Alamos Computer Science Institute, Santa Fe, NM, USA, October 17 2006.

B. Wylie: Scalable Performance Analysis of Large-Scale Parallel Applications, University of Tennessee, Computer Science Department Seminar, Knoxville, TN, October 13 2006.

F. Wolf: Scalable Trace-Based Performance Analysis of Parallel Applications, Carleton University, Computer Science Department Seminar, Ottawa, Canada, October 13 2006.

M. Geimer: Scalable Parallel Trace-Based Performance Analysis, European PVM/MPI Users’ Group Meeting (EuroPVM/MPI) Conference, Bonn, Germany, September 18 2006.


F. Wolf: Large Event Traces in Parallel Performance Analysis, 8th Workshop 'Parallel Systems and Algorithms' (PASA), in conjunction with the 19th International Conference on Architecture of Computing Systems (ARCS), Frankfurt/Main, Germany, March 16 2006.

Publications


Dissertations
Most commercial-of-the-shelf database management systems are not suited for managing the complex documents which are created during any development activity. Especially, fine-grained dependencies between these documents can not be managed very well. The shortcomings of these database systems can be solved by using a data model which represents complex dependencies better than the relational data model used by these databases.

As part of the IPSEN project the graph-oriented database system GRAS was developed, which utilizes graphs to express documents and the dependencies between them to overcome the shortcomings of the relational model. Since its development the requirements for such a database system changed and could not be fulfilled by GRAS anymore. Therefore, the database system DRAGOS (Database Repository for Applications using a Graph Oriented Storage) has been developed as part of Boris Böhlen's dissertation.

The major drawbacks of GRAS were its limited extendibility and adaptability. Examples are the graph model, which could not be extended to support more complex types of graphs, or the non-existent support for distributed graph operations. Based on the limitations and the long experience in building graph-based tools for supporting development process the requirements for DRAGOS were defined and a suitable system architecture was developed.

To fulfill the requirements, DRAGOS uses a very general graph model which can easily express any other graph model and implements a kernel which offers basic database functionality. The DRAGOS Kernel provides persistence, event management, rule evaluation, and transaction management. This functionality is implemented using standard components like relational or object-oriented database systems wherever possible. All other functionality is built on top of this kernel as extensions which can be reused and recombined by different applications. Examples for such extensions are versioning mechanisms or incremental attribute evaluation. Above these extensions the support for different kinds of applications is realized by providing specialized graph models. For supporting the development of specialized graph models the tool SUMAGRAM has been developed. SUMAGRAM uses annotated UML class diagrams to generate the source code which implements the mapping of the specialized graph model to the general graph model of DRAGOS.

Examples are the Fujaba or PROGRES graph models which provide support for these particular graph transformation systems. Before DRAGOS, the applications developed with the graph transformation system PROGRES required GRAS. Today, the PROGRES graph model of DRAGOS allows us to fully replace GRAS as part of these applications and use PROGRES for broader range of applications. The graph replacement system Fujaba partially aims in the same directions as PROGRES. With the current Fujaba-support in DRAGOS long-missed features like non-determinism and complex path expressions can be implemented quite easily in Fujaba in the future.

The aforementioned concepts were development and validated as part of the dissertation.
Thus, DRAGOS fully replaces its predecessor GRAS. The open architecture is tailored towards future modifications and new requirements.

**Reviewer:** Prof. Dr.-Ing. Manfred Nagl, Prof. Dr. Andy Schürr  
**Day of oral exam:** 26. Mai 2006
Algorithmic Aspects of Some Combinatorial Problems in Bioinformatics

Dirk Bongartz

The consistently growing field of bioinformatics exhibits the success of cooperative work in biology and computer science. The interaction between new experimental techniques gaining more and more data about molecular structures and processes and the knowledge how to prepare, structure, and analyze this data and even more to predict relations based on this data, is the driving force within this field.

In this thesis, we study models and combinatorial problems arising from current bioinformatics research focussing on the algorithmic point of view.

Protein structure prediction, sometimes referred to as the holy grail of bioinformatics, is the problem to infer the spatial structure of proteins from their amino-acid sequence. We propose two extensions to the popular HP model for this task, which significantly improve its applicability in practice. Namely, we remove the drawback of bipartiteness of the grid lattice that was used in the original HP model to discretize the space. We denote these extended models by HPd and $\alpha$-DC-HP model, respectively. For the optimization problems emerging from these models, we design and analyze approximation algorithms. In particular, our approximation algorithms for the HPd model achieve approximation ratios of $\frac{26}{15}$ and $\frac{8}{5}$ for the two- and three-dimensional case respectively, which are the best approximation ratios obtained for HP-like problems so far.

In the next part of this thesis, we study a model proposed in the context of protein engineering. The installation of the 21th amino acid selenocysteine into a protein, has been shown to enhance its function often, which makes the design of such selenoproteins a desired goal. Since the incorporation of selenocysteine depends on the spatial structure of the mRNA in the process of biosynthesis, we are aiming to design an appropriate mRNA that obeys the corresponding structure constraints. A model to formulate this goal was given in the literature. We will prove that some optimization problems resulting from this model are APX-hard, i.e., they cannot be approximated arbitrarily well unless P=NP. Therefore, it seems to be appropriate to consider more restricted models that more carefully take into account the specific characteristics of the real problem setting, but do not become too general.

The last part of this thesis focuses on the computation of genomic distances between organisms. To measure the degree of relationship between organisms, for instance as a preliminary step for the construction of phylogenies, a common step is to model their genomes as sequences of homologous genes and to compute the number of specific genomic operations required to transform one genome into the other. Most popular operations in this context are reversals and transpositions. Instead of mere counting the number of operations required, recently it was proposed to measure each performed operation according to the length of the touched gene sequence. This was comprehensively studied lately with respect to the reversal operation. We will show in this thesis how to transfer most of these results to the transpositions, too, establishing upper and lower bounds on the diameter, i.e., the maximal...
weighted distance between two arbitrary genomes, and showing approximation results as well.

**Evaluator:** Prof. Dr. Juraj Hromkovič

**Evaluator:** Prof. Dr. Berthold Vöcking

**Date of oral exam:** April 13, 2006
Parallel CFD Post-processing Methods for Realtime Visualization and Interaction in Virtual Environments

Andreas Gerndt

Because of the steadily increasing performance of supercomputers, computational fluid dynamics (CFD) simulations are capable of producing constantly growing amounts of raw data. These data sets are essentially useless without subsequent post-processing. One particularly attractive evaluation approach is the interactive exploration within virtual environments. However, common visualization systems are not able to process large data sets while maintaining real-time interaction and visualization at the same time. Therefore, the obvious idea is to decouple flow feature extraction from visualization.

The work presented mainly covers the functionality of the parallel CFD post-processing toolkit Viracocha. The distributed framework architecture relieves the visualization host by moving all time-consuming computation tasks to the parallelization backend. This makes it easier to guarantee real-time interaction within virtual environments. Additionally, the response time a user has to wait before requested post-processing results are visualized can be substantially reduced by optimized extraction algorithms adapted to parallel environments.

Two further aspects are discussed in more detail. A considerable bottleneck in parallelization of CFD post-processing is the time needed to load large data sets. Therefore, a first extension of Viracocha aims at the reduction of the loading time, by implementing strategies mainly based on data caching and prefetching. The second aspect concerns an approach called data streaming, which minimizes the time a user has to wait for first results of a requested extraction. In order to achieve this, Viracocha sends back coarse intermediate data to the virtual environment before the final result is available. Some implemented streaming strategies also make use of multi-resolution data structures.

Advisors: Prof. Dr. Bischof, Dr. Westermann
Day of exam: 20.01.2006
Modeling of Image Variability for Recognition

Daniel Keysers

This thesis presents the application of different models of image variability to visual recognition problems using the paradigm of appearance-based recognition. We first discuss linear models of variability and relate them to the use of Gaussian distributions, which enables the use of well-understood estimation methods to estimate the vectors representing the variability. We also relate the discriminative maximum entropy approach to the Gaussian case and use the relationship to derive the novel maximum entropy linear discriminant analysis. Secondly, we investigate discrete deformation models — that map pixels onto pixels — of order zero, one, and two, where the order is determined by the constraints imposed on the two-dimensional image distortion. We prove for the first time that the determination of the best match for the second order model belongs to the class of NP-hard problems. We show that it is important to include a suitable context for each pixel to achieve low error rates, which is then possible using the less complex models of lower order. We furthermore discuss the use of local patches for visual object categorization as a model allowing high image variability and show how the use of discriminative training leads to very competitive results. Finally, we describe a model for holistic scene analysis that allows us to determine a visual representation of objects present in a set of images.

The methods are primarily applied to the tasks of handwritten character recognition and medical image categorization, yielding excellent results in both cases. In particular, we achieve an error rate of 0.52% on the well-known MNIST benchmark and 12.6% on the IRMA-10,000 database, the lowest within the 2005 ImageCLEF evaluation. We will show that the models of image variability also improve the recognition performance of appearance-based sign language and gesture recognition systems. This emphasizes the models’ broad applicability.

Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr.-Ing. Hans Burkhardt
Oral exam: March 14, 2006

Martin Marinov

The computer-aided design (CAD) of various products, machines and details, virtual movie heroes and video game characters is a computer science area with significant practical implications and challenging open scientific problems. One of these open problems is the automatic generation of 3D geometric designs of existing physical objects, a process widely known as reverse engineering. The manual reverse engineering of a geometric design typically incurs costs comparable to engineering a completely new design from scratch. Therefore, the CAD industry is very interested in algorithmic solutions which generate such designs automatically or with a minimal user guidance.

In this talk we present a set of techniques which combined deliver a solution for reverse engineering physical objects, which surface geometry is represented by dense triangle meshes. The output of our system is a piecewise smooth Catmull-Clark subdivision surface representing the original object. Its control mesh provides the available degrees of freedom to manipulate and edit the shape of the represented object. Since our algorithms are designed to produce high quality control meshes, aligned to the structure and the features of the input shape, the output surface representation can be used in various mainstream computer graphics applications such as CAD systems, computer-simulated physical processes and animations (movies and games).

We will outline the general work-flow of our reverse engineering CAD system and present in detail several novel algorithms and important contributions in the following geometry processing areas: polygonal mesh simplification, quad-dominant remeshing and scattered data approximation. Algorithms and results illustrating the application of our techniques for multiresolution polygonal mesh modeling will be also demonstrated.

Evaluator: Prof. Dr. L. Kobbelt
External Evaluator: Dr. Pierre Alliez
Date of oral exam: October 24, 2006
Core Network Mobility : Active MPLS

Rajendra Persaud

This dissertation covers mobility in packet-switched wireless networks and presents a new mechanism based on Multi-Protocol Label Switching (MPLS). The mechanism is named 'Active MPLS'. The wireless packet-switched networks existing today (WLANs, WiMAX environments, 2.5G and 3G systems) generally offer a number of different packet-based services. When user mobility is supported, a mobile device may be moved between locations without disrupting the running data sessions. Such a movement is called a handover and is implemented by a mobility mechanism. Any mobility mechanism has the task of updating the location of the mobile device during a handover so that the data packets of the running data sessions are always sent to the correct location. Active MPLS is a mobility mechanism that does not only solve this task but that also provides for a scalable and efficient way for packet redirection during a handover. In contrast to many other mobility mechanisms, in Active MPLS packet redirection is achieved without impairing the forwarding of data packets not involved in a handover. The feasibility of Active MPLS is demonstrated through an implementation on real hardware and through simulation. A performance evaluation of Active MPLS in comparison to other mobility approaches completes the dissertation.

Evaluator: Prof. Dr. O. Spaniol
External Evaluator: 
Date of oral exam: 15. September 2006
Modeling Spontaneous Speech Variability for Large Vocabulary Continuous Speech Recognition

Hauke Schramm

In this work a number of novel techniques for improved treatment of spontaneous speech variabilities in large vocabulary automatic speech recognition are developed and evaluated on US English conversational speech and spontaneous medical dictations. Two main aspects of spontaneous speech modeling are addressed: The general handling of pronunciation variability and the individual and parallel treatment of multiple speech variabilities in the acoustic and pronunciation model of a one-pass speech recognizer. The problem of an optimal incorporation of multiple alternative pronunciations into the search framework is addressed in the first part of the thesis. This includes the question of how to efficiently combine the probabilistic contributions of alternative pronunciations in the course of a left to right search procedure. The well known maximum approximation, usually applied in this context, is compared to a novel time synchronous sum approximation technique which integrates alternative pronunciations in a weighted sum of acoustic probabilities. It is shown on a conversational speech task that this approach outperforms the maximum approximation by 2% relative and reduces the search costs by 7%. Another important issue with respect to the incorporation of alternative pronunciations into the search framework is the statistical weighting of the pronunciations. The usually applied pronunciation unigram prior probabilities are typically estimated by the relative frequencies of pronunciations in the training hypotheses. This standard maximum likelihood solution is compared to a novel discriminative training scheme which is an extension of the Discriminative Model Combination technique, proposed in [Beyerlein 01]. The developed iterative reestimation procedure is shown to adjust the influence of a specific pronunciation prior probability in the discriminant function in dependence of (1) the word error rate, (2) the frequency of occurrence of this pronunciation in the correct hypothesis and its rivals, and (3) the underlying acoustic, pronunciation and language model. An evaluation of this technique on a conversational speech task showed a 6.5% relative improvement on the training corpus and a 2% relative gain on an independent test set. The second major part of this thesis addresses the development and evaluation of a novel training and search framework which enables a specific, parallel treatment of multiple speech variabilities in the acoustic and pronunciation model. This technique (1) classifies portions of speech (e.g. words) with respect to given variability classes (e.g. rate of speech), (2) builds class specific acoustic and pronunciation models, and (3) properly combines these models later in the search procedure on a word level basis. A theoretical framework for an efficient integration of the class specific acoustic and pronunciation models into a one-pass search procedure is developed which incorporates contributions from class specific alternatives in a weighted sum of acoustic probabilities. This multi variability framework applies a very general model combination technique which may be applied to combine arbitrary acoustic and pronunciation models on word level. In this work, it is especially used for a parallel, explicit treatment of three important spontaneous speech variabilities: pronunciation variability, rate of speech variability, and filled pause variability. The best
multi variability system combines 6 class specific acoustic and pronunciation models on word level and achieves a word error rate reduction of 13% relative on a highly spontaneous medical dictation task and a gain of 9% relative on conversational speech.

Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr.-Ing. Reinhold Häb-Umbach
Oral exam: March 6, 2006
Christian Spannagel concluded his dissertation on “Benutzungsprozesse beim Lernen und Lehren mit Computern” at the Pädagogische Hochschule Ludwigsburg. In his dissertation, he designed, developed and evaluated a tool which allows to capture and symbolically represent user-software-interaction processes in order to support learning and teaching processes, which utilize software tools. The interaction processes can be automatically analyzed and structured and evaluated statistically. The requirements and design guideline were derived from various cognitive theories about human-computer interaction and multimedia learning as well as instructional theories and models. The tool and exemplary didactic scenarios were utilized in an empirical study in integrated natural science lessons in undergraduate school (8th grade). In this study the effects of different support types in combination with the computer self-efficacy of learners. Young students were supported with text manuals, animated demonstrations, or animated demonstrations combined with a training wheels interface. In this context, they had to solve physical and mathematical problems with a spreadsheet program. Results showed that animated demonstrations outperformed text manuals in many cases. Training wheels interfaces seemed to have disadvantages compared to unmodified user interfaces. In addition, motivational aspects have been investigated. Test persons with high computer self-efficacy were more motivated than their counterparts. The analysis of variance revealed no interaction effects between the treatment and computer self-efficacy.

Advisors: Prof. Herbert Lthe (Ph Ludwigsburg), Prof. Dr. Ulrik Schroeder
Day of exam: 23. 11. 2006
Word Confidence Measures for Machine Translation
Nicola Ueffing

Due to continuous research which led to improved concepts and algorithms, the quality of automatically generated translation has significantly improved in recent years. However, the performance of machine translation systems is still not perfect. For human users dealing with these systems, it is desirable to obtain a reliable indication of possible errors in the system output. The same holds for applications based on machine translation technologies. They could explore the knowledge about possible mistakes. Interactive machine translation systems, for example, can modify or even discard predicted translations which are identified as possible errors. The aim of this work is to provide knowledge about when a translation generated by the system is incorrect by calculating measures of confidence for each word in this translation. This topic has hardly been investigated in machine translation before. Different ways of determining confidence measures are proposed and experimentally evaluated in this thesis. The basic concept behind all these approaches are word posterior probabilities. The goal is to set up a sound theoretical framework for the calculation and evaluation of confidence measures in machine translation.

The main problem which has to be solved for the computation of word posterior probabilities is to define the underlying concept. There exists no intuitive definition of this concept. Possible approaches include the word posterior probability of a word based on its position in the sentence and the occurrence in any position. Several solutions to this problem are presented in this thesis. Furthermore, different approaches to the calculation of word posterior probabilities are introduced and compared. They can be divided into two categories: system-based methods which explore knowledge provided by the translation system that has generated the translations, and direct methods which are independent of the translation system. The system-based techniques make use of system output, such as word graphs or N-best lists. The word posterior probability is determined by summing the probabilities of all sentences which contain the target word. The direct confidence measures developed here take other knowledge sources, such as word or phrase lexica, into account. They can be applied to the output of non-statistical machine translation systems as well.

The word posterior probabilities introduced in this thesis can directly be applied as confidence measures as follows: For a given translation generated by a machine translation system, the posterior probabilities of all words are determined and compared to a threshold. All words whose posterior probability is above this threshold are tagged as correct and all others are tagged as incorrect. To evaluate the proposed confidence measures, the information on which words are correct is needed. In machine translation, it is not intuitively clear how to determine the correctness of single words. As a solution to this problem, several different ways of deriving word error measures from existing machine translation evaluation metrics are suggested and investigated. The relation between the word error measure and the word posterior probabilities is studied in detail. From the formulation of the posterior risk for different error measures, a theoretical foundation of the word posterior probabilities is derived.

382
The different confidence measures proposed here explore information from various knowledge sources, such as sentence probabilities provided by the machine translation system and statistical word and phrase lexica. To explore the knowledge from all these sources, a combination of several confidence measures is investigated.

The suggested methods are evaluated on different translation tasks and several language pairs. In order to assess the general discriminative power of the confidence measures, they are tested on output from four different machine translation systems. Three of those are state-of-the-art phrase-based systems, and the fourth is an established rule-based system. A significant improvement in terms of confidence error rate is achieved in all settings.

In this work, applications of confidence measures that improve translation quality of state-of-the-art systems are investigated. These include rescoring with confidence measures and their use in an interactive machine translation system. Rescoring with confidence measures is shown to improve translation quality.

In the interactive machine translation environment, word confidence measures are successfully applied to select and discard possible translations based on their confidence. For the evaluation of the interactive translation experiments, an existing automatically determined metric is used. An extension to this metric is proposed to better model the gain achieved from using the system in a real-world application. The experiments show that the quality of the predicted translations is improved through the use of confidence measures.

Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr. Enrique Vidal
Oral exam: March 15, 2006
Presently, organizational scenarios demand employees to exchange and obtain information from various sources to accomplish their duties. Said in other words, there is an increasing need for teamwork, for collaboration and for coordination. One aspect of this scenario that has been under investigation for decades concerns the decision making process, especially the use of decision support systems. However, very little has been done regarding the decision implementation phase, in particular about decisions made in meetings.

This work analyses the concepts related to this problem looking at it from the viewpoints of Decision Support Systems and the Computer Supported Cooperative Work. We visit the literature and related work in both areas and show how they evolved to the state-of-the-art, and how decision implementation was not often included in the various initiatives.

After that, we define the focus of our own approach and scope, and propose a solution based on automated mechanisms to assist the activities of formalizing the meeting cycle (i.e. pre-meeting, meeting and post-meeting phases), representing decisions explicitly, and obtaining follow-ups through an integrated approach based on task management and e-mail exchange. We present the conceptual model and theories that were the basis of our research and show how we have implemented them as an extension of a Document Management System.

Finally, we discuss the evaluation realized with the system and the results obtained. We conclude this document pointing out the added value of our approach, the limits we had to deal with along the process and we indicated some directions for future research.

**Advisors:** Prof. Dr. Matthias Jarke, Prof. Wolfgang Prinz Ph.D., Prof. Dr. Carla Simone (Milano University)

**Day of exam:** May 3, 2005
The model-checking problem is the question whether a given system model satisfies a property. The property is usually given as formula of a temporal logic, and the system model as labelled transition system. However, the well-known state-space explosion effect is responsible for yielding transition systems of exponential size when compared to their description, and common sequential algorithms often are not capable to solve the model-checking problem with resources available on a single computer. In this thesis, we develop parallel and, in particular, distributed algorithms which exploit the combined resources of a network of commodity workstations to solve problem instances which are beyond the capabilities of today’s sequential algorithms. In a second part, we investigate ways to efficiently generate (low-level) transition systems suitable for many verification tools from compact high-level descriptions of the input model. We propose a virtual-machine based approach, which uses an intermediate format to break the translation from high-level to low-level representations of a model into two steps. This well-known compiler technique simplifies the translation and still is very fast in practice.

**Evaluator:** Prof. Dr. K. Indermark  
**External Evaluator:** Prof. Dr. L. Brim (Brno, CZ)  
**Date of oral exam:** January 24, 2006
Efficient Data Structures for Distributed and Mobile Geometry Processing

Jianhua Wu

T3D geometry data is now establishing as a new digital multimedia data type after text and sound in 1980’ and images and video in 1990’. One of the major advantages of 3D data is that it enables users to actually interact with the displayed contents, which has embraced more and enhanced interactive multimedia applications.

On the other hand, the rapid evolution of the network technology brings new potentials for communication between people and computers in heterogeneous environments. Computing hardware becomes more powerful and ubiquitous thanks to the ever increasing availability of distributed and mobile digital devices.

When we combine the strengths from both above areas, we come to an emerging interdisciplinary research field of distributed and mobile geometry processing. This talk will address the fundamental data structure and geometry representation problems in this field. More specifically, I will present a wide range of high-quality algorithms to produce efficient geometric data structures finely adapted to distributed and mobile geometry processing.

The resulting geometric structures and representations are with four important features (compactness, progressiveness, robustness, and security), and are prone to be of crucial usage in diverse 3D multimedia communication applications like distributed CAD, CSCW, movie/animation production, 3D mobile services, online internet games, 3D online documentation, and so on.

Evaluator: Prof. Dr. L. Kobbelt
External Evaluator: Prof. Dr. Shi-Min Hu
Date of oral exam: March 7, 2006
In this thesis, the use of multiple acoustic features of the speech signal is considered for speech recognition. The goals of this thesis are twofold: on the one hand, new acoustic features are developed, on the other hand, feature combination methods are investigated in order to find an effective integration of the newly developed features into state-of-the-art speech recognition systems.

The most commonly used feature extraction methods are the Mel Frequency Cepstrum Coefficients (MFCC), Perceptual Linear Prediction (PLP), and variations of these techniques. These methods are mainly based on the models of the human auditory system. A detailed review of the implementation of these features is presented in this thesis. There have also been attempts at using articulatory motivated acoustic features for speech recognition which are motivated by models of the human speech production system. This thesis focuses partially on the development of new articulatory motivated acoustic features. The voicing information is one of the most commonly used articulatory features. Three voicing extraction methods are presented in this work followed by a systematic comparison. Besides the analysis of the voicing feature, the novel spectrum derivative feature is introduced which aims to capture the differences between magnitude spectra produced by obstruct and sonant consonants.

The articulatory motivated features are tested in combinations with state-of-the-art acoustic features based on auditory models mainly. The features are combined both directly using Linear Discriminant Analysis (LDA) as well as indirectly on model level using Discriminative Model Combination (DMC). Both methods have already been used successfully in automatic speech recognition systems. In this work, a comparative study is presented which describes and analyzes the application of these methods to feature combination. Robustness issues of the LDA based method are addressed which are induced by increasing the amount of acoustic features coefficients. An application of DMC to feature combination is introduced based on the splitting of the acoustic model into separate scalable knowledge sources. After the analysis of the individual methods, a comparison is carried out on the basis of the underlying acoustic emission models.

Experimental results are presented for small- and large-vocabulary tasks. The results show that the accuracy of automatic speech recognition systems can be significantly improved by the combination of auditory and articulatory motivated features. The combination of the Vocal Tract Length Normalized MFCC and articulatory motivated features demonstrates that additional articulatory information can even improve the performance of speaker adapted systems. The word error rate is reduced from 1.8% to 1.5% on the SieTill, a German digit string recognition task. Consistent improvements in word error rate have been obtained on two large-vocabulary corpora. The word error rate is reduced from 19.1% to 18.2% on the VerbMobil II, a German large vocabulary conversational speech task, and from 14.1% to 13.5% on the European Parliament Plenary Sessions task.
Referent: Prof. Dr.-Ing. Hermann Ney
Coreferent: Prof. Dr.-Ing. Reinhold Häb-Umbach
Oral exam: August 14, 2006
Central Services
System Administration Group

- Faculty:
  Prof. Dr.-Ing. Hermann Ney

- Research Assistants:
  Dipl.-Inform. Willi Geffers

- Technical Staff:
  Marion Brandt-Röhrig, M.A.
  Stefanie Scholten
  Frank Tammer
  Karl-Heinz Thevis

- Student Workers:
  Moaffak Assassa
  Uta Christoph
  Jens Forster
  Enisa Mušović
  Ilhan Ucar
Overview

Since 1985 the System Administration Group (RBI\(^1\)) operates several computer labs and provides technical support for the Department of Computer Science at RWTH Aachen. The principal task of the RBI is to install, maintain, and evolve the local network and several central services, including file servers, a database server, mail server, and web server. Students, faculty, and staff have free unlimited access to the computer labs operated by the RBI.

The computer labs are used in computer science courses and for student and faculty research projects. Especially for novice users a user helpdesk is offered during business hours. The labs are provided with PCs running the Debian GNU/Linux operating system. The computers are equipped with various hardware extensions and software to support the students in doing their exercises and projects. All computers are part of the local area network and provide unrestricted access to the campus backbone and the internet.

Equipment

### Computer Laboratories

Altogether the RBI operates five labs in the basement of the E1 and E2 building. The labs are provided with various hardware platforms running the Debian GNU/Linux operating system.

<table>
<thead>
<tr>
<th>Room</th>
<th>Computers</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>4U13</td>
<td>6</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>4U15</td>
<td>20</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>4U16</td>
<td>16</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>6U07</td>
<td>8</td>
<td>Intel P-IV PC</td>
</tr>
<tr>
<td>6U09</td>
<td>8</td>
<td>AMD Opteron PC</td>
</tr>
</tbody>
</table>

Also available are two high-quality postscript laser printers. The outputs can be obtained from the user helpdesk located next to the labs in building E1.

Two computer labs and the staff offices are located in the basement of building E2. The labs are particularly intended for practical courses and student research projects.

Most GNU tools and many other free- and shareware tools are installed. For documentation purposes the typesetting system \(\LaTeX/\tex\) and desktop publisher OpenOffice are available. Programming languages are particularly important and C, C++, Fortran, Pascal, and JAVA including extension libraries, source code management systems like CVS and subversion as well as source level debuggers are available. Coding is done with popular editors like vi.

\(^1\)Rechnerbetrieb Informatik
and XEmacs. Especially for students in the first stage of the study course interpreters and compilers for Clisp, Scheme, and Prolog are installed.

In addition the computers in the labs are configured for cluster grid computing. The NI Grid Engine software is used to schedule jobs on the cluster.

## Server Equipment

- Currently the RBI operates 3 file servers, a Sun Fire 280R, a Sun Enterprise 250, and a Sun Enterprise 3000, with a total hard disk capacity of almost 3 terabyte.

- Install servers for Linux speed up and simplify the installation of the computers in the labs. The operating system is automatically installed from network including all customizations.

- A dedicated mail server provides email service for the students and cluster users.

- Furthermore the RBI provides the primary web server of the department.

- A database server 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 100BaseT and 1000BaseT are widely-used.

The bandwidth increased significantly due to inexpensive switching technology and an increase of the transfer rate from 100 to 1000 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. file servers 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:

<table>
<thead>
<tr>
<th></th>
<th>mon</th>
<th>tue - thu</th>
<th>fri</th>
</tr>
</thead>
<tbody>
<tr>
<td>during terms</td>
<td>9 a.m. - 7 p.m.</td>
<td>9 a.m. - 9 p.m.</td>
<td>9 a.m. - 6 p.m.</td>
</tr>
<tr>
<td>between terms</td>
<td>mon - thu</td>
<td>9 a.m. - 7 p.m.</td>
<td>9 a.m. - 5 p.m.</td>
</tr>
<tr>
<td></td>
<td>fri</td>
<td>9 a.m. - 7 p.m.</td>
<td></td>
</tr>
</tbody>
</table>

For detailed information and current changes please note the announcements on the billboards or check http://www-rbi.informatik.rwth-aachen.de for a listing of all RBI labs’ hours of operation, including exceptions due to holidays and breaks.

Computer Science Library

The RBI maintains the entire hard- and software of the computer science library. This includes the workstations and PCs of the library staff and library users as well as the database.
server. The database contains the entire stock of books and journals of the library. The RBI develops and supports dedicated software for cataloging and querying the database.
Computer Science Library
RWTH Aachen

Staff

- Head:
  Dipl.-Bibl. Renate Eschenbach-Thomas

- Assistants:
  Nadine Behnke
  Ingo Hengstebeck
  Florian Hillebrand (until 30.06.2006)
  Michael Rose
  Dieter Schwache (since 01.07.2006)
  Nora Smets (since 03.04.2006)
  Martina Witt
  Birgit Zagolla

The library is open to everyone. Students use it as a reference library, but they may take books home overnight. Professors and scientific assistants may borrow books and use them in their offices.

Opening hours:  Mo-Fr: 9 a.m. - 8 p.m.

Address: Bibliothek der FG Informatik, RWTH Aachen,
Ahornstr. 55, D-52056 Aachen, Germany
http://www-bib.informatik.rwth-aachen.de

Phone:  +49/241/ 80-21025
Fax:  +49/241/ 80-22366
E-Mail: biblio@informatik.rwth-aachen.de
1 What you can find in our library:

- More than 35,500 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 2005; 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 suppliers
- Literature search training in online databases and catalogues for computer science students in connection with their proseminars and seminars; individually prepared exercises for each participant and her/his topic
- Website containing plenty of information on our stock as well as interesting computer science links
- Three workstations and 60 comfortable work places; separate student group work spaces
- MoPS-zone for laptop users
- Scanner and copier
- Guided tours through the library for new members of our department providing information on our services
- Friendly and qualified consulting and assistance for our visitors
- Up-to-date press reviews on computer science, student life and the RWTH Aachen
2 News

The Open-Air Reading Room ("Lesegarten")

On 20. June 2006, after a long time of waiting, our Lesegarten open-air reading room was opened with an afternoon-party. The team of the library welcomed all guests from the department and the university administration (Mr. Gaube from the Building Department) for beer, grilled sausages and other snacks. A special feature was prepared by the team of Lehrstuhl Informatik 4: the live TV-Show of the World Championship soccer match between Germany and Ecuador. More than hundred guests came, bought books from the book-fair and enjoyed the food and the discussions on many topics, among them how Germany won the match.
Children’s Corner

As a special offer of the library for young mothers, fathers and their babies, the library opened a children’s corner in 2006. On the initiative of the librarian, children’s furniture and a collection of toys was purchased from private money and assembled in a corner of room 4002 which is open to parents with children who use the library. Our first baby visitors responded with excitement and enthusiasm, and it seems that this part of the library will be quite popular.
Fachschaft I/1

Ahl, Mareike     Lehnen, Patrick
Botzen, Matthias Lipp, Hedwig
Depenbrock, Stefan Loch, Eva
   Georg         Martini, Andrea
Fuchs, Christian Meichsner, Julian
Forster, Jens    Middendorf, Lukas
Ganser, Andreas  Mungard, Nan
   Andreas       Nelles, Anna
Gray, Nicholas   Podgorski, Matthäus
   Nicholas      Reidl, Felix
Hillebrand, Florian Rispler, Manuel
Hoppe, Niklas    Runte, Sven
   Jana           Sanchez Vilaamil, Fernando
Jabs, Dominic    Schandnait, Florian
Kesselheim, Thomas Schitthelm, Oliver
   Vera       Klumb, Florian
Klinke, Vera     Schmiedt, Jacob
   Florian
Klumb, Florian   Scholtes, Sebastian
Kube, Ralph      Segger, Ingolf
Kuramoto, Nobuyoshi Vaegs, Tobias
   Nobuyoshi
Krycki, Kai      Wüsten, Sebastian
Langer, Stephan

Overview
Fachschaft Mathematik, Physik, Informatik  Tel. (02 41) 80-45 06
Kármánstraße 7, 3rd level (mail at: FS I/1, Templergraben 55, 52056 Aachen)
e-mail: fs@fsmpi.rwth-aachen.de
WWW: http://fsmpi.rwth-aachen.de/
Opening hours during lecture period:  Mo–Fr  12–14 h
during lecture free period:          Tu & Th  12–14 h
Meetings of the Fachschaft:         Mo 19 h in the rooms of the Fachschaft
Plenary meetings:                   at the beginning of each semester

The Fachschaft (group of student representatives) is a part of the student body and represents
the interests of all students who study mathematics, physics, or computer science at the
RWTH Aachen.
At the beginning of each semester a plenary meeting is held where every student of mathematics, physics, and computer science at the RWTH Aachen is invited. Here, the election of the collective takes place, and the major topics concerning the upcoming semester and the work of the Fachschaft in general are addressed. The collective is a group of students who take responsibility towards the accomplishment of the aspired goals and tasks. In addition to the collective other students work for/in the group of student representatives. Working at this group is complimentary.

We have weekly meetings where current concerns are discussed and work is coordinated. Any student of mathematics, physics, or computer science at the RWTH Aachen is welcome, allowed to speak, and invited to participate. Decisions are made in consensus.

Service
The Fachschaft has regular opening hours and offers support to students by students concerning the course of study but also on issues not directly related to the university. We have a collection of old exercises and protocols of exams which can be viewed and copied in our rooms. We have implemented a digital collection of old exercises and protocols which is used for all newly incoming exercises and protocols. Furthermore there are books, magazines and newspapers.

Dealing with the Situation of the Students
To work against the anonymity of the university and help beginners to orient we work together with the ErstsemesterInnen Projekt der Fachschaften (fresh(wo)men project) and support the ErstsemesterInnen-AG. For further information, see next section.

The Fachschaft delegates students into several academic boards in accordance with the elections.
Introduction of new Students

To introduce the new students to their new environment there are events organized by students. The ErstsemesterInnen-AG, a work group of the Fachschaft, arranges tutoring groups. These groups consist of several beginners and two tutors (students in a higher semester) as a first step for the new students to get to know each other.

Further, there is a weekend organized in a youth hostel. Every year the ErstemesterInnen-AG publishes a magazin (ES-Info) containing information and guidance to people planning to study mathematics, physics or computer science at RWTH.

The goals of these activities are:

- Build social contact after the loss of the old environment.
- Help to cope with the transfer from school to university (learning in individual responsibility) and to form groups (studying in a group, teamwork).
- Support in managing their studies.
- Basic approaches to reflect one’s own study situation.
- Information/Discussion on opportunities to exert influence in the university (academic self-management).
- Inspire studying in a solidary environment.

Working groups

The Fachschaft supports the foundation and work of student working groups. Hence the facilities of the Fachschaft is used by a few working groups.

ErstsemesterInnen-AG: Supports the beginners. See above.

Geier: The Geier (engl. vulture) is a leaflet (twosided DIN A4) with newsworthy information and references to events. The Geier is published every two weeks.

Video-AG: The Video-AG records lectures and provides those recordings to students as download for exam preparation.

Interdisciplinary Discussion Forum (IDF): The IDF organizes talks on topics of sciences and their role in our society. One talk that took part in 2006 was on video surveillance in German universities with special regard to RWTH.

Publications

Web-pages, http://www.fsmpi.rwth-aachen.de/ information on all kinds of current topics
Was’n los, magazine of the Fachschaft, published once or twice a semester.
ES-Info, information for beginners, published once a year.
Joint Projects and Organizations
The Bonn-Aachen International Center for Information Technology (B-IT) is a pioneering activity of the German Federal government and the state of North-Rhine-Westphalia in their effort to establish excellence clusters across universities and research institutes in Germany. B-IT is a joint institute of RWTH Aachen University and Bonn University in cooperation with the Fraunhofer Institute Center Birlinghoven Castle and the FH Bonn-Rhein-Sieg in Sankt Augustin. B-IT aims at the internationalization and acceleration of study programmes in Applied Informatics.

Supported by the B-IT Foundation and supplementary NRW state and federal funds, B-IT offers highly selective English-language master programmes in Media Informatics, Life Science Informatics, and Autonomous Systems. Moreover, B-IT offers summer and winter schools for qualified undergraduate students from Bonn and RWTH Aachen University. The B-IT programmes are distinguished by a deep integration of teaching and research through close cooperation with the participating Fraunhofer institutes of Applied Information Technology (FIT), Intelligent Analysis and Information Systems (IAIS), 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. Jurgen Rapp serves as study advisor. Main highlights of the year 2006 include:

- the filling of the last of B-IT’s nine endowed professorships.
- the practical implementation of the Erasmus-Mundus programme awarded to the Media Informatics programme together with the Computer Science departments of the Universities of Trento (Italy) and Edinburgh (UK). This 2.5 million EUR programme, called the European Master of Informatics (EuMI), will enable us for the next five years to support top extra-European students with quite generous stipends.
- an extension of B-IT’s international cooperation network by the Japanese Waseda University, and mutual visits with the Chinese province of Jiangsu, a partner province of NRW which cooperates closely with B-IT.
- the hosting of national and international computer science events, including “Informatiktage 2006”, the annual national top student conference of Gesellschaft
für Informatik, the Junior Academy 2006, and the Second International Conference on Media Informatics.

- participation in Beethovenfest 2006 with an exhibit “Personal Orchestra” presented by Prof. Jan Borchers and his team.

All study programs have now reached full capacity, despite a further strengthened emphasis on selection of highly qualified students. A major effort was dedicated to the preparation of a BITGRAD proposal within the Graduate School section of the German Excellence Initiative, aimed at augmenting B-IT with a doctoral programme. The proposal has reached the final round of decision making for a possible start in November, 2007.
The mission of the Fraunhofer FIT Institute for Applied Information Technology in Birlinghoven Castle and Aachen is to support human-centered computing in the context of organizational processes. Researchers in FIT study lifecycle-wide methods for the design and evolution of adaptive, user-oriented information and cooperation systems in the interplay of human work practice with organizational processes.

Third-party funding of FIT grew by over 25% to 5.8 million Euros in 2006, fostered by very strong growth in European projects as well as solid increases in industry projects and national funding. There was a significant growth in personnel of ca. 20% such that now about 110 permanent employees and 60 students work with FIT.

FIT pursues its mission in three major research areas which are complemented by special business fields and competence centers

(see [http://www.fit.fraunhofer.de](http://www.fit.fraunhofer.de) for details):

- **FIT.CSCW** (leader: Prof. Wolfgang Prinz, PhD) investigates the field of Co-operation Support Systems. In 2006 five EU-funded and two BMBF funded projects were started. ECOSPACE is an integrated project (IP) coordinated by FIT.CSCW. The project goal is the development of a reference architecture, a collaboration middleware and services, as well as new cooperation tools to
enable seamless and instant collaboration among knowledge workers, beyond organisational boundaries. CoSpaces, another IP, focuses on innovative collaborative work environments for individuals and teams in design and engineering. The third IP, C@R investigates collaboration technologies for rural areas. FIT also participates in DemoNet, a network of excellence with the objective to strengthen scientific, technological and social research excellence in eParticipation by integrating the research capacities of individuals and organisations spread across Europe. The vision of the IPCity project (another IP coordinated by FIT.CSCW) is to provide citizens, visitors, as well as professionals involved in city development or the organisation of events with a set of technologies that enable them to collaboratively envision, debate emerging developments, experience past and future views or happenings of their local urban environment, discovering new aspects of their city. The two BMBF funded projects focus in the development of a collaboration and task management platform for distributed development and engineering processes (SAGE) as well as on the development of methods and a toolbox for the development of service oriented applications for collaboration environments (MITSOA).

The following projects were successfully finished: Within the European CONNECT project we have developed and used leading edge information and communication technology to create an advanced learning environment, the virtual science thematic park. An application of CONNECT for facility management has been successfully demonstrated at an innovation exhibition of Bayer Business Services. Broadband for barefoot bankers was an ASIA@IT C project with the aim to bring cutting edge ICTs to underdeveloped markets in China for practical benefit for poor and low-income farmers and strengthening of microfinance operations in rural areas. With the Mobile Outdoor Training Assistant a new mobile application together with a community site was developed that enables users to exchange track and performance data of a jogging or cycling path with other users in a community. Our Pervasive Game Epidemic Menace that was played during a game event in summer demonstrated the vast opportunities of mobile augmented reality technologies for the development of a new generation of computer games.

- **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.

In the FUSION project on minimally-invasive liver therapy (http://www.somit-fusion.de), new algorithms for registration of 3D ultrasound with preoperative data were developed and have been evaluated with patient data in cooperation with the University of Düsseldorf.

The development of user-trainable analysis software for cell-based high through-
put experiments that resulted in a first release that has been tested with several customers. This software is also used for supervised cell cultivation in the context of a Fraunhofer cooperation.

Together with Axiogenesis AG (Cologne), a microsystem and software have been developed to conduct cardiotoxicity analysis on purified mouse cell cultures derived from stem cells. The system is able to characterize the effects of toxic substances in detail.

- **FITICON** (leader: Prof. Dr. Reinhard Oppermann) develops context-adaptive and mobile systems for eLearning and mobile work. Jointly with Informatik 5, they are main partners in the ProLearn European Network of Excellence in Professional Technology-Enhanced Learning; other large eLearning projects include the AILB project which develops novel tools to enhance the basic professional competencies for hearing-impaired young workers; the latter is a joint project with the DESIRE research team at RWTH Aachen University led by Prof. Dr. Ludwig Jäger; AILB was successfully demonstrated at CeBIT 2007, e.g., to Minister of Health Ulla Schmidt, and at the Science Summer 2006 in Munich to Federal President Horst Köhler and Research Minister Annette Schavan. Contextualisation in mobile work settings is also the main topic of the MICA project that demonstrates novel mobile user interface solutions in RFID-based warehouse worker scenarios, and was part of SAP’s lead exhibit “Future Factory” at CeBIT 2007 which was demonstrated, among others, to Chancellor Angela Merkel. A number of new European projects were started in 2006, addressing metadata for architectural learning (MACE), self-organizing photo collections (aceMedia), and middleware for mobile, networked device integration (HYDRA).

In the business process and decision support area (Prof. Dr. Thomas Rose), new European projects were started in the field of emergency management and engineering informatics. In cooperation with the group of Prof. Kowalewski at RWTH Aachen University, the new BMBF project ZAMOMO investigates the interplay of model-driven software engineering and model-based controller design for car engines. Moreover, the competence center on micro-economic modeling acquired the largest-ever research contract in the history of FIT, concerning the regular prediction of impacts proposed law changes would have on income taxes in Germany, for the Federal Ministry of Finance.

The FIT working group in Aachen is led by Dr. Andreas Becks and addresses information management aspects in business and engineering processes. Besides several contract research projects on information access and data exploration technologies for industrial customers, a major activity in 2006 was the launch of the “Zentrum für Softwarekonzepte - ZfS Aachen”, an initiative of Microsoft Germany in cooperation with Fraunhofer-FIT. In ZfS Aachen, researchers from FIT and Informatik work together
in transferring research and development knowledge related to .NET technologies to small and medium enterprises, e.g. in seminars on modern software concepts for senior developers, or envisionings on SharePoint technologies for IT decision makers.

Moreover, an international research consortium under participation of FIT Aachen started a new EU-funded research project, “AsIsKnown”, which aims at creating a semantic-based knowledge flow system for the European home textile industry. Bringing in its competence in explorative data analysis systems, FIT leads the development of the Trend Analyser - a software component that helps marketing specialists to detect trend indicators in such heterogeneous data sources like ordering data, click data in online catalogues, or fashion magazines.

FIT participated in the Informatikjahr 2006, e.g., through the co-organization of an Open Day in May 2006 for which the Institute Center Birlinghoven Castle was awarded the “Land der Ideen” label within the program of Federal President Köhler.
Graduiertenkolleg „Software für Kommunikationssysteme“ (Software for Communication Systems)

The „Graduiertenkolleg“ initiative is funded by the German Research Association (DFG). Its major intention is to substantially reduce the average time necessary to complete a PhD thesis. This time is generally considered as overly high and should, ideally, be reduced to three years while keeping the scientific quality at the highest possible level.

- a. the initiative will be ongoing without further support from DFG (i.e. that there is an automatic dissemination and continuation aspect)

- b. there is always room for new proposals and new subjects in the programme.

1 Research Programme

The ideas of our „Graduiertenkolleg“ SSoftware 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. Within the framework of the Graduate School research will focus on three areas: 'Applications', 'Middleware and New Services' and 'Network Infrastructure'. New applications will be specified, implemented, and tested. Middleware architectures and associated new services will on the one hand be designed to meet user and application requirements. On the other hand, they will be capable of adapting to different underlying communication architectures and infrastructures. Work will focus on those applications and services which lend themselves to access via wireless networks. Mechanisms to improve efficiency and reliability will be designed and evaluated. In addition, co-operation is sought with partners
from industry. Major companies, including Ericsson, Philips, T-Mobile, and Nokia are co-
operating with members of the ‘Graduiertenkolleg’ on a non-profit basis. Likewise, there
is close co-operation with the Collaborative Research Centres ’IMPROVE’. Last year the
members of the ‘Graduiertenkolleg’ organised the first international Workshop on Mobile
Services and Personalized Environments (MSPE’06). This Workshop focused on recent
research results on mobile computer systems. It pursued two goals. The first was to offer
researchers a possibility to discuss freely. The second was to bring together experienced
researchers and industry representatives with young PhD students.

2 Members of the „Graduiertenkolleg“

We are more than happy that all positions have been taken by highly qualified students. The
current (April 2007) grant holders include:

• Dipl.-Inform. Ibrahim Armac, Chair Informatik III, Prof. Dr. Nagl
• M. Sc. Juan Miguel Espinosa Carlin, Chair Informatik IV, Prof. Dr. Spaniol
• Dipl.-Inform. Gernot Fabeck, Chair Theoretische Informationstechnik, Prof. Dr. Mathar
• Dipl.-Inform. Ulrich Meis, Chair Informatik IV, Prof. Dr. Spaniol
• Dipl.-Inform. Tobias Heer, , Chair Informatik IV Lab, Prof. Dr. Wehrle
• Dipl.-Inform. Sebastian Max, Chair Comnets, Prof. Dr. Walke
• Dipl.-Inform. Cem Mengi, Chair Informatik III, Prof. Dr. Nagl
• Dipl.-Inform. Christof Mosler, Chair Informatik III, Prof. Dr. Nagl
• M.Sc. M. Sc. Elena Meshova, Chair Mobilfunknetze, Prof. Dr. Mähönen
• M.Sc. Satish Narayana Srirama, Chair Informatik V, Prof. Dr. Jarke
• Dipl.-Inform. Stefan Schiffer, Chair Informatik IV Lab, Prof. Dr. Lakemeyer
• Dipl.-Inform. Arne Schiffer, Chair Informatik VIII, Prof. Dr. Kobbelt
• Dipl.-Inform. Martin Wenig, Chair Informatik IV, Prof. Dr. Spaniol
• Dipl.-Inform. Alexander Zimmermann, Chair Informatik IV, Prof. Dr. Spaniol
• Dipl.-Inform. M. Sc. Milan Zivkovic , Chair Theoretische Informationstechnik , Prof.
  Dr. Mathar
Four students left the ‘Graduiertenkolleg’ during the reporting period. By now, they have successfully completed their theses, or are near completion.

- Dipl.-Inform. Ingo Fliegen, Chair Informatik IV, Prof. Dr. Spaniol
- M.Sc. Lucia Draque Penso Rautenbach, Chair Informatik IV Lab, Prof. Dr. Freiling
- M.Sc. Janne Riihijaervi, Chair Mobilfunknetze, Prof. Dr. Mähönen
- Dipl.-Inform. Dominik Schmitz, Chair Informatik V, Prof. Dr. Jarke
The Collaborative Research Center IMPROVE was established after a successful peer review in the spring 1997 by German Research Foundation (DFG) on August 1, 1997. Speaker is Prof. Dr.-Ing. M. Nagl, Computer Science 3, speaker substitute is Prof. Dr.-Ing. W. Marquardt, Process Engineering. IMPROVE was successfully peer reviewed also in May 2000 and April 2003, giving additional three year funding starting mid 2000 or mid 2003, respectively. In spring 2006 the Transfer Center 61 was also successfully peer reviewed and established mid 2006 for further three years.

**Topic and Aims**

The topic of CRC 476 IMPROVE is computer science support of cross-company development processes in chemical engineering. Development processes are regarded in their early phases (conceptual design and basic engineering). The long-term goal was/is the investigation and definition of an integrated process and product model for development processes in chemical engineering.

Based upon this model model tools have been developed, which are part of an integrated design environment and which, again, can be synergetically integrated. The development environment also uses existing tools to avoid the reimplementation of already existing and estimated functionality. The development environment is based on a software architecture, taking the above mentioned process and product models into account, but also the a-posteriori integration of existing tools.
Ideas and concepts developed in the CRC are practically tested and evaluated by using a reference scenario (development of a polyamide-6 plant).

**Status of CRC 476 and Transfer Center 61**

After three successful peer reviews in 1997, 2000, and 2003 in the spring 2006 the last peer review took place. It was again successful. We had applied for establishing a new Transfer Center “New Concepts and Tools for Chemical Engineering Practice” as the fourth phase of the CRC. Five subprojects were accepted. A further one is still in the reviewing process. Another project is being financed from another source but coupled with the Transfer Center. Furthermore, another DFG-project will continue its cooperation with the CRC/Transfer Center.

A volume, containing all scientific results of the CRC up to the end of 2006 is nearly completed. It will appear in the series “Lecture Notes in Computer Science” of Springer Verlag about mid 2007 and contains approximately 800 pages. It will show all the CRC achievements to the chemical engineering community. Furthermore, as the results can also be transferred to other engineering disciplines and to Computer Science, the volume will also be communicated in these disciplines.

There is a series of workshops together with industry which is planned to be continued. Furthermore, an international workshop is scheduled for 2008 or 2009 which is going to present the research results of CRC 476/TC 61 in relation to other big research projects.

There are many results described in the book. Nevertheless, it has to be stated that the big scientific question of CRC/TC, namely to develop a formal process/product model for development processes in chemical engineering has not been finished. There are a lot of interesting questions that are still open.

**Data at one glance**

**Partners within RWTH Aachen University:**
Process Engineering (LPT) http://www.lpt.rwth-aachen.de
Labour Research (IAW) http://www.iaw.rwth-aachen.de
Software Engineering (Inf. 3) http://www-i3.informatik.rwth-aachen.de
Information Systems (Inf. 5) http://www-i5.informatik.rwth-aachen.de
Distributed Systems (Inf. 4) http://www-i4.informatik.rwth-aachen.de

**Closely related projects:**
Plastics Processing (IKV) http://www.ikv-aachen.de
Computer and Communication Center (RKZ) http://www.rz.rwth-aachen.de
Contact:
Prof. Dr. M. Nagl (Software Engineering, Inf. 3; speaker of CRC/TC)
Tel.: +49-241-80-21300, Fax: +49-241-8888-218
e-mail: nagl@informatik.rwth-aachen.de

Web sites for CRC 476
http://www-i3.informatik.rwth-aachen.de/sfb476

Web sites for TC 61
http://www-i3.informatik.rwth-aachen.de/research/tb61
On 1st July 2006, the DFG Research Training Group AlgoSyn started its work at RWTH Aachen. It is a highly interdisciplinary research project led by a group of ten professors representing five different faculties in our university. The aim is to develop methods for the automated design of software and hardware, and its main challenge is to make progress in integrating quite diverse approaches from computer science and engineering disciplines.

Scientific Aims

While methods of software validation and verification are by now well established, based on adequate formal models and tested in practical applications, the approach of automatic synthesis of software (and hardware) is as yet only developed in quite rudimentary form. On the other hand, in theoretical computer science as well as in engineering disciplines a rapidly increasing stock of techniques for the development of algorithmic synthesis is emerging, triggered by the demand to decrease development costs by invoking algorithmic procedures based on adequate formal models. The approach of program synthesis is only applicable in restricted scenarios, in particular in control systems and in reactive (multi-agent-)systems with low data complexity. Central issues in the area are the establishment of system models which allow an algorithmic solution of the synthesis problem, the combination of discrete and continuous parameters in hybrid systems (as this is also familiar from verification), and the exploration of the potential of applications. The aim of the Research Training Group is to unify the expertise from computer science, mathematics, and four engineering disciplines and to push forward the desired integration of methods.

How it started

In 2004, the computer science department had reached a new configuration by the fact that several new professors had been appointed, among them B. Vöcking (Algorithms and complexity), Joost-Pieter Katoen (Software modeling and verification), as well as S. Kowaleski (Software for embedded systems). At the same time, contacts to engineering departments were intensified (mostly by S. Kowalewski from computer science and D. Abel and U. Epple from engineering) in order to establish a new master curriculum “Automatisierungstechnik”. Another important aspect was the success of the European network GAMES (“Games and automata for synthesis and validation”) in which theoreticians from Aachen played a major role.
role (E. Grädel being the coordinator). All this led to the idea that it would be promising to set up a Research Training Group in which this unusual combination of competencies could be merged. A circle of ten colleagues from five faculties of the university was formed, and long and fruitful discussions led to a convincing concept.

The actual formulation of an application was coordinated by W. Thomas at the end of 2004. The application was completed in January 2005 and defended at a referees’ meeting in Bonn in June 2005. Finally, on 19th December 2005, the great news arrived from DFG that AlgoSyn was among those Research Training Groups (in fact, a quarter of the number of applications) which were approved.

AlgoSyn has 15 positions for PhD students and one additional postdoc position. On 1st July, the first stipendiates started their work officially, the first postdoc was on board, and since then many others have joined. There are also collegiates and research students who are attached to the Research Training Group. You can find the complete list of people involved on the website www.algosyn.rwth-aachen.de.

The structure of AlgoSyn

There is a unit working on foundations comprising two branches A and B, a central unit supplying methodological interfaces for implementations, and a range of application areas from four engineering disciplines. In a little more detail, the areas are:

A. Algorithmics for agent-based, probabilistic, and hybrid systems (J.P. Katoen, B. Vöcking),
B. Formal methods of reactive systems and game-theoretic methods (E. Grädel, W. Thomas),
C. Software development and modelling languages (J. Giesl, S. Kowalewski),
D. Applications and demonstrators, in the fields of processor architectures (R. Leupers), automatic control (D. Abel), process control engineering (U. Epple), and train traffic systems (E. Wendler).

The actual research activities always touch more than one of these subject areas, and a central objective is to intensify the interaction, by tuning models towards applications, and by making practical case studies accessible to a treatment in the existing formal and algorithmic frameworks.

Anyone who is interested in the activities of AlgoSyn is invited to visit the AlgoSyn website or to write an e-mail to algo@syln.rwth-aachen.de.
Computational Science has evolved into the third leg of science, complementing theory and experimentation. In fact, the exponential growth of data collected coupled with the continuing increase in computing power make algorithmic exploration, i.e., computing, one of the primary innovating factors in science. This poses great challenges and opens up exciting opportunities for computer science, both with respect to algorithmic as well as tool and software development.

As an illustration take the simulation of so-called ventricular assist devices (VAD), small rotor-driven pumps that are implanted into the aorta of a person with weakened heart muscles. Modelling and initial code development was done by Prof. Behr from the Institute for Computer Analysis of Technical Systems, but only in collaboration with computer scientists was he able to really address the scientific issues underlying his work: Automatic differentiation enabled rigorous model calibration and sensitivity studies, performance analysis tools pointed to scaling impediments on large-scale parallel computers, and immersive visualization techniques allowed for an intuitive understanding of the complex flow structures produced by the VAD.

To provide a structure for such interdisciplinary activities in computing science, the Center for Computational Engineering Science (CCES) was founded in 2005 as a joint effort of 4 faculties. Acknowledging the fact that advanced methods of mathematical modelling and numerics as well as up-to-date computing, visualization, and software techniques are necessary to understand engineering problems and to make scientific progress, CCES is pushing interdisciplinary activities that join methodological and application competence in computational engineering science. CCES’ goal is to put RWTH Aachen at the forefront of computational science in engineering and to advance the interaction with natural science. In this context, a diploma course CES was developed, which also has substantial mandatory computer science course requirements, including programming, data structures, software engineering, high-performance computing and data intensive computing.

In November 2006, the Graduate School Aachen Institute for Advanced Study in Computational Engineering Science (AICES) was established within the framework of the Excellence Initiative of the German federal and state governments. AICES provides education to a new generation of graduates, who will receive thorough training at the interface of classical engineering, applied mathematics and computer science (4 out of the 15 faculty submitting AICES are from computer science). With its interdisciplinary and method-oriented focus, AICES stays abreast of the fast-paced developments within the comparatively young discipline of simulation-based engineering science, which will decisively shape the future technological development. In this way, AICES ultimately addresses the socioeconomic de-
mands for innovative scientific discovery processes and industrial research and development processes.

Lastly, computer science is involved in the German Research School for Simulation Sciences (GRS), a joint effort of RWTH and the research center Jülich to develop a (non-consecutive) master and doctoral program for excellent students. GRS has model character for collaboration of universities and research organizations and, in addition, leverages the unique computational environment offered by RWTH’s computing and visualization capabilities and the world-class computing facilities of the John-von-Neumann Institute for Computing (NIC).

These activities show the vibrancy of computational science at RWTH. Computer science plays a vital role in all of them, providing skills essential for developing efficient computing solutions in today’s parallel and distributed computing ecosystem. The interaction between CS, engineering, and science in this context is by no means one-way - problems from engineering and science provide valuable stimuli to drive CS research. This is exemplified by the participation of CS faculty in collaborative research centers SFB401, SFB476, and SFB 540 as well as the recently awarded graduate school AICES and the research cluster “Integrative Production Technology for High-Wage Countries”.

CS faculty have a recognized expertise in automatic differentiation, data intensive computing, geometry processing, parallel algorithms and programming tools. These capabilities have been slowly built up over the last years, capitalizing on the readiness of the Research Center Jülich to fund a junior professorship, and a vibrant group on virtual reality at the Center for Computing and Communication. However, challenges remain. The fact that all but a few programs will be running on parallel hardware in distributed or grid environments is on the surface obvious through ubiquitous multi-core laptops and web services, but the integration of such suitable capabilities into the fabric of the scientific computing software ecosystem will continue to pose challenges for quite some time to come.
Organisation

Board

Prof. Dr. rer.nat. Otto Spaniol (Chairman of the board)
Prof. Dr.-Ing. Dirk Abel
Prof. Dr.-Ing. Gerd Ascheid
Prof. Dr.-Ing. Christian Brecher
Prof. Dr.-Ing. Manfred Nagl
Prof. Dr.-Ing. Jens-Rainer Ohm
Prof. Dr. rer. pol. Kai Reimers
Prof. Dr. rer.nat Dr. med. Dipl.-Math. Klaus Spitzer
Prof. Dr.-Ing. Dipl.-Wirt. Ing. Thomas Gries
(University Representative of the Interdisciplinary Fora)
Prof. Dr.rer.nat. Reinhart Poprawe M.A.
(Vice Rector for Structural and Human Resources Development and Research)

Office

Nicole Siepmann M.A. (Executive Manager)
Carolina Getto M.A. (Assistant of the office) Dr. Regina Oertel (Coordinator of the Interdisciplinary Fora)

Industrial partner

REGINA e.V. - Kompetenznetz IT/Informatik Aachen-

Scientific activities in the field specified by the terms information, information technology and computer science extend far beyond the faculties known under the name of “computer science” or “information technology”. Nowadays, many faculties such as the humanities, social sciences, psychology, linguistics, economics, to name but a few, have now turned their attention to the possibilities of this technology and its application. Therefore, a major task of the Forum Informatik 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 infra-
structure, and is working on the development of information and communication services.
Following are the current activities:

- The SFB 427 "Media and Cultural Communication” approaches the analysis of the
“media revolution” from a cultural studies perspective. With the cultural-sciences
research-programme “Media and Cultural Communication” (founded in 1999) one of
the largest human-sciences research projects in Germany of the last decade has entered
its third phase (2005-2008) in 2005. The programme is unique due several aspects:
Foremost it represents a new type of a collaborative-research-programme which in-
tegrates 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 interna-
tionalisation, the promotion of young scientists and by a co-ordinated study program.
contact: Prof. Matthias Jarke, Chair of Computer Science 5, jarke@cs.rwth-aachen.de
further information at: http://www.graeculus.de/

- The SFB 476 IMPROVE (Information Technology Support for Collaborative and Dis-
tributed 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 engi-
neering, information systems, and communication systems. Since midyear 2006 the
SFB is transferred in the Transfer Center 61 New Concepts and Tools for Chemical En-
geineering Practice. contact: Prof. Manfred Nagl (Speaker), Department of Computer
Science 3, nagl@i3.informatik.rwth-aachen.de further information at: http://www-
i3.informatik.rwth-aachen.de/sfb476

- The SFB 540 “model-supported experimental analysis of kinetic phenomena in mul-
tiphase 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. 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 4, 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, 42 Professors and 10 companies are organized within VRCA, and more than 30 research activities are being carried out in an interdisciplinary cooperation between RWTH institutes, primarily in mechanical engineering and medicine. The VRCA-workshop took place in November 2006 and had approximately 100 visitors. The VRCA hosted aswell the 11th international Workshop “ Vision, Modeling & Visualization 2006 ” (VMV) with more than 100 participants. contact: Dr. Torsten Kuhlen, Center for Computing and Communication, kuhlen@rz.rwth-aachen.de Further information at: http://www.rwth-
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 “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, Institut for Biology II, wagner@bio2.rwth-aachen.de, Further information at: http://www.bio2.rwth-aachen.de/research/ITDrobot-e.htm

- The “Center for Computational Engineering Science (CCES)”, contact: Prof. Marek Behr Ph.D., Computational Analysis of Technical Systems, behr@cats.rwth-aachen.de, Further information at: http://www.cces.rwth-aachen.de

- The “WebKnowledge Map - WeKnow, contact: Prof. Dr. Klaus Henning, ZLW/IMA, henning@zlw-ima.rwth-aachen.de, Further information at: http://www.zlw-ima.rwth-aachen.de

- The “The Ultra High-Speed Mobile Information and Communication (UMIC), contact: Prof. Ascheid, Integrated Signal Processing Systems (ISS), gerd.ascheid@iss.rwth-aachen.de, Further information at: http://www.iss.rwth-aachen.de/
Members of the network

- over 80 companies based in the Aachen region
- 22 chairs and institutes of RWTH Aachen University
- Aachen University of Applied Sciences
- Research Center Jülich
- Aachen chamber of industry and commerce

The Aachen IT Competence Network REGINA e.V. covers the whole spectrum of business, research and education in the region. REGINA e.V. provides a focus for the activities of the member institutions, and strengthens their collaboration on a commercial, scientific and educational level. REGINA brings together companies of all sizes, from small start-ups to large international enterprises, drawing the majority of its members from the SME sector. Specialist fields include:

- Communication
- Hardware
- Domain specific software
- Technical applications/automation
- Control & Optimization
- Infrastructure, Internet, e-commerce
- Media manufacturing/production
- Telematics for the transportation sector
- 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, by order of RWTH Aachen (manager)
Dipl.-Math. R. Geisen
Dipl.-Ing. M. Bayer, Chamber of Industry and Commerce
Dr.-Ing. J. Mansfeld,
Dipl.-Ing. M. Wallrath, Ascom Deutschland GmH

**Contact:**

Daria Adenaw M.A. c/o RWTH Aachen
Templergraben 55
52062 Aachen
Tel: +49 (0) 241/809-4565
Tax: +49 (0) 241/809-2122
e-Mail: regina@zhv.rwth-aachen.de
http://www.regina.rwth-aachen.de

**Activities in 2006**

The events organized by the REGINA IT network address 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 2006:

- Round-table Discussion: What are the duties of an entrepreneur?
- INFOrmatica 2006: Annual ICT-company presentation event
- Working groups: Project management, Software testing
- Coaching by experienced managers & researchers
- Recruiting Support
Social Event

**International Activities:**

As an experienced network of competence and a strategic partner in the InnoTri project (a sub-project of the EU program “Regional Triangle of Weimar”), REGINA in 2006 has drawn up a concept for economic collaboration between the regions of Nord-Pas de Calais in France, Slask (Silesia) in Poland, and North Rhine-Westphalia in Germany.

Following the example of REGINA, other IT Competence Networks have been established in neighboring countries: REGITEL (Netherlands) and Flanders Multimedia Valley (Belgium).

**Transfer of personnel from universities to regionally based companies**

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 at the RWTH Aachen University have been donated by REGINA companies.
Technical Reports in Computer Science at the RWTH

This is a list of recent technical reports. To obtain copies of technical reports please consult http://aib.informatik.rwth-aachen.de/ or send your request to: Informatik-Bibliothek, RWTH Aachen, Ahornstr. 55, 52056 Aachen, Email: biblio@informatik.rwth-aachen.de

95-11 * M. Staudt / K. von Thadden: Subsumption Checking in Knowledge Bases
95-12 * G.V. Zemanek / H.W. Nissen / H. Hubert / M. Jarke: Requirements Analysis from Multiple Perspectives: Experiences with Conceptual Modeling Technology
95-13 * M. Staudt / M. Jarke: Incremental Maintenance of Externally Materialized Views
95-14 * P. Peters / P. Szczurko / M. Jeusfeld: Business Process Oriented Information Management: Conceptual Models at Work
95-15 * S. Rams / M. Jarke: Proceedings of the Fifth Annual Workshop on Information Technologies & Systems
95-16 * W. Hans / St. Winkler / F. Sáenz: Distributed Execution in Functional Logic Programming
96-1 * Jahresbericht 1995
96-2 M. Hanus / Chr. Prehofer: Higher-Order Narrowing with Definitional Trees
96-3 * W. Scheufele / G. Moerkotte: Optimal Ordering of Selections and Joins in Acyclic Queries with Expensive Predicates
96-4 K. Pohl: PRO-ART: Enabling Requirements Pre-Traceability
96-5 K. Pohl: Requirements Engineering: An Overview
96-6 * M. Jarke / W. Marquardt: Design and Evaluation of Computer–Aided Process Modelling Tools
96-7 O. Chitil: The ζ-Semantics: A Comprehensive Semantics for Functional Programs
96-8 * S. Sripada: On Entropy and the Limitations of the Second Law of Thermodynamics
96-9 M. Hanus (Ed.): Proceedings of the Poster Session of ALP’96 — Fifth International Conference on Algebraic and Logic Programming
96-10 R. Conradi / B. Westfechtel: Version Models for Software Configuration Management

429
96-11 * C. Weise / D. Lenzkes: A Fast Decision Algorithm for Timed Refinement


96-15 * H. Schimpe / M. Staudt: VAREX: An Environment for Validating and Refining Rule Bases

96-16 * M. Jarke / M. Gebhardt, S. Jacobs, H. Nissen: Conflict Analysis Across Heterogeneous Viewpoints: Formalization and Visualization

96-17 M. Jeusfeld / T. X. Bui: Decision Support Components on the Internet

96-18 M. Jeusfeld / M. Papazoglou: Information Brokering: Design, Search and Transformation

96-19 * P. Peters / M. Jarke: Simulating the impact of information flows in networked organizations

96-20 M. Jarke / P. Peters / M. Jeusfeld: Model-driven planning and design of cooperative information systems


96-22 * S. Jacobs / M. Gebhardt, S. Kethers, W. Rzasa: Filling HTML forms simultaneously: CoWeb architecture and functionality

96-23 * M. Gebhardt / S. Jacobs: Conflict Management in Design

97-01 Jahresbericht 1996

97-02 J. Faassen: Using full parallel Boltzmann Machines for Optimization

97-03 A. Winter / A. Schlüer: Modules and Updatable Graph Views for PROgrammed Graph REwriting Systems

97-04 M. Mohmen / S. Tobies: Implementing Context Patterns in the Glasgow Haskell Compiler

97-05 * S. Gruner: Schemakorrespondenzaxiome unterstützen die paargrammatische Spezifikation inkrementeller Integrationswerkzeuge

97-06 M. Nicola / M. Jarke: Design and Evaluation of Wireless Health Care Information Systems in Developing Countries

97-07 P. Hofstedt: Taskparallele Skelette für irregulär strukturierte Probleme in deklarativen Sprachen

430
97-08  D. Blostein / A. Schürr: Computing with Graphs and Graph Rewriting
97-10  M. Nicola / M. Jarke: Integrating Replication and Communication in Performance Models of Distributed Databases
97-13  M. Mohnen: Optimising the Memory Management of Higher-Order Functional Programs
97-14  R. Baumann: Client/Server Distribution in a Structure-Oriented Database Management System
97-15  G. H. Botorog: High-Level Parallel Programming and the Efficient Implementation of Numerical Algorithms
98-01 * Jahresbericht 1997
98-02  S. Gruner / M. Nagel / A. Schürr: Fine-grained and Structure-oriented Integration Tools are Needed for Product Development Processes
98-03  S. Gruner: Einige Anmerkungen zur graphgrammatischen Spezifikation von Integrationswerkzeugen nach Westfechtel, Janning, Lefering und Schürr
98-04 * O. Kubitz: Mobile Robots in Dynamic Environments
98-05  M. Leucker / St. Tobies: Truth — A Verification Platform for Distributed Systems
98-08 * H. Aust: Sprachverstehen und Dialogmodellierung in natürlichsprachlichen Informationssystemen
98-09 * Th. Lehmann: Geometrische Ausrichtung medizinischer Bilder am Beispiel intraoraler Radiographien
98-10 * M. Nicola / M. Jarke: Performance Modeling of Distributed and Replicated Databases
98-13  K. Indermark: Semantik rekursiver Funktionsdefinitionen mit Stichtheitsinformation
99-01 * Jahresbericht 1998
99-02 * F. Huch: Verification of Erlang Programs using Abstract Interpretation and Model Checking — Extended Version
99-03 * R. Gallersdörfer / M. Jarke / M. Nicola: The ADR Replication Manager
99-04 M. Alpuente / M. Hanus / S. Lucas / G. Vidal: Specialization of Functional Logic Programs Based on Needed Narrowing
99-07 Th. Wilke: CTL+ is exponentially more succinct than CTL
99-08 O. Matz: Dot-Depth and Monadic Quantifier Alternation over Pictures
2000-01 * Jahresbericht 1999
2000-02 Jens Vöge / Marcin Jurdziński: A Discrete Strategy Improvement Algorithm for Solving Parity Games
2000-05 * Mareike Schoop: Cooperative Document Management
2000-06 * Mareike Schoop, Christoph Quix (Ed.): Proceedings of the Fifth International Workshop on the Language-Action Perspective on Communication Modelling
2000-07 * Markus Mohnen / Pieter Koopman (Eds.): Proceedings of the 12th International Workshop of Functional Languages
2000-08 Thomas Arts / Thomas Noll: Verifying Generic Erlang Client-Server Implementations
2001-01 * Jahresbericht 2000
2001-02 Benedikt Bollig / Martin Leucker: Deciding LTL over Mazurkiewicz Traces
2001-03 Thierry Cachat: The power of one-letter rational languages
2001-04 Benedikt Bollig / Martin Leucker / Michael Weber: Local Parallel Model Checking for the Alternation free μ-calculus
2001-05 Benedikt Bollig / Martin Leucker / Thomas Noll: Regular MSC languages
2001-06 Achim Blumensath: Prefix-Recognisable Graphs and Monadic Second-Order Logic
2001-07 Martin Grohe / Stefan Wührle: An Existential Locality Theorem
2001-08 Mareike Schoop / James Taylor (eds): Proceedings of the Sixth International Workshop on the Language-Action Perspective on Communication Modelling
2001-09 Thomas Arts / Jürgen Giesl: A collection of examples for termination of term rewriting using dependency pairs
2001-10 Achim Blumensath: Axiomatising Tree-interpretable Structures
2001-11 Klaus Indermark / Thomas Noll: Kolloquium Programmiersprachen und Grundlagen der Programmierung

432
2002-01 Jahresbericht 2001

2002-02 Jürgen Giesl / Aart Middeldorp: Transformation Techniques for Context-Sensitive Rewrite Systems

2002-03 Benedikt Bollig / Martin Leucker / Thomas Noll: Generalised Regular MSC Languages

2002-04 Jürgen Giesl / Aart Middeldorp: Innermost Termination of Context-Sensitive Rewriting

2002-05 Horst Lichter / Thomas von der Maßen / Thomas Weiler: Modelling Requirements and Architectures for Software Product Lines

2002-06 Henry N. Adorna: 3-Party Message Complexity is Better than 2-Party Ones for Proving Lower Bounds on the Size of Minimal Nondeterministic Finite Automata

2002-07 Jörg Dahmen: Invariant Image Object Recognition using Gaussian Mixture Densities

2002-08 Markus Mohnen: An Open Framework for Data-Flow Analysis in Java

2002-09 Markus Mohnen: Interfaces with Default Implementations in Java

2002-10 Martin Leucker: Logics for Mazurkiewicz traces

2002-11 Jürgen Giesl / Hans Zantema: Liveness in Rewriting

2003-01 Jahresbericht 2002

2003-02 Jürgen Giesl / Renée Thiemann: Size-Change Termination for Term Rewriting

2003-03 Jürgen Giesl / Deepak Kapur: Deciding Inductive Validity of Equations

2003-04 Jürgen Giesl / Renée Thiemann / Peter Schneider-Kamp / Stephan Falke: Improving Dependency Pairs

2003-05 Christof Löding / Philipp Rohde: Solving the Sabotage Game is PSPACE-hard

2003-06 Franz Josef Och: Statistical machine Translation: From Single-Word Models to Alignment Templates

2003-07 Horst Lichter / Thomas von der Maßen / Alexander Nyßen, Thomas Weiler: Vergleich von Ansätzen zur Feature Modellierung bei der Softwareproduktlinienentwicklung

2003-08 Jürgen Giesl / Renée Thiemann / Peter Schneider-Kamp / Stephan Falke: Mechanizing Dependency Pairs

2004-01 Jahresbericht 2003

2004-02 Benedikt Bollig / Martin Leucker: Message-Passing Automata are expressively equivalent to EMSO logic

2004-04 Slim Abdennadher / Christophe Ringeissen: RULE 04 – Fifth International Workshop on RuleBased Programming

2004-05 Herbert Kuchen (ed): WFLP 04 – 13th International workshop on Functional and (Constraint) Logic Programming

2004-06 Sergio Antoy / Yoshihito Toyama (eds): WRS 04 – 4th International Workshop on Reduction Strategies in Rewriting and Programming

2004-07 Michael Codish / Aart Middeldorp (eds): WST 04 – 7th International Workshop on Termination

2004-08 Klaus Indermark / Thomas Noll: Algebraic Correctness Proofs for Compiling Recursive Function Definitions with Strictness Information

2004-09 Joachim Kneis / Daniel Mölle / Stefan Richter / Peter Rossmanith: Parameterized Power Domination Complexity


2005-01 Jahresbericht 2004


2005-03 Jürgen Giesl / René Thiemann / Peter Schneider-Kamp: Proving and Disproving Termination of Higher-Order Functions

2005-04 Daniel Mölle / Stefan Richter / Peter Rossmanith: A Faster Algorithm for the Steiner Tree Problem

2005-05 Fabien Pouget / Thorsten Holz: A Pointillist Approach for Comparing Honeypots

2005-06 Simon Fischer / Berthold Vöcking: Adaptive Routing with Stale Information

2005-07 Felix C. Freiling / Thorsten Holz / Georg Wicherski: Botnet Tracking: Exploring a Root-Cause Methodology to Prevent Distributed Denial-of-Service Attacks

2005-08 Joachim Kneis / Peter Rossmanith: A New Satisfiability Algorithm With Applications To Max-Cut

2005-09 Klaus Kursawe / Felix C. Freiling: Byzantine Fault Tolerance on General Hybrid Adversary Structures

2005-10 Benedikt Bollig: Automata and Logics for Message Sequence Charts

2005-11 Simon Fischer / Berthold Vöcking: A Counterexample to the Fully Mixed Nash Equilibrium Conjecture

434
2005-12 Neeraj Mittal / Felix C. Freiling / S. Venkatesan / Lucia Draque Penso: Efficient Reductions for Wait-Free Termination Detection in Faulty Distributed Systems

2005-13 Carole Delporte-G / Hugues Fauconnier / Felix C. Freiling: Revisiting Failure Detection and Consensus in Omission Failure Environments

2005-14 Felix C. Freiling / Sukumar Ghosh: Code Stabilization

2005-15 Uwe Naumann: The Complexity of Derivative Computation

2005-16 Uwe Naumann: Syntax-directed Derivative Code (Part I: Tangent-Linear Code)

2005-17 Uwe Naumann: Syntax-Directed Derivative Code (Part II: Intraprocedural Adjoint Code)


2005-19 Uwe Naumann / Andre Vehreschild: Tangent-Linear Code by Augmented LL-Parsers


2005-22 Felix Freiling / Maurice Herlihy / Lucia Draque Penso: Optimal Randomized Fair Exchange with Secret Shared Coins

2005-23 Heiner Ackermann / Alantha Newman / Heike Röglin / Berthold Vöcking: Decision Making Based on Approximate and Smoothed Pareto Curves

2006-01 Jahresbericht 2005

2006-02 Michael Weber: Parallel Algorithms for Verification of Large Systems

2006-03 Michael Maier / Uwe Naumann: Intraprocedural Adjoint Code Generated by the Differentiation-Enabled NAGWare Fortran Compiler

2006-04 Ebadollah Varnik / Uwe Naumann / Andrew Lyons: Toward Low Static Memory Jacobian Accumulation

2006-05 Uwe Naumann / Jean Utke / Patrick Haimbach / Chris Hill / Derya Ozyurt / Carl Wunsch / Mike Fagan / Nathan Tallent / Michelle Strout: Adjoint Code by Source Transformation with OpenAD/F

2006-06 Joachim Kneis / Daniel Mölle / Stefan Richter / Peter Rossmanith: Divide-and-Color
2006-07  Thomas Colcombet / Christof Löding: Transformation structures by set interpretations
2006-08  Uwe Naumann / Yuxiao Hu: Optimal Vertex Elimination in Single-expression-Use Graphs
2006-09  Tingting Han / Joost-Pieter Katoen: Counterexamples in Probabilistic Model Checking
2006-10  Mesut Günes / Alexander Zimmermann / Martin Wenig / Jan Ritzerfeld / Ulrich Meis: From Simulations to Testbeds - Architecture of the Hybrid MCG-Mesh Testbed
2006-11  Bastian Schlich / Michael Rohrbach / Michael Weber / Stefan Kowalewski: Model Checking Software for Microcontrollers
2006-13  Wong Karianto / Christof Löding: Unranked Tree Automata with Sibling Equalities and Disequalities
2006-15  Sebastian Ulrich / Jakob T. Valvoda / Torsten Kuhlen: Utilizing optical sensors from mice for new input devices
2006-17  Eric Lee / Henning Kiel / Jan Borchers: Scrolling Through Time: Improving Interfaces for Searching and Navigating Continuous Audio Timelines

* These reports are only available as a printed version.
Please contact biblio@informatik.rwth-aachen.de to obtain copies.