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

This report provides a summary of the activities of the Computer Science Department at RWTH Aachen University for the extended period from January 2007 to September 2008. The reason for this unconventional reporting period is that we decided to move the publishing date of the department’s annual report from the Computer Science Summer Festival to the “Tag der Informatik”, our main public event and graduation ceremony which traditionally takes place on the first Friday in December. Consequently, we cover a longer period in this report before we will continue to report on the academic year in the future issues.

In this booklet you will find ample information not only about our research and teaching activities, but also about social life and important developments in the department. The first part, Faculty Life, looks back on events like the “Tag der Informatik 2007” or “Bright Brains in Computer Science”, which received considerable public attention. It also introduces the staggering number of six new colleagues in the faculty, Erika Ábrahám, Paolo Bientinesi, James Gross, Thorsten Kuhlen, Bastian Leibe, and Ulrike Meyer. Part two, Teaching, presents the different study programs offered by the Computer Science Department and the courses taught. In the third part, Research, our research groups report on their many projects. The forth part, Central Services, introduces three indispensable organisational entities of the department: the System Administration Group, the Computer Science Library, and the “Fachschaft”, our students’ organisation. Finally, there is a part on joint projects carried out by different groups of the department together with partners from other disciplines within RWTH Aachen University or from outside organizations.

Although you will find detailed coverage on all the individual topics in this report and even though we risk to leave out some of the important achievements, we still want to list a number of selected highlights in the following to spark the interest of the reader.

- The success of the Institutional Strategy „RWTH 2020: Meeting Global Challenges“ of our university in the Excellence Initiative of the German federal and state governments in 2007 had enormous impact on the Computer Science Department. Several members of the faculty contributed to the various measures in the proposal. Considering all the different major projects now being funded at RWTH Aachen by the Excellence Initiative, there is hardly a single one where Computer Scientists are not involved. The major involvement certainly being in the Excellence Cluster “Ultra High-speed Information and Communication” (UMIC) which gained considerable momentum in this reporting period.

- As a result of these activities, several new faculty positions could be established and filled. In UMIC, Ulrike Meyer accepted a professorship for IT Security, James Gross and Bastian Leibe became Junior-Professors for Mobile Network Performance and for Mobile Multimedia Processing, respectively. Two other strands of the Excellence Initiative, the measure “Strengthening the Natural Sciences” and the Graduate School “Aachen Institute of Advanced Study in Computational Engineering Science” provided two further junior-professorships which were taken by Erika Ábrahám (Theory of Hybrid Systems) and Paolo Bientinesi (Algorithm Oriented Code Generation for High-Performance Architectures). Finally, Torsten Kuhlen was appointed a professor for Virtual Reality.

- The number of freshmen increased again to 300. All in all, the faculty is still responsible for slightly more than 2000 Computer Science students. The number of graduates in all Computer Science programs together is roughly 200 per year and some 20 computer scientists graduate with a Ph.D. from our department.

- The State Ministry for Innovation, Science, Research, and Technology approved the establishment of the B-IT Research School in Applied Informatics, which is
complementing the successful Bonn-Aachen Institute of Information technology (B-IT) and provides stipends for 20 Ph.D. students. It will be run by RWTH Aachen University and our partners University of Bonn and Fraunhofer Institute Center Birlinghoven. The speaker of the research school is Matthias Jarke.

- The Collaborative Research Center IMPROVE (Sonderforschungsbereich 476) published its final report in form of 851 pages strong book, M. Nagl, W. Marquardt (Eds.), Collaborative and Distributed Chemical Engineering, LNCS 4970. The results have lead to a Transfer Center (TB 61).
- The team of the Knowledge-Based Systems Group won the 2007 German Championship and the World Championship in the Robocup league ‘Robocup@Home’ in Atlanta, USA. In 2008, they won the German Championship and became runner-up at the World Championships in Suzhou, China.
- The department hosted several prestigious conferences and conventions, e.g.:
  - The Conference “Zukunft Ingenieurwissenschaften – Zukunft Deutschland” (Future of the Engineering Sciences – Future of Germany) by 4ING (Union of Faculty Conferences in Mechanical Engineering, Electric Engineering, Civil Engineering, and Informatics), together with the First Common Plenary Assembly of 4ING Faculty Conferences 2008 was organized by Computer Science Chair 3.
  - The Computer Science Chairs 5 and 9 organized BTW 2007, the largest German Data Base conference, with roughly 300 participants in Aachen.
- Faculty members have been active in numerous key positions in the scientific community, just to name a few:
  - Manfred Nagl is Chairman of the German Informatics Faculties Conference (Fakultätentag) and Chairman of the Board of 4ING (see above).
  - Otto Spaniol was appointed “Fellow of the German Informatics Society (GI)”.
  - Matthias Jarke finished his 8 years terms as DFG elected reviewer for practical computer science and as President of the German Informatics Society (GI) on December 31, 2007. He was elected Deputy Chairman of the Fraunhofer Group “Information and Communication Technology”.
  - Prof. Wehrle was awarded “Nachwuchswissenschaftler des Jahres 2007” (Junior Researcher of the Year 2007) by the journal „Die ZEIT“ and the German University Association (Deutscher Hochschulverband).
- Finally, our colleague Wolfgang Thomas had his 60th birthday. This was celebrated by a two days long scientific colloquium “Automata and Logic: History and Perspectives” with over 160 participants.

After this brief list of appetizers, we would like to invite you to browse through the following pages where many more accounts of our activities can be found. We also invite you to contact us or the respective members of the department if we have stimulated a deeper interest in one of the topics or if you want to share your feedback with us.

Finally we would like to thank Kai Jakobs for compiling this report.

Aachen, November 2008

Leif Kobbelt
Spokesman of the Computer Science Department until September 2008

Stefan Kowalewski
Current Spokesman of the Computer Science Department
Faculty Life

The ‘Tag der Informatik’ at the RWTH Aachen is the traditional colloquium where the chairs of the computer science department present their research and teaching activities. This event gives the opportunity to gather information about the computer science department and to establish interdisciplinary contacts. This is accomplished by poster, software and hardware exhibitions of a multitude of computer science chairs as well as industrial and research partners. It took place on December, 7th 2007 and was organized by the Chair of Computer Science I (Algorithms and Complexity).

The welcome address was given by Vice Dean Prof. Dr. Ulrich Simon and by the spokesman of the computer science department, Prof. Dr. Leif Kobbelt.

Selected research topics were presented by members of the CS department in two technical sessions. In detail these were ‘Echtzeiterkennung von Gesten und Berührungsevents für menschliche Computerinteraktion mittels Stereo Cameras’ (Thomas Deselaers, i6), ‘Der Mensch als Problemquelle in der Softwaretechnik’ (Dirk Wilking, i11), ‘Konsistenzsicherungswerkzeuge für die verfahrenstechnische Entwicklung’ (Anne-Thérèse Körtgen, i3), ‘Lastverteilung von hierarchischen Tetraedergittern mittels Graphen’ (Oliver Fortmeier, i12), ‘3D Photography’ (Alexander Hornung, i8), ‘Word Rewriting and Infinite-State System Verification’ (Jan-Henrik Altenbernd, i7) and ‘The TS-Tree: Efficient Time Series Search and Retrieval’ (Ira Assent, i9).

The highlights of the scientific program were invited talks from Prof. Dr. Rolf Möhring (TU Berlin) speaking about ‘Optimierung in Verkehr und Logistik’, Prof. Bruce Maggs (Carnegie Mellon University and Akamai Technologies) discussing ‘Engineering a Large Self-Managed Network’ and Prof. Dr. Guido Burkard (Fachgruppe Physik, RWTH Aachen) talking about ‘Quanten-Computer: Traum oder Realität?’.

After the scientific part of the day, the yearly student grant, which was sponsored by AMB Generali, was awarded to the selected student Sten Gröner. Following this, the highly entertaining final rounds of the annual ‘Sun Microsystems Softwarepreis’ were played out. Traditionally, participants in this contest have to implement clever strategies for a particular strategic game. As a novelty, this year’s game, Hexit, was a multi-player game, and four winners of the preliminary round competed in the finals. In an entertaining and enthralling match, team Bearbot came of as the winner, with runners up teams Wumpus, HexHex, and Doppelrot. The prize money of 2,500 euro in total was handed to the teams by Sun Microsystems.
The afternoon programme was closed with a laudatio held by Prof. Dr. Dr. h.c. Wolfgang Thomas before awarding the diplomas to more than one hundred recent graduates. Accompanying music was given by the strings quartet ‘Ad Libitum’.

Following the official part of the day was the traditional evening banquet, which attended roughly five hundred people including the graduates and their families, many current students and alumni, most of the CS department staff and many visitors from industry and academia. Finishing an extremely successful ‘Tag der Informatik’ the band ‘Lagerfeuermusik’ entertained the guests until late in the night, rounding up a successful ‘Tag der Informatik’ 2007.
Sommerfest der Informatik – Computer Science
Summer Party

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. Once again, the events took place at Computer Science Centre (and its
adjoining parking lot). Each event started with an introductory talk that was followed by a
more humorous ceremonial talk. The official part ended with the presentation of the diploma
certificates; over 50 students received their certificates at each summer party.

Said official ceremony was followed by the – less formal – party proper. A small buffet and
plenty of drinks were on offer. The typical crowd of about 500 – 600 people attended the
events, 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 made possible by the support of some several sponsors; they
are listed on the respective posters (see below).
InfoCup 2007 and InfoCup 2008 by Software AG

‘Mens sana in corpore sano’ could have been the slogan of the InfoCup tournaments. Here, teams of the individual Computer Science Chairs competed in the less scientific disciplines of ‘Table Soccer’ and ‘Indoor Soccer’.

The 2007 event was the first of its kind, following a number of smaller indoor soccer ‘tournaments’ between i3, i4, and LuFGi4. In 2007, twelve – highly motivated – teams participated, ten of them with their own jerseys.

Due to only 8 minutes per match, the preliminary rounds saw only few goals, but several penalty shoot-outs. Here, the future champion survived only by luck and the other teams’ fairness ………

Starting with the quarter-finals, the length of the matches was extended to 10 minutes, not least to reduce the need for penalty shoot-outs. Virtually all matches were exciting, and occasionally some teams played at a very high level. Eventually, i5 secured the championship through a 2:0 win over (the self-proclaimed favourite) i3. The team of i4 beat LuFGi9 in the petite finale.

On the other end of the spectrum i10 won the competition for the red lantern – much to their enjoyment. They also won first price for their tricots and, unofficially, for the best looking female participants ………

The original idea for the table soccer tournament had been to have ‘professor and secretary’ teams. This failed, mostly due to a lack of secretaries. Anyway, most teams that survived the preliminaries (despite participation of profs) decided to substitute profs for students ……

And the winners were: 1. LuFG i4, 2. LuFG i3, 3. i4, 4. i11

The sportive activities were – inevitably – followed by a party.

The general impression was that this had been a huge success – great teams, enthusiastic fans, excellent weather. A follow-up event was immediately scheduled for 2008.

It seems to be safe to say that this very positive impression helped to find a sponsor for 2008 event – Software AG. Compared to 2007, three teams withdrew (for whichever reasons). But 2 new teams joined the tournament, and LuFGi4 competed with two teams.

Surprisingly, the playing ability of some teams had changed dramatically from 2007. In the preliminaries, last year’s red lantern (i10) beat last year’s champion (i5), who only made seventh place this time. This time, the final ranking was 1. i3 (without a goal against), 2. i4, 3. LuFG84, 4. i8 (a ‘newcomer’). The B-team of LuFGi4 secured the red lantern.

The table soccer tournament saw a superior LuFGi4 – their two teams made places one and two, followed by i10 and i3.
Bright Brains in Computer Science –
Helle Köpfe in 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, which was continued in 2007 and 2008. 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.

Both rounds in summer 2007 and 2008 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)
- How does the internet work? (Prof. Wehrle)
- Create your own music instrument on the computer (Prof. Borchers)
- Kara, the programmable ladybug (Prof. Lichter)
- Programming a robot (Prof. Kowalewski)

Photos of all events can be found in the internet:
http://www.informatik.rwth-aachen.de/Aktuelles/HelleKoepfe

The experiences made in the first three rounds were very positive, and the program will be
continued in the next years.
4ING Conference and Common Plenary Session
July 14-15, 2008, RWTH Aachen University

A “Fakultätenstag” in Germany is an Association of Faculties offering a specific study program. For example, “Fakultätenstag Informatik” has about 50 faculty members, which offer informatics curricula. Faculty conferences assure quality of study programs, but also care about the necessary research infrastructure.

In 2006 the Faculty Conferences in Mechanical Engineering, Electrical Engineering, Civil Engineering, and Informatics built up a new umbrella organization 4ING “Faculty Conferences of Engineering and Informatics Sciences at Universities in Germany”. The aim of this new organization is to care about quality aspects in changing university organizations according to the Bologna process and ongoing globalization.

4ING represents about 2,500 professors, 15,000 research assistants, and about 120,000 students in the above disciplines. The role of 4ING is, furthermore, to introduce facts in order to de-emotionalize the ongoing discussions. Furthermore, 4ING elaborates proposals and evaluates proposals from others. Summing up, 4ING is the voice of engineering disciplines at universities in Germany.

In order to show the role of 4ING to the outside world, a common plenary session of the above faculty conferences was scheduled on July 15, this year. To make 4ING even more visible to the public, a conference on the relation of engineering science and the national economy of Germany was organized one day before.

Topics of both events were (a) the above relations between Engineering Sciences and enterprises and how to further improve them, (b) the lack of engineers in Germany and how to overcome this problem, and (c) quality assurance issues of research in engineering.

About 350 participants from faculties but even more from enterprise associations, science organization, university and research organizations, politics, media etc. were present. Most of the above organizations were involved in the organization of both events and thus supported them. Furthermore, industrial sponsors gave donations in order to cover the expenses.

A common resolution was signed on July 14 by most of important national organizations, responsible for engineering and their economic outcome in Germany. This resolution contains essentials of the tertiary education system in Germany and of the ongoing reform according to the Bologna process.

The contributions of both events, conference and common plenary session, will be published in a volume of Springer-Verlag by November 2008.

M. Nagl
Chairman 4ING
Chairman Fakultätenstag Informatik
PROGRAM
Program 4 ING Conference “Future Perspectives and Engineering”

Words of Welcome
Future Perspectives and Engineering
Prof. B. Rauhut, Rector of RWTH Aachen University
Research Policy of Federal Government in Germany
Thomas Rachel, Parliamentary Secretary of State, Federal Ministry for Education and Research
A State in Evolution – Northrhine-Westphalia on the Way to a High-tech-Country
Dr. M. Stückradt, Secretary of State, Ministry for Innovation, Science, Research, and Technology of NRW

Invited Lecture
The Economic Importance of Engineering Disciplines – also Important for the Average Citizen?
Prof. M. Hüther, Institut der Deutschen Wirtschaft, Cologne

Demos in the noon break
Demonstrations of Engineering and Informatics Research Institutions, Industrial Fora of the Aachen Region, and Interdisciplinary Fora of RWTH Aachen University.

Impulse Lecture
Technology transfer, a new instrument of DFG
Prof. Bernd Scholz-Reiter, Vice-President of German Research Association

Fascination of Engineering
Case Study Mechanical Engineering: Novaled: From the Idea to the Product
Dr. Blochwitz-Nimoth, Novaled
Case Study Electrical and Information Engineering: 3D Electromagnetic Simulation
Prof. Weiland, CST
Case Study Civil Engineering: Flood Prevention and Groundwater Protection in the Sultanate of Oman
Dr. F. Kleist, SKI
Case Study Informatics: Rise and Growing of a HighTech Enterprise
Dr. Hanselmann, dSpace

Cross-Section Themes
Engineering Sciences as Suppliers for Young Talents for Research, Development, and Management Positions in Industry
Dr. G. Kegel, Member ZVEI Board
Future Requirements for the Engineering Education
Prof. E. Kottkamp, Member VDMA Board
The Relation between University Research and Industry: Facets and Advantage for the National Economy
P.H. Bonn, Vice President of BITKOM
Dinner Speech
Mind moves Matter – The Relation of Technology and Humanity
Prof. M. Kerner, RWTH Aachen University

Common Plenary Session
Shortage of Engineers and Computer Scientists – Impulse Lectures
Shortage in Germany – An Image or a Communication Problem?
Prof. H. Biemann, TU Freiberg
Does the Secondary School make Appetite?
Prof. Bos, TU Dortmund
Gender: Why Do we Relinquish 40% of our Creative Humans?
Prof. H. Hofmeister, RWTH Aachen University
Are Engineering Disciplines still the Career for Social Advancements?
Prof. M. Hartmann, TU Darmstadt
Demographic Change – Reasons and Implications
Prof. H. Brand, University of Erlangen-Nürnberg
Quality of Education: More Graduates by less University drop-outs
M. Tropp, vbw – Vereinigung der Bayer. Wirtschaft e.V.

Current Topics w.r.t. Quality of Research and Education
Quality Label: A Procedure for Determining a Position and Building up Strategies for Faculties and Universities
Prof. A. Albers, Universität Karlsruhe, Allgemeiner Fakultätentag
Bistowing Quality Labels for Faculties of Mechanical Engineering
Prof. N. Müller, TU Clausthal
Doctoral Degree in Engineering Today – Discontinued or even a Money Maker
Prof. M. Zäh, acatech
The 12th Conference on Business, Technology and the Web (BTW) of the German Computer Society (GI) was held on 5 - 9 March 2007 at the RWTH Aachen University. The conference was organized by the chairs Informatik 5 (Information Systems, Prof. M. Jarke) and Informatik 9 (Data Management and Exploration). About 275 participants registered for the conference.

The BTW 2007 conference included a research, an industrial, and a demo track. In addition, several workshops, tutorials and a workshop for undergraduate students were co-located with the conference. The research program focused on the development of core database technologies, such as query processing and optimization, indexing, and integration, but also on related areas such as web systems and XML. The industrial program included presentations on database applications in industry and addressed topics such as data transformation, distributed and mobile databases. In the demonstration track, software demonstrations on data warehousing and peer data management systems were shown.

The conference organizers were also able to invite three renowned database experts who gave interesting keynote presentations: Christian Jensen from Aalborg University in Denmark presented a project for the management of mobile Internet services; Rudolf Munz from SAP AG in Germany reported on the experiences on data management in SAP applications; and Götz Graefe from HP Labs in USA discussed locking strategies for b-trees.
Invited Speaker Christian Jensen from Aalborg University in Denmark during his presentation "When the Internet Hits the Road"
P2P ‘08

From the 8th to the 11th of September 2008, the Distributed System Group, headed by Prof. Dr. Klaus Wehrle, hosted the major P2P’08 conference. P2P’08 is the eighth conference in a series of annual conferences concerned with overlay network technologies and massively distributed systems and applications. The conference raised a large interest in the research community, with over 150 attendees from all over the world. 161 papers were submitted to the conference, from which less than 20% were selected for the conference program. The high number of submissions and the selectivity proves the importance and the reputation of the conference series.

Following its name, the main focus of the conference is peer-to-peer (P2P) systems. P2P systems benefit from and share the resources owned by systems that are distributed around the Internet. Examples of such technologies include peer-to-peer applications and grids, and in general, any large-scale distributed system characterized by decentralization and sharing of resources.

Recently, interesting applications of P2P technology have begun to emerge, together with new platforms for application development. The conference program involved papers that reflected such experiences with practical applications in this field and explored new application areas. Furthermore, many key issues, like scalability, robustness, and security were addressed in the presented publications.
Moreover, all conference attendees were invited to an exclusive dinner in the coronation hall in Aachen's ancient Town Hall. Our impression was that this opportunity for informal exchange was highly acclaimed, and we believe that the international relations between the attending researchers were fostered that evening.
New Professors

Not least thanks to the UMIC Cluster of Excellence, we could welcome six new professors. In the following the new colleagues introduce themselves with a brief description of their research fields and some biographical information.

Erika Ábrahám

I joined the Computer Science Department at the RWTH Aachen in October 2008 as a junior professor. The new research group I am heading was initiated in the context of the Excellence Initiative at RWTH Aachen, and is devoted to the theory of hybrid systems.

Hybrid systems are systems with combined discrete continuous behaviour. They accompany our everyday life: The space heating gets switched on and off by some discrete sensors in order to keep the temperature, a continuous physical quantity, in a certain interval.

A more complex example is the real, continuous behaviour of our cars, that is controlled by embedded discrete control units. With the increasing application of such systems formal methods for hybrid systems, the research area of my group, become more and more important at international research institutions as well as in the industry.

I got my master degree (Diploma) 1999 with award from the Christian-Albrechts-University Kiel. The topic of my master thesis was in the field of artificial intelligence. I continued my studies as a doctoral student in Kiel, working on deductive proof methods for hybrid systems as well as for programming languages. At that time I was member of the group headed by Prof. Dr. Willem-Paul de Roever. Besides him, I closely collaborated with Dr. Martin Steffen from the chair, and within the German-Dutch research project MobiJ also with researchers from the CWI Amsterdam and from the University of Leiden (from which I received my Ph.D. 2005). I was also participating in the European Omega project (Correct Development of Real-Time Embedded Systems).

During my Ph.D. I moved to Freiburg 2002 and enjoyed the hospitality in the group of Prof. Dr. David Basin at the Albert-Ludwigs-University Freiburg. In 2005 I joined the group of Prof. Dr. Bernd Becker in Freiburg and started working in the context of the DFG SFB project AVACS (Automatic Verification and Analysis of Complex Systems). My main research area was bounded model checking for hybrid systems. From spring 2006 till autumn 2007 I was a guest at the RWTH Aachen in the group of Prof. Dr. Joost-Pieter Katoen. During the last year before I joined the RWTH I was associated with the Forschungszentrum Jülich.

I am married and have two wonderful children Judith (12) and Andras (9), who are also very interested in computers, at least in playing and chatting. My hobbies are my children, reading, hiking, and painting.
Paolo Bientinesi

In June 2008 I joined the RWTH Aachen University as Young Research Leader in the Aachen Institute for Advanced Study in Computational Engineering Science (AICES). Since October 2008 I am also appointed as Junior Professor on “Algorithm Oriented Code Generation for High-Performance Architectures” in the Computer Science Department.

My research interests center around the fields of scientific computing, high-performance & parallel computing, and automation. Research in these fields is motivated by real-world scientific and engineering applications, and deals with the development of fast and accurate numerical algorithms. The nature of my research is interdisciplinary, naturally leading to collaborations both within and outside the boundaries of computer science.

Two are my long-term research objectives. On one hand, I aim at bridging the gap that traditionally separates algorithm development from both architectures and scientific applications. Superior algorithms, in terms of performance and/or accuracy, result from integrating knowledge from applications, algorithms, and architectures. In addition, I am also interested in making the process of discovery and development of algorithms automatic: in my mind, one problem can be labeled as fully understood only if it can be solved by an automated system with limited, if any, human intervention. Throughout my career, I pursued and made contributions in both these two research themes.

As a Computer Science student at the University of Pisa, in 1998 I completed my Laurea degree (Summa cum Laude) with a thesis on “Computational Geometry Techniques for Approximating Electrostatic Forces”. The following year I served as officer in the Italian Navy, ranking first of the class and receiving the “Officer of the Year” award and fellowship. In 2000 I moved to the US to join the Ph.D. program in Computer Sciences at the University of Texas at Austin. During my graduate studies I worked on parallel computing, numerical analysis, high-performance computing and automation. In July 2006 I defended the dissertation "Mechanical Derivation and Systematic Analysis of Correct Linear Algebra Algorithms". This dissertation, supervised by Prof. Robert van de Geijn, was selected as the Computer Sciences department candidate for the 2006 ACM Doctoral Dissertation Award, and was finalist for the Householder Award for the best dissertation in numerical linear algebra in the years 2006-08. In September 2006 I was appointed as a Research Associate in the Computer Science department at Duke University, where I worked on Fast Fourier Transforms and emerging architectures like the Cell Broadband Engine.

Currently I am working on linear algebra algorithms for multi-core architectures and massively parallel supercomputers, performance analysis & prediction, direct linear solvers for hierarchical matrices, and automatic generation of algorithms. My hobbies include hiking in the Dolomites, dj-ing, and all sorts of card and board games.
James Gross

In January 2008 I joined RWTH Aachen University as assistant professor and head of a (junior) research group on ‘Mobile Network Performance’. On the one hand this group is associated with Lehrstuhl I4 for Communication and Distributed Systems, however, we are also part of the “DFG Exzellenzcluster UMIC - Ultra-High Speed Mobile Communication and Information”. In 2002, I graduated from TU Berlin in computer engineering after having spent one year at the University of California, San Diego as stipendiary. Afterwards, I joined the Telecommunication Networks Group of Prof. Adam Wolisz at TU Berlin as Ph.D. scholar of the "DFG Graduiertenkolleg MAGSI" (from 2002 - 2006) and as post-doc in 2007. I received my doctoral degree with honours for my thesis on dynamic resource allocation in wireless OFDMA networks. This work was also awarded the VDE-ITG/GI KuVS Ph.D. thesis prize in 2007. Apart from that I also received the "Erwin-Stephen" prize of TU Berlin for my master degree in 2002. My research interests are in the area of adaptation for wireless networks. This includes topics like network design, network management, optimization, resource allocation, quality-of-service provisioning, modeling and performance evaluation. I like working on clear problem definitions in the mathematical sense and exploring solutions with respect to theoretical models but also considering performance in practice. Currently, I am contributing to the IEEE 802.11 standardization committee on the design of future (i.e. post 802.11n) wireless local area networks. On the other hand, within the UMIC research centre I am actively pushing the interdisciplinary topic of large-scale, high-detail wireless network simulations. I am a member of the IEEE, VDE and GI and served on several program committees for major conferences in the above research fields. If not doing something related to my job at RWTH Aachen University, I like doing sports (cardio-stuff) as well as reading good books (about history as well as more philosophical things). However, most of all do I enjoy the company of my two girls (Theresa – close to my age – as well as Helena – 2 years old) and spending time with them.

Torsten Kuhlen

In June 2008, I was appointed to an apl. professorship in the Department of Computer Science at RWTH Aachen University.

From 1985 until 1992, I studied Computer Science at RWTH. My diploma thesis was about the optimization of interconnection networks in distributed parallel computers and was supervised by Professor Walter Oberschelp, whose teaching philosophy and insights about the bigger picture have had a deep influence on my attitude and approach to Computer Science.

In the following five years, I worked as a research assistant at the Institute of Technical Computer Science, where my research focus switched to innovative human-computer interfaces and in particular Virtual Reality (VR). In a joint research project with the University Hospital Düsseldorf, I discovered my talent for interdisciplinary work. Throughout my collaboration with the neurologists there, I developed a tool for research on the
sensorimotor organization of the human brain with focus on reaching and grasping. The tool made extensive use of VR techniques as well as self-organizing neural networks, and was the core of my doctoral thesis which I finished in 1998 at the faculty of Electrical Engineering under the supervision of Professor Karl-Friedrich Kraiss.

Virtual Reality is not only an interesting research topic in itself, but furthermore a valuable tool in science. As a consequence, I did not hesitate when Professor Christian Bischof gave me the opportunity to establish VR technology at the Center for Computing and Communication of RWTH Aachen University to complement computing as fundamental infrastructure for Computational Science. Thus, the Virtual Reality Group at the Center for Computing and Communication was founded with the goal to provide state of the art VR infrastructure and methods and, beyond that, to develop new methods of VR-based visualization and interaction in its own research work. Since this research ultimately is intended to enable other researchers to analyze complex technical and physical phenomena in Engineering Science, Life Science, and Medicine, my activities are application-driven and characterized by joint projects across disciplines with other RWTH institutes from multiple faculties, other research organizations from all over the world, and industry.

In the year 2000, I founded the Virtual Reality Center Aachen (VRCA) together with Christian Bischof in order to further bundle and expand the VR activities at RWTH and the region of Aachen. Since its foundation under the roof of the “Forum Informatik”, I have been serving the Center as the “CEO”, although this title is somewhat misleading since the VRCA is a non-profit research network. Today, more than 40 RWTH Professors, and 15 companies as well as external research institutions are organized in the VRCA, carrying out more than 50 research projects. For 3 years now, I have also been the speaker of the “Fachgruppe Virtual & Augmented Reality” in the “Gesellschaft für Informatik”. The goal of this section is to bundle the expertise of the various German-speaking research groups in academia as well as industry.

Since 1999, I have been teaching Virtual Reality at RWTH Aachen. In summer this year, Bayreuth University offered me a W2-professorship for Applied Computer Science, which I turned down in favour of an apl. professorship here in Aachen. As such, I again missed the opportunity to leave Aachen. So feel free to call me a couch potato! However, the RWTH environment with its potential for top-notch interdisciplinary VR research, capitalizing on strong Computer Science and Simulation Science, is really unique and makes me feel at home in Aachen.

Bastian Leibe

In August 2008, I joined the Computer Science Department at RWTH Aachen University as Juniormprofessor in order to found the Mobile Multimedia Processing group at the Chair of Computer Sciences 8. Before joining RWTH Aachen University, I passed through the following locations.
I started my studies of Computer Science at the University of Stuttgart in 1995. From 1998 to 1999, I then had the opportunity to go to Georgia Institute of Technology in Atlanta for a 1-year study period. This stay abroad was a great experience, which I can recommend to every student. It was there that I got to know and like the US style of graduate-level teaching and performing hands-on research, and it was ultimately this experience that convinced me of continuing for a PhD. During my M.Sc. thesis at Georgia Tech, I also first came into contact with Computer Vision and found it to be a very interesting and exciting field of study. It is therefore not surprising that after coming back from Georgia Tech to finish my Diplom in Stuttgart, I went straight on to pursue a PhD in Computer Vision. For this, I joined the group of Prof. Dr. Bernt Schiele at ETH Zurich in January 2001. In October 2004, I received my doctoral degree for my dissertation on “Interleaved object categorization and segmentation”, for which I was awarded the ETH Medal. As my PhD advisor Prof. Schiele took on a call for a tenured professor position at TU Darmstadt during the final year of my PhD, I joined him for a one-year postdoc period directly after finishing my thesis in order to help build up the new group there. In January 2006, I then went back to ETH Zurich to take on a position as postdoctoral research associate in the computer vision group of Prof. Dr. Luc Van Gool, where I supervised a subgroup of between 5 and 6 PhD students.

My research interests lie in visual object recognition, segmentation, 3D reconstruction, and tracking, and especially in combinations of those areas. This is a very exciting time to work in Computer Vision, as many of its individual areas are reaching a level where research approaches start to work under difficult real-world conditions and where practical applications suddenly become possible. Through my research, and that of the PhD students I supervised, I have contributed to this development. During my PhD thesis, I developed an approach for local-feature based visual object categorization that can recognize novel objects of a learned category, while simultaneously segmenting them from the image background. In later work, I then extended this approach to create a state-of-the-art pedestrian detector which is particularly suited for recognition in crowded scenes. Through a combination of this approach with tracking and motion estimation, my group built a mobile vision system that can, in its latest instantiation, automatically detect other traffic participants (cars, pedestrians, bicyclists) in a vehicle’s field of view and track them through highly dynamic inner-city scenes. In other work, we combined recognition with 3D reconstruction in order to automatically build visually pleasing and semantically meaningful 3D city models. Finally, we developed methods for the automatic extraction of interesting objects and landmark buildings from community photo collections such as Flickr and for using those results for visual object recognition from mobile phones. This research work has been internationally widely recognized and has won a number of awards, including the DAGM Main Prize in 2004, the CVPR Best Video Award in 2006, the CVPR Best Paper Award in 2007, the Optical 3D Measurement Techniques Best Paper Award in 2007, and the DAGM Olympus Prize in 2008.

At RWTH, I am affiliated with the Excellence Cluster “UMIC – Ultra High Speed Mobile Information and Communication”. This cluster provides a very exciting research environment for my new group to develop computer vision applications for mobile devices and platforms. Apart from continuing the abovementioned research lines, a main focus of our work will be on creating computer vision applications for mobile phones. In addition, I will start my
teaching this winter semester with a lecture on Computer Vision, in which I hope to pass on my excitement for this research area to new generations of students.

**Ulrike Meyer**

In August 2008, I joined the Computer Science Department of RWTH Aachen to lead the newly established IT-Security Research Group (Lehr- und Forschungsgebiet IT-Security). This Research Group was established along with the Cluster of Excellence “UMIC - Ultra-High-Speed Mobile Communication and Information”, a joint initiative of the Faculty of Engineering and Information Technology and the Department of Computer Science. As the name of the research cluster already indicates, the focus of our research group is on security in mobile communications. Topics of interest include designing security mechanisms for decentralized networks, securing mobility in heterogeneous networks, analyzing security architectures of existing standards, and designing and implementing new security architectures and protocol extensions.

Right before joining RWTH, I worked in the research departments of Siemens AG and Nokia Siemens Networks in Munich. There, I worked on internal and external security-related research and consulting projects as well as on the standardization of the security architectures for next generation mobile networks and filed several patent applications.

After studying Mathematics at the University of Heidelberg, I joint the Department of Cryptography and Computer Algebra headed by Prof. Johannes Buchman at the Computer Science Department of Darmstadt University of Technology in 2001. I’ve received my doctoral degree with honours for my thesis on Secure Roaming and Handover Procedures in Wireless Networks in 2005. During my PhD studies, I spend almost two years at Stevens Institute of Technology in Hoboken, New Jersey, working with Prof. Susanne Wetzel. During this time I was supported by stipends of the German Research Foundation (DFG) and the German Academic Exchange Service (DAAD). Additionally, my research was funded by the Wireless Networks Security Centre (WinSec) co-located with the Stevens Institute.
Teaching
Description of the contents and curriculum of the

*Computer Science (Diploma) - program*

at RWTH Aachen University

**Short description:**

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

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

**Degree:** Diploma

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

**Required qualifications**

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

Overall structure

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

Stage I (Vordiplom)

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

Stage II (Hauptdiplom)

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

Study courses

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

Post-graduate studies

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

**Foreign study offer**

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

**Subject-related specialty**

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

**Professional areas**

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

**Short description**

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

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

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

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

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

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

Overall Structure

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

Stage I

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

Stage II

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

Professional Areas

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

The subject of computer science at school

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

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

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

An overview of the curriculum

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

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

The essential prequisites for a successful study of computer science are similar as for the diploma curriculum: a certain 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 Programme

Software Systems Engineering

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

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

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

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

Since September 2004, Software Systems Engineering is also part of the Erasmus Mundus programme European Master in Informatics, which is offered together with the University of Edinburgh and the University of Trento. Participating students receive a two-year scholarship and spend the middle two semesters at one of the partner universities. At the end of the programme, they receive a double degree.
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; Dsseldorf) 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 2007 and 2008, two workshops took place which were organized in collaboration of several computer science chairs. The workshops were attended by about 34 pupils.

In 2007, 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 RatPack project of the Distributed Systems Group (LuFGI4), which deals with programmable sensor nodes to analyse social networks of rats, was illustratively presented to the girls. At the end, the Computer Graphics and Multimedia Group (I8) presented among others dynamic simulations of fluids, 3D reconstruction of photographs, and character animation from 2D pictures. These demonstrations were followed by the girls with big interest.

In 2008, the workshop was organised as interactive walk through computer science to see different facets. Starting with a game to get to know each other and a short introduction about studying computer science at RWTH Aachen University, the girls played the TableLemmings game. All girls played together and had to bring as many running penguins as possible safely to an exit by leading them e.g., over gorges by building bridges. The game is based on modern computer technology and is controlled by gestures performed on the table. Afterwards, the RatPack project and computer graphics demonstrations were presented which again caused big interest. These were then topped by the visit of the CAVE at the Center for Computing and Communication which builds a virtual reality. The day ended there with a virtual walk through the market of the city of Aachen.
Courses Taught in 2007 and 2008

Summer Term 2008 – Undergraduate Courses

Borchers, Weiß, Karrer
Mensch-Maschine-Interaktion
PST (2)

Bücker, Lülfesmann, Willkomms, Rasch, Wolf
Parallele Programmierung mit OpenMP
VÜPT (V1+Ü3)

Giesl, Fuhs, Schneider-Kamp, Swiderski
Proseminar: Fortgeschrittene Programmierkonzepte in Java, Haskell und Prolog
PST (2)

Grädel
Mathematische Logik
V (3)

Grädel
Mathematische Logik (Diskussion)
F (1)

Grädel
Mathematische Logik (Übung)
Ü (2)

Jarke, Quix
Web-basierte Software-Entwicklung mit .NET
VP (P3+V1)

Katoen, Kern, Rieger, Heinen
Softwarepraktikum: Implementierung heuristischer Algorithmen für Brettspiele
PT (3)

Kobbelt
Datenstrukturen und Algorithmen
V (4)

Kobbelt, Habbecke, Dekkers
Datenstrukturen und Algorithmen (Übungen)
ÜT (2)

Kobbelt, Habbecke, Dekkers
Datenstrukturen und Algorithmen (Fragestunde)
F (2)

Kobbelt, Möbius
Proseminar: Ausgewählte Kapitel der Computergraphik
PST (2)

Kowalewski, Li
Programmieren eingebetteter Systeme mit Lego-Mindstorms
VPT (4)

Kowalewski, Mitsching, Stollenwerk
Elektrotechnische Grundlagen der Informatik
P (2)

Lakemeyer, Calmes, Ferrein, Schiffer
Künstliche Intelligenz
PS (2)

Lichter, Nyßen, Schackmann, Hoffmann, Ganser
Java-Plugin-Entwicklung für Eclipse
P (3)

Nagl, Wörzberger, Armac
Pioniere in der Softwaretechnik
PST (2)

Naumann, Varnik
Grundzüge der Softwareentwicklung
VÜ (1+2)

Ney
Softwarepraktikum Muster- und Bilderkennung
VÜPT (4 (V1+Ü3))

Noll, Neuhäußer, Klink, Kern, Rieger
Spezifikationsformalismen
PST (2)

Rossmanith
Graphalgorithmen
VP (V1+P3)

Spelten, Thomas
Formale Systeme, Automaten, Prozesse (Hörsaalübung)
Ü (2)

Spelten, Thomas
Formale Systeme, Automaten, Prozesse (Gruppenübungen)
Tut (2)

Thißen, Spaniol
Netzwerkprogrammierung
P (V1/P3)

Thomas
Formale Systeme, Automaten, Prozesse
V (3)

Wehrle, Sasnauskas, Spaniol
Grundlagen Rechnernetze und Internet
PST (2)

Summer Term 2008 – Graduate Courses

Abraham
Erfüllbarkeitsüberprüfung
VÜ (V3 Ü1)

Bemmerl
Betriebssysteme II
V (2)

Bemmerl, Finocchiaro
Betriebssysteme II
Ü (1)
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<td>Praktikum Virtuelle Realität</td>
<td>PT (4)</td>
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<tr>
<td>Bischof, Lülfesmann,</td>
<td>Einführung in High-Performance Computing</td>
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<td>Willkomm, Petera, Fortmeier</td>
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<tr>
<td>Bischof, Petera, Fortmeier</td>
<td>Einführung in High-Performance Computing</td>
<td>VT (3)</td>
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<td>Bohnenkamp</td>
<td>Testen reaktiver Systeme</td>
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<td>Borchers</td>
<td>CHI Club</td>
<td>FK (2)</td>
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<td>Borchers</td>
<td>Club i10</td>
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<td>Borchers, Diehl, Spelmezan</td>
<td>The Media Computing Project (Praktikum Hauptstudium)</td>
<td>P (4)</td>
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<tr>
<td>Borchers, Karrer, Weiß</td>
<td>Designing Interactive Systems II</td>
<td>VÜ (V4/Ü2)</td>
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<td>Borchers, Spelmezan</td>
<td>Current Topics in Media Computing and HCI</td>
<td>VÜT (V2/Ü1)</td>
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<td>Bücker, Lülfesmann,</td>
<td>Parallele Programmierung mit OpenMP</td>
<td>VÜPT (V1+Ü3)</td>
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<td>Willkomm, Rasch, Wolf</td>
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<td>Deselaers, Mauser</td>
<td>Praktikum &quot;Data Mining Cup&quot;</td>
<td>P (4)</td>
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<td>Deserno, Kobelt, Ney,</td>
<td>Medizinische Bildverarbeitung</td>
<td>ST (2)</td>
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<td>Rossmanith, Seidl, Spitzer</td>
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<td>Giesl</td>
<td>Logikprogrammierung</td>
<td>V (3 for Bachelor, 4 for Diploma)</td>
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<td>Giesl, Fuhs, Schneider-Kamp, Swiderski</td>
<td>Seminar Verifikationsverfahren</td>
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<td>Giesl, Fuhs, Schneider-Kamp, Swiderski</td>
<td>Arbeitsgemeinschaft Programverifikation</td>
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<td>Giesl, Swiderski</td>
<td>Logikprogrammierung</td>
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<td>Algorithmische Modelltheorie</td>
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<td>Grädel</td>
<td>Seminar: Logik, Komplexität, Spiele</td>
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<td>Grädel, Thomas</td>
<td>Arbeitsgemeinschaft: Logik und Automaten</td>
<td>AG (2)</td>
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<td>Gross</td>
<td>Discrete Event Simulation</td>
<td>V (2+1)</td>
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<td>Jarke, Brandt, Raddatz</td>
<td>Arbeitsgemeinschaft Verfahrenstechnische Informationssysteme</td>
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<td>Jarke, Klamma</td>
<td>Arbeitsgemeinschaft Metadata in Community Information Systems</td>
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<td>Jarke, Klamma, Cao,</td>
<td>Gaming Communities</td>
<td>P (4 (5 for media informatics))</td>
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<td>Glukhova</td>
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<td>Jarke, Klamma, Lübbers,</td>
<td>Einführung in Datenbanken</td>
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<td>Kensche,</td>
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<td>Jarke, Lakemeyer</td>
<td>Doktorandenseminar</td>
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<tr>
<td>Jarke, Oppermann</td>
<td>User-oriented system design and personalized information services</td>
<td>P (5)</td>
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<td>Jarke, Quix</td>
<td>Arbeitsgemeinschaft Model Management</td>
<td>AG (2)</td>
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<td>Jarke, Quix, Chatti</td>
<td>Web 2.0 Enterprise Mashups für Global Sourcing</td>
<td>PT (4)</td>
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<td>Jarke, Quix, Li</td>
<td>Advanced Data Models</td>
<td>VÜ (V2/Ü1)</td>
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<td>Kariantanto, Thomas</td>
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<td>Katseen, Bohnenkamp</td>
<td>Testen reaktiver Systeme</td>
<td>Ü (2)</td>
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<td>Neuhäußer, Han, Klink,</td>
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<td>Kobbelt</td>
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<td>Kobbelt, Hornung</td>
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<td>Kobbelt, Möbius</td>
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<td>Kobbelt, Pavic</td>
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<td>Diplomanden- und Doktorandenseminar</td>
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<td>Kowalewski, Palczynski</td>
<td>Modellierung technischer und physikalischer Systeme</td>
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<td>Kowalewski, Weise, Schlich</td>
<td>Formale Methoden für eingebettete Systeme</td>
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<td>Lakemeyer, Beck, Claßen</td>
<td>Introduction to Knowledge Representation</td>
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<td>Schiffer, Beck</td>
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<td>Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge</td>
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<td>Nagl, Heer, Retkowitz</td>
<td>Softwaretechnik-Projektpraktikum im Hauptstudium: Workflowschwenden Dienste für eHomes</td>
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<td>Nagl, Körtgen</td>
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<td>Nagl, Mengi, Weinell</td>
<td>Modellgetriebene Unterstützung für die Automotive Produktlinienentwicklung</td>
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<td>Nagl, Ranger</td>
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<td>Naumann, Varnik</td>
<td>Ableitungscodemompiler</td>
<td>VÜ (2+2)</td>
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<td>Naumann</td>
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<td>Ney</td>
<td>Statistical Methods in Natural Language Processing</td>
<td>V (4 (for Diploma, Master SSE and Master MI)/3 (for Bachelor))</td>
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<td>Statistical Methods in Natural Language Processing</td>
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<td>Lehrstuhlseminar Advanced Topics in Speech and Language Processing</td>
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<td>Pimenidis, Panchenko, Spaniol</td>
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<td>Prinz</td>
<td>CSCW und Groupware: Konzepte und Systeme zur computergestützten Zusammenarbeit</td>
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<td>Seminar Mobile Robots II - on Ground and in the Air</td>
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<td>Schroeder, Giani</td>
<td>eLearning</td>
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<td>Schroeder, Rohde, Stalljohann</td>
<td>Programmierung von webbasierten Software-Portalen (Web Technologien 2)</td>
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<td>Schroeder</td>
<td>Einführung in die Fachdidaktik Informatik</td>
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<td>Fachdidaktisches Seminar zu den Praxisphasen</td>
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<td>Massively Distributed Systems 2 - Sensor Networks</td>
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<td>Communication Systems Engineering 1</td>
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<td>Praktikum Sensor-Netzwerke</td>
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<td>Peer-to-Peer System</td>
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<td>Wehrle, Landsiedel, Götz</td>
<td>Communication Systems Engineering</td>
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<td>Westermann</td>
<td>Approximations- und Online-Algorithmen</td>
<td>V (2)</td>
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<td>Wolf</td>
<td>Grid Computing</td>
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<td>Wehrle</td>
<td>Multithreading</td>
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**Winter Term 2007/2008 – Undergraduate Courses**

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**Winter Term 2007/2008 – Graduate Courses**

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<td>Spaniol</td>
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<td>Spaniol, Krebs, Pham, Wenig, Zimmermann</td>
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<td>Spaniol, Krempels</td>
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<td>Spaniol, Seipold, Espinosa Carlin</td>
<td>Arbeitsgemeinschaft: Multimediakommunikation</td>
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<td>Spaniol, Thißen</td>
<td>Datenkommunikation und Internet-Technologie</td>
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<td>Spaniol, Thißen, Tantidham</td>
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<td>Spaniol, Wehrle, Pimenidis, Panchenko, Wienzek</td>
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Thomas, Löding, Karianto, Radmacher
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ST (2)

Thomas, Spelten
Automata and Reactive Systems
Ü (2)

Unger, Mertzios
Kommunikationsprobleme
V (4)

Unger, Mertzios
Kommunikationsprobleme
Ü

Vöcking
Lehrstulseminar: Effiziente Algorithmen
S (2)

Vöcking, Fischer
Algorithmische Spieltheorie
VÜ (3)

Vöcking, Mertzios
Algorithms for Wireless Networks
S (2)

Wehrle
Peer-to-Peer Systems and Applications (Massively Distributed Systems I)
VÜ (V1/Ü1 or Practical with 2 SWS)

Wehrle
Massively Distributed Systems
S (2)

Wehrle
Praktikum Linux Kernel Programmierung
P (4)

Wehrle
Lehrgebietsseminar
S (1)

Wehrle
Einführung in Intrusion Detection
VP (1+1 SWS)

Wehrle, Götz, Heer
Peer-to-Peer Systeme
AG

Westermann, Englert
Effiziente Algorithmen
S

Wolf
Multithreading
VÜT (V2/Ü1)

Summer Term 2007 – Undergraduate Courses

Aach
Klausur Elektronische Grundlagen für Informatiker (unbenoteter Leistungsnachweis)
KIT

Bischof
Klausur Programmierung
T

Borchers, Spelmezan
Mensch-Maschine-Interaktion
PST (2)

Cramer
Einführung in die Stochastik für Informatiker
V (3)

Cramer
Einführung in die Stochastik für Informatiker (Diskussion)
Ü (2)

Cramer
Klausureinsicht Einf. i. d. Stochastik für Informatiker

Cramer
Frage-Tage zur Klausur "Einführung in die Stochastik für Informatiker"

Cramer
Klausureinsicht Einf. i. d. Stochastik für Informatiker

Cramer
Klausur Einf. i. d. Stochastik für Informatiker
KIT

Cramer
Klausur Einführung in die Stochastik für Informatiker (WdhL)
KIT

Cramer, Seehafer
Einführung in die Stochastik für Informatiker
Ü (1)

Esser
Numerisches Rechnen (Vorkurs)
V (1)

Esser
Numerisches Rechnen
V (3)

Esser
Numerisches Rechnen (Diskussion)
F (1)

Esser
Klausur Numerisches Rechnen
T

Esser, Frings, Pankratz, Plesken
Numerisches Rechnen (Großübung)
Ü (2)

Esser, Frings, Pankratz, Plesken
Numerisches Rechnen
ÜT (2)

Esser, Pankratz, Plesken, Frings
Klausur Numerisches Rechnen
KIT

Giesl, Schneider-Kamp, Thiemann, Swiderski, Fuhs
Proseminar: Fortgeschrittene Programmierkonzepte in Java, Haskell und Prolog
PST (2)
Hanke, Zerz  Lineare Algebra I (fuer Informatiker)  V (4)
Hanke, Zerz  Lineare Algebra I (Übungsgruppen fuer Informatiker)  ÜT (2)
Hanke, Zerz  Klausur Lineare Algebra I (fuer Informatiker)  KIT
Hanke, Zerz  Klausur Lineare Algebra I (Wdhl. fuer Informatiker)
Jarke, Klamma, Cao, Chatti  Multidimensionale und Metrische Datenstrukturen  PS (2)
Katoen  Automatentheorie und Formale Sprachen  V (3)
Katoen  Klausur Automatentheo. u. Form. Sprachen  KIT
Katoen, Han  Automatentheorie und Formale Sprachen  Ü (2)
Katoen, Han  Automatentheorie und Formale Sprachen  Tut (2)
Katoen, Han  Formale Systeme, Automaten, Prozesse (Gruppenübungen)
Katoen, Kern  Softwarepraktikum: Implementierung heuristischer Algorithmen für Brettspiele  PT (3)
Kobbelt, Bommes  Proseminar: Ausgewählte Kapitel der Computergraphik  PST (2)
Kowalewski, Palczynski, Li  Proseminar Automotive Software Engineering  PST (2)
Lakemeyer, Calmes, Ferrein, Schiffer  Künstliche Intelligenz  PS (2)
Nagl, Mosler, Schultchen  Werkzeugkiste für den Kammerjäger: Konzepte, Techniken und Werkzeuge zum Testen von Software  PST (2)
Naumann, Varnik  Softwareentwicklung  VÜ (2+1)
Naumann, Varnik  Compilerbau  P(3)
Ney  Softwarepraktikum Muster- und Bilderkennung  PT (3)
Noll  Hardware-Praktikum (f. Informatiker 4. Sem.)  PT (4)
Noll  Hardware-Praktikum (f. Informatiker 4. Sem.)  PT (4)
Seidl  Softwarepraktikum: Datenstrukturen  PT
Spaniol  Klausur Systemprogrammierung  T
Unger, Franke  Proseminar: Algorithmen auf Graphen  PS (2)
Vöcking  Klausur Berechenbarkeit u. Komplexität  T
Wehrle, Götz  Grundlagen der Rechnernetze  PS (2)
Wienzek, Spaniol  Netzwerkprogrammierung  P (2)
Wolf  Rechnerstrukturen  VT (4)
Wolf, Lakemeyer, Claßen  Rechnerstrukturen (Übungen)  ÜT (2)
Zerz  Klausur Lineare Algebra I (Wdhl. fuer Mathematiker)  KIT

Summer Term 2007 – Graduate Courses

Bemmerl  Betriebssysteme II  V (2)
Bemmerl, Finocchiaro  Betriebssysteme II  Ü (1)
Bischof, Kuhlen, Valvoda, Schirski  Softwarepraktikum Virtuelle Realität  PT (4)
Bischof, Petera, Fortmeier  Einführung in High-Performance Computing  VT (3)
Bohnenkamp  Testen reaktiver Systeme  Ü (1)
Borchers  CHI Club  FK (2)
Borchers  Club i10  FK (2)
Borchers, Holman  Current Topics in Media Computing and HCI  VÜ (V2/Ü1)
Borchers, Karrer, Spelmezan  Designing Interactive Systems II  VÜ (V4/Ü2)
Borchers, Russell, Holman  The Media Computing Project (Praktikum)  P (4)
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<td>Bücker, Vehreschild, Lülfesmann</td>
<td>Software Tools für Computational Science VÜPT (V1+Ü4)</td>
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<td>Deserno, Kobbelt, Ney, Rossmanith, Seidl, Spitzer</td>
<td>Medizinische Bildverarbeitung ST (2)</td>
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<td>Giesl</td>
<td>Grundlagen der Funktionalen Programmierung V (4)</td>
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<td>Giesl, Schneider-Kamp, Swiderski</td>
<td>Grundlagen der Funktionalen Programmierung Ü (2)</td>
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<td>Giesl, Thiemann, Schneider-Kamp, Swiderski, Fuhs</td>
<td>Seminar Verifikationsverfahren ST (2)</td>
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<td>Giesl, Thiemann, Schneider-Kamp, Swiderski, Fuhs</td>
<td>Arbeitsgemeinschaft Programverifikation Ü (2)</td>
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<td>Grädel</td>
<td>Logik und Spiele V (4)</td>
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<td>Grädel</td>
<td>Logik und Spiele (Übungen) Ü (2)</td>
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<td>Arbeitsgemeinschaft Deduktive Objektbanken AGT (2)</td>
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<td>Jarke, Lakemeyer</td>
<td>Doktorandenseminar Ü (2)</td>
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<td>Jarke, Oppermann</td>
<td>User-oriented system design and personalized information services PT (5)</td>
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<td>Jarke, Quix</td>
<td>Arbeitsgemeinschaft Model Management AG (2)</td>
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<td>Jarke, Quix, Kensing</td>
<td>Accenture Campus Challenge ST (2)</td>
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<td>Jarke, Quix, Lübbers</td>
<td>Introduction to Database Systems VÜ (V3/Ü2)</td>
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<td>Arbeitsgemeinschaft Verfahrenstechnische Informationssysteme AG (2)</td>
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<td>Einführung in Model Checking V (4)</td>
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<td>Katoen, Giesl</td>
<td>Lehrstuhlseminar Ü (2)</td>
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<td>Arbeitsgemeinschaft: Probabilistic Model Checking Ü (2)</td>
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<td>Kesdogan, Spaniol</td>
<td>Arbeitsgemeinschaft: Privacy Enhancing Techniques AG (2)</td>
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<td>Kesdogan, Wienzek, Pimenidis, Panchenko, Spaniol</td>
<td>Arbeitsgemeinschaft: Sicherheit in der Kommunikationstechnik AG (2)</td>
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<td>Computergraphik II V (4)</td>
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<td>Diplomanden- und Doktorandenseminar S (2)</td>
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<td>Kowalewski, Herberich, Schlich</td>
<td>Formale Methoden für eingebettete Systeme VÜ (V2/Ü1)</td>
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<td>Kowalewski, Klünder, Wilking</td>
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<td>Interaktion und Lernen in komplexen Domänen</td>
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<td>Arbeitsgemeinschaft Kognitive Robotik</td>
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<td>Vermittlungssysteme</td>
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<td>Prinz</td>
<td>CSCW und Groupware: Konzepte und Systeme zur computergestützten Zusammenarbeit</td>
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<td>Stochastische Simulation II</td>
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<td>Seidl</td>
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<td>Komplexe Objekte in Datenbanken</td>
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<td>Thißen, Spaniol, Wehrle</td>
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<td>Unger, Ackermann, Franke</td>
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<td>Effiziente Algorithmen (2. Teil)</td>
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<td>Algorithmische Spieltheorie</td>
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<td>Effiziente Algorithmen / Randomisierte Algorithmen</td>
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Computer Science Colloquium – Talks

24.07.2008: Static Analysis Meets Model Checking  
Dr. Ralf Huuck, National ICT Australia (NICTA)

10.07.2008: The Chemical Metaphor as a Paradigm for Modelling Biological, Social, and Organic Computing Systems  
PD Dr. Peter Dittrich, Friedrich-Schiller-Universität Jena

26.06.2008: Prozessorientierte Unterstützungsmaßnahmen beim Lernen mit Computern  
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12.06.2008: An Introduction to Statistical Relational Learning: A Logical Perspective  
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09.06.2008: Computational Proteomic  
Prof. Frank Dehne, School of Computer Science, Carleton University, Ottawa, Kanada

06.06.2008: Bridging Paper and Digital Worlds  
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03.06.2008: Integrated and Automated Abstract Interpretation, Verification and Testing of C/C++ Modules  
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18.01.2008: *Modellbasiertes Security Engineering*
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19.11.2007: *Sicherheitsaspekte bei breitbandigen Internetzugängen und Insider-Angriffen auf verschlüsselte Übertragung*
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## Diploma and Master Theses

### Diploma Theses

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**Software Systems Engineering**

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Enrolled Students per Semester (1 - 13+)
as of WS 2007/2008

Gesamtzahl: 1804
Research
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. Matthias Englert (DFG Research Group) (until August)
  Dipl. Inform. Alexander Fanghänel
  Dr. Simon Fischer
  Dipl. Inform. Thomas Franke (until September 2007)
  Dr. Martin Hoefer (since October 2007)
  Dipl. Math. George Mertzios
  Dipl. Inform. Marcel Ochel (since December 2007)
  Dipl. Inform. Heiko Röglin (until April 2008)
  Dipl. Inform. Alexander Skopalik

- PhD scholarship holders
  Dipl. Math. Lars Olbrich

- Technical Staff
  Math.-Techn. Ass. Viktor Keil
• **Student Researchers and Teaching Assistants**
  Clemens Adolphs
  Nadine Bergner
  Johannes Dams
  Oliver Göbel
  Sten Grüner
  Thomas Kesselheim
  Tilo Müller
  Marcel Ochel
  Torsten Sattler
  Nadine Schlonies
  Melanie Winkler

• **Guests**
  Patrick Briest (University of Liverpool)
  Paul W. Goldberg (University of Liverpool)
  Piotr Krysta (University of Liverpool)
  Bruce Maggs (CMU Pittsburgh)
  Rolf Möhring (TU Berlin)
  Xavier Munoz (Universitat de Barcelona)
  Vahab S. Mirrokni (Microsoft Research)
  Harald Räcke (University of Warwick)
  Alexander Souza (University Freiburg)
  Rob van Stee (MPII Saarbrücken)
Overview

The group focusses both in research and teaching on following topics:
• randomized algorithms
• approximation and online algorithms
• algorithms for interconnection networks
• probabilistic analysis of algorithms
• algorithmic game theory

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

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

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

This project was successfully finished in February 2008.

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**DELIS: Dynamically Evolving Large Scale Information Systems**

H. Ackermann, S. Fischer, A. Skopalik, B. Vöcking

*(funded by European Union, Integrated Project)*

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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.

This project was successfully finished in February 2008.

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

W. Unger

*(funded by European Science Foundation, CostAction)*
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:

- **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.

- **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.

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

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**DFG Research Group: Flexible Online Algorithms**

M. Englert, M. Westermann

*(funded by DFG, Emmy-Noether-Programm)*

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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.
Probabilistic Analysis of Discrete Optimization Problems
H. Röglin, B. Vöcking
(funded by DFG)

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

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

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

This project was successfully finished in April 2008.

Generalized Congestion Games: Analysis, Computation, and Evolution
A. Skopalik
(funded by the German Isreali 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 2007
- Lecture on Efficient Algorithms
- Lecture on Randomized Algorithms
- Lecture on Selected Topics from Complexity Theory
- Seminar on Algorithmic Game Theory
- Seminar on Algorithmic Cryptography
- Seminar on Strategic Aspects in Networks
- Proseminar on Algorithms on Graphs

Winter semester 2007/08
- Lecture on Network Communication Problems
- Lecture on Algorithmic Game Theory
- Lecture on Computability and Complexity Theory
- Seminar on Algorithms for Wireless Networks
- Seminar on Efficient Algorithms
- Proseminar on Algorithms on Graphs
- Bridging Course on Theoretical Computer Science

Summer semester 2008
- Lecture on Efficient Algorithms
- Lecture on Approximation and Online Algorithms
- Seminar on Pricing and Mechanism Design
- Seminar on Network Communication Problems
- Seminar on Highlights from Algorithm Theory
- Proseminar on Communication on Graphs
Berthold Vöcking’s scientific activities

- Speaker of special interest group Theoretical Computer Science (Fachausschuss Theoretische Informatik) of the GI <http://www.gi-ev.de/english/>.
- Co-Chair of the steering committee of the Symposium on Theoretical Aspects of Computer Science (STACS).
- Member of the organization committee for STACS <http://www-i7.informatik.rwth-aachen.de/stacs07/> 2007 in Aachen.
Talks and Publications

Talks


Martin Hoefer: *The Influence of Link Restrictions on (Random) Selfish Routing*. Symposium on Algorithmic Game Theory (SAGT), Paderborn, Germany, April 2008.


Publications


Staff

- Group head
  Prof. Dr. Peter Rossmanith

- Secretary
  Birgit Willms

- Research Assistants
  Dipl.-Inform. Joachim Kneis
  Dr. rer. nat. Daniel Mölle (until Nov. 2007)
  Dipl.-Inform. Stefan Richter

- Guest Researchers
  Ling-Ju Hung, M.Sc., Chung Cheng University, Taiwan (2007-2008)
  Chuang-Chieh Lin, M.Sc., Chung Cheng University, Taiwan (2007-2008)

- Student Assistants
  Michael Nett
  Felix Reidl
  Fernando Sanchez Villaamil
Overview

Our teaching and research profile mainly consists of

- Efficient Algorithms
- Parameterized Algorithms
- Complexity Theory
- Formalizing Mathematics
- Analysis of Algorithms
- Algorithmic Learning Theory
- Anonymity in P2P Networks

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

We are particularly interested in solving NP-hard problems. Many problems relevant in practice are in this category, and hence often solved by inexact methods that do not necessarily output the optimal solution, although in the case of approximation algorithms, there still is 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, sometimes exact solutions are asked for, and we concentrate on such exact algorithms.

While the NP-hardness implies an exponential worst-case running time, practical instances can surprisingly often be solved quite efficiently. In the field of parameterized complexity, the hardness of a problem is measured by some parameter $k$. An algorithm with a running time of, e.g., $O(f(k) \cdot n^2)$ is quite efficient in practice if $k$ is small, in particular when $f(k)$ is a moderately growing exponential function.

To exemplify this view, consider the problem to find a spanning tree with many leaves: Given a graph $G$ and a number $k$, the problem is to find a spanning tree of $G$ such that $G$ has at least $k$ leaves. It turns out that this problem, although being NP-hard, can be solved in $O(4^k \cdot k^2 + poly(n))$ steps.
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 $O(3^{|D|} n^c)$ for a small constant $c$, which, for small values of $|D|$ (like, $|D| < n/4$), 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.
Today’s best algorithms for hard graph problems are often highly optimized in order to gain the last bit of improvement in runtime or approximation ratio. For example, they usually handle a large amount of special cases, or use involved results to find certain properties that can then be exploited. Hence, these algorithms are usually rather complicated and both, hard to understand and hard to implement. Furthermore, these algorithms are often subject to large constants or even large polynomial factors, which are usually discarded in papers on graph theory when estimating the runtime using the Landau-notation.

However, in practical applications simple algorithms are often preferable over such involved techniques. The main reason is that such involved graph-theoretical results are usually competitive for large input sizes, but inferior for small instances occurring in practical applications. For example, insertion sort is faster than quicksort on small arrays.

Furthermore, there are examples where the most simple algorithm known even yields the best results. Take for example the Vertex Cover problem: The classical factor two approximation, which can be implemented in a handful of lines, still yields the best constant approximation ratio known and is of course extremely fast.

The goal of this project is to find intuitive, but competitive algorithms for NP-hard problems, that can easily be understood and implemented without large factors in the run time. By a detailed and involved analysis, we aim to show that our algorithms can compete with much more involved results or even beat them.

To illustrate this paradigm, consider the NP-hard problem of finding spanning trees with many leaves in undirected or directed graphs. Previous results used involved results from extremal graph theory, and in the directed case even used dynamic programming, which requires exponential space. We found a simple branching algorithm using only polynomial space, which can easily be verified and allows an efficient implementation. The runtime can be bounded by $O(poly(|V|) + 4^k \cdot k^2)$ on undirected graphs, and $O(4^k |V| |E|)$ on directed graphs. This improves over the previously fastest algorithms with run times of $O(poly(|V|) + 6.75^k \cdot k)$ and $2^{O(k \log k)} \cdot poly(|V|)$, respectively.
Recognizing Probe Graphs
Ling-Ju Hung, Peter Rossmanith

*Funded by the NSC-DAAD Sandwich Program*

A graph $G=(V, E)$ is called a probe graph of graph class $C$ if $V$ can be partitioned into two sets $P$ (probes) and $N$ (nonprobes), where $N$ is an independent set, such that $G$ can be embedded into a graph of $C$ by adding edges between certain nonprobes. A graph is distance-hereditary if the distance between any two vertices remains the same in every connected induced subgraph. Distance-hereditary graphs have been studied by many researchers. Bipartite distance-hereditary graphs are graphs that are both distance-hereditary and bipartite. In this research project, we gave the first polynomial time algorithms for recognizing probe graphs of distance-hereditary graphs and of bipartite distance-hereditary graphs. The time complexity of the algorithms is $n^3$.

Fixed Parameter Algorithms and Property Testing
Chuang-Chieh Lin, Peter Rossmanith

*Funded by the NSC-DAAD Sandwich Program*

Joseph studied the minimum quartet inconsistency problem (MQI) and worked with Professor Rossmanith and Professor Maw-Shang Chang to figure out three fixed-parameter algorithms. They submitted our results to the International Workshop on Exact and Parameterized Computation (IWPEC'08) and the paper was accepted. As to the other work on property testing, Joseph studied the Regularity Lemma, which plays a very important role in property testing. Joseph gave a talk to introduce this important graph theoretical result to the Theoretical Computer Science Group of Professor Rossmanith. They discussed applications and the possibility of extending this lemma to parameterized complexity.

Towards Sharing Large Data Volumes in Privacy
Stefan Richter

File sharing has become a politically loaded topic. Maybe this is one reason why we have yet to witness the emergence of a data sharing network able to emulate the success of Napster while at the same time conserving the privacy of its users. We look at the more technical difficulties in establishing an efficient, scalable, and privacy-aware technology for sharing
large data volumes in an untrusted environment. This entails analyzing existing systems, looking for theoretical lower bounds, and ultimately building real-life networks. In one aspect of this research line, we look at security/anonymity aspects of distributed hash tables, in collaboration with Andriy Panchenko from the networking group (I4).
Other Activities

Courses
Our group offered the following lectures and seminars:

Summer 2007
- Lecture on "Datenstrukturen und Algorithmen"
- Seminar on "Medizinische Bildverarbeitung" (with Deserno, Kobbelt, Ney, Seidl, Spitzer)

Winter 2007/08
- Lecture on "Parametrisierte Algorithmen"
- Proseminar on "Datenstrukturen und Algorithmen"
- Seminar on "Exakte Algorithmen"
- Lecture on "Medizinische Bildverarbeitung" (with Deserno, Kobbelt, Ney, Seidl, Spitzer)

Summer 2008
- Lecture on "Analyse von Algorithmen"
- Softwarepraktikum on "Graphalgorithmen"
- Seminar on "Medizinische Bildverarbeitung" (with Deserno, Kobbelt, Ney, Seidl, Spitzer)
Talks and Publications

Talks


Peter Rossmanith: Fast Set Convolutions to Compute Minimal Dominating Sets. Exact, Approximative, Robust and Certifying Algorithms on Particular Graph Classes, Schloss Dagstuhl, Germany, May 2007

Peter Rossmanith: Fast Set Convolutions to Compute Minimal Dominating Sets. National Chung Cheng University, Chiayi, Taiwan, September 2007

Peter Rossmanith: An Efficient Version of Courcelle's Theorem. National Chung Cheng University, Chiayi, Taiwan, September 2007


Peter Rossmanith: Treewidth-based approaches to efficient exact algorithms. National Dong Hwa University, Hualien, Taiwan, September 2008.

Peter Rossmanith: Finding trees with many leaves. National Chung Cheng University, Chiayi, Taiwan, September 2008

Peter Rossmanith: Tutorial on Fixed-Parameter and Exact Algorithms. Academia Sinica, Taipei, Taiwan, September 2008

Publications


**Technical Reports**

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 (until 08/2007)
  Dr. Henrik Bohnenkamp
  Dr. David Jansen (from 01/2007 until 08/2007)
  Tingting Han, M.Sc. (funded by the NWO)
  Dipl.-Inform. Jonathan Heinen (from 05/2007)
  Dipl.-Inform. Carsten Kern
  Dipl.-Inform. Daniel Klink (DFG funding)
  Alexandru Mereacre, MSc (from 11/2007, DFG funding)
  Dipl.-Inform. Martin Neuhäußer (funded by the NWO)
  Viet Yen Nguyen, M.Sc. (from 02/2008, ESA funding)
  Dipl.-Inform. Stefan Rieger
  Dipl.-Inform. Haidi Yue (from 05/2008, DFG funding)
  Ivan Zapreev, M.Sc. (until 03/2008, funded by the NWO)

- Technical Staff
  Arnd Gehrmann
• Diploma/Master Students
  Lars Helge Haß
  Alexandru Mereacre

• Student Researchers
  Yen Cao
  Falko Dulat
  Ulrich Hülscher
  Johanna Nellen
  Christina Jansen
  Denise Nimmerrichter
  Christian Löcking
  Maximilian Odenbrett
  David Piegdon
  Franziska Roloff
  Ulrich Schrempp
  Stefan Schulz
  Ulrich Schmidt-Goertz
  Benjamin Zimmermann

• Visiting Scientists
  Varun Aggarwala (Indian Inst. of Techn. Guwahati, India)
  Dr. Suzana Andova (TU Eindhoven, NL)
  Miguel Andres (Radboud University Nijmegen, NL)
  Machiel van der Bijl (Univ. Twente, NL)
  Eric Bodden (McGill Univ, CA)
  Dr. Benedikt Bollig (LSV Cachan, F)
  Dr. Dragan Bosnacki (Technical Univ. Eindhoven, NL)
  Prof. Dr. Ed Brinksma (Emb. Systems Inst., Eindh., NL)
  Dr. Manuela Bujorianu (Uni Twente, NL)
  Dr. Lucia Cloth (University Twente, NL)
  Berteun Damman (University of Twente, NL)
  Wan Fokkink (Vrije Universiteit Amsterdam, NL)
  Dr. Sven Johr (Universität Saarbrücken, D)
  Marijn Jongerden (University of Twente, NL)
  Stephan Tobies (Europ. Microsoft Innov. Center, Aachen)
  Dr. Tomas Krilavicius (Vytautas Magnus Univ., Lithuania)
  PD Dr. Martin Leucker (TU Munich, D)
  Anne Remke (University of Twente, NL)
Dr. Wolfram Schulte (Microsoft Res., Redmond USA)
Jeremy Sproston (Univ. Torino, Italy)
Mani Swaminathan (Uni Oldenburg, D)
Dr. Hagen Voelzer (IBM Zurich, CH)
Mikhail Volkov (Ural State University, Russia)
Dr. Verena Wolf (EPFL, CH)
Overview

The years 2007 and 2008 have been extremely dynamic and active. First and foremost, we successfully acquired a project funded by the European Space Agency (ESA) which is aimed at system software co-engineering and focuses on the combination of performance and verification, an active research field at our chair. With the Italian research institute FBK and the French company Thales Alenia Space, we have two years to convince ESA that formal methods are pivotal to model and analyze both correctness and efficiency aspects of aerospace systems. A true and interesting challenge indeed. Several students are actively participating in this project.

Since the beginning of 2008, we are also involved in the EU project Quasimodo that focuses on quantitative aspects of embedded systems. Issues like resource usage, uncertainty, response times, and so forth, are central in this project. It covers modeling formalisms, model checking techniques, as well as formal testing techniques to assess and model these aspects at various levels of the software development process. The project is led by Aalborg University (Kim G. Larsen), and involves besides six academic partners three industrial partners that contribute with case studies to be tackled. A wonderful testbed to apply formal methods in practice!

Due to these projects, as well as our participation in the Research Training Group ALGOSYN and the excellence cluster UMIC, several new researchers joined our chair: Jonathan Heinen, Alexandru Mereacre, Viet Yen Nguyen, and Haidi Yue. Ivan Zapreev successfully defended his dissertation in March 2007 and joined the group of Jan van Schuppen (hybrid systems) at CWI, Amsterdam.

What else? Too much to all be mentioned. Let's pick some of the highlights. New courses have been set up, such as Testing of Reactive Systems, where the focus is on formal methods towards system testing, and Foundations of the UML, a course that attempts to pinpoint at semantical and analysis issues in notations such as sequence diagrams, statecharts and the OCL. The book ´Principles of Model Checking´, a joint (and longlasting) project with Christel Baier (TU Dresden) was completed and has been published by MIT Press. We were involved in the organization of several events, such as the Workshop on Automata and Logics (WAL'07) in 2007, an event that was organized as a birthday salute to colleague Wolfgang Thomas and that attracted more than 160 participants, a Dagstuhl seminar on quantitative methods for embedded systems (organized together with colleagues Boudewijn Haverkort (Twente) and Lothar Thiele (ETH Zurich)), a Quasimodo Workshop in Aachen, and a Lorentz Centre (Leiden) Workshop on the Validation of Stochastic Systems with more than 50 participants. Last, but definitely not at least, I mention the enormous productivity of the researchers at the chair. Various high-quality papers have been produced, and important advances have been achieved, both in theory as well as in tool development. It's a real pleasure and very stimulating to work with such an active and talented team!

At the time of reading of this annual report, the chair has been extended with a junior professorship on the topic of ´Theory of Hybrid Systems´, an important field of research on the edge of mathematics, computer science, and various engineering disciplines. This position has been financed by the excellence initiative of the DFG and is occupied since October 2008 by Prof. Dr. Erika Abraham (formerly at the Research Centre at Julich). We warmly welcome Erika and are looking forward to a prosperous cooperation.

Joost-Pieter Katoen.
Research Projects

PROJECT: Smyle Modeling Approach


FUNDING: partially funded by the DAAD PROCOPE 2008 project

The Smyle Modeling Approach (SMA) is a model-based software development methodology which is centered around Smyle, a dedicated learning procedure to support engineers to interactively obtain design models from requirements, characterized as either being desired (positive) or unwanted (negative) system behavior. The learning approach is complemented by scenario patterns where the engineer can specify clearly desired or unwanted behavior. This way, user interaction is reduced to the interesting scenarios limiting the design effort considerably. In SMA, the learning phase is complemented by an effective analysis phase that allows for detecting design flaws at an early design stage.

PROJECT: Learning Residual Finite-State Automata


FUNDING: partially funded by the DAAD PROCOPE 2008 project

The class of residual finite-state automata (RFSA) is a subclass of non-deterministic finite automata (NFA). It was shown by Denis et al. that for each regular language a unique RFSA (a so-called canonical RFSA) can be determined which may be exponentially more succinct than the corresponding minimal deterministic finite automaton (DFA) for this language. Together with the LSV (ENS Cachan) and the Technical University Munich, we developed a learning algorithm for inferring RFSA. It is an incremental learning algorithm and closely related to Angluin's learning algorithm L* for DFA. As we employ non-determinicity our approach allows for learning compact representations of regular languages. Many fields of application are available where the need for compact representations is by far more important than the determinicity of the model. Moreover, we developed a first prototype that implements our learning approach and showed its functionality in several small-size examples. However, larger size case studies are left for future work.
Embedded software typically executes on devices that, first and foremost, are not personal computers. Due to its embedded nature, its robustness is of prime importance, and timely reactions to stimuli from its -- mostly physical -- environment are essential. The aim of the QUPES project is to assess these quantitative aspects (e.g., timeliness and robustness) as an integral part of the embedded software validation phase. To accomplish this, probabilistic model-checking techniques can be applied for models that are equipped with randomness and variants thereof which also exhibit nondeterminism. Based on efficient numerical methods and abstraction techniques, quantitative properties can be checked automatically even on large state space with millions of states using dedicated tools. Oppose to, amongst others, the essential feature of model checking, where evidences will be provided on a property refutation, counterexamples generation in probabilistic model checking is almost not developed. We provide the theoretical and algorithmic foundations for counterexample generation in probabilistic model checking, in particular for discrete-time Markov chains. One of the key principles is the casting of the concepts of strongest evidence and smallest counterexample as (variants of) shortest path problems. This enabled the use of efficient and well-studied graph algorithms for counterexample generation. These results can be extended to Markov chains with rewards, to Markov decision processes (MDPs), to LTL model checking, and have been recently been adopted in probabilistic counterexample-guided abstraction-refinement (CEGAR) techniques for MDPs as well as in counterexample generation for continuous-time Markov chains (CTMC) and cpCTL logic. Compact representation of a counterexample by regular expressions are also studied.

Further, compositional reasoning is a key strategy in analyzing complex systems as it allows the use of hierarchical and modular modeling formalisms like stochastic process algebras, stochastic activity networks or generalized stochastic Petri nets. Continuous-time Markov Decision processes (CTMDPs) are the nondeterministic counterpart of the aforementioned CTMCs and are well suited for compositional verification techniques. We define stochastic logics (like CSL) on CTMDPs and provide their measure-theoretic basis. Further, well-known equivalences like strong and weak bisimulation relations are adapted to CTMDPs which considerably reduce the state-space needed for quantitative analysis.
Due to their enormous size – networks typically consist of thousands or even millions of nodes – and their strong reliance on mobility and interaction, performance and dependability issues are of utmost importance for ‘network-aware computing’. Spontaneous computer crashes may easily lead to failure of remote execution or process movement, while spurious network hick ups may cause loss of code fragments or unpredictable delays. The enormous magnitude of computing devices involved in global computing yields failure rates that no longer can be ignored. The presence of such random phenomena implies that correctness of global computing software and their privacy guarantees are no longer rigid notions like: ‘either it is safe or it is not’

but have a less absolute nature, e.g.:
‘in 99.7% of the cases, privacy can be ensured’.

The intrinsic complexity of global computers, though, complicates the assessment of these issues severely. Systematic methods, techniques and tools, all based on solid mathematical foundations i.e., formal methods, are therefore needed to establish performance and dependability requirements and guarantees.

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

**PROJECT: MC=MC: Model Checking Infinite-State Markov Chains**

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

**FUNDING:** funded by the NOW

Model-based performance evaluation aims at forecasting system behaviour in a quantitative way, starting from an abstract system model. Due to the ever-increasing size and complexity of modern computer and communication systems, performance models that are directly amenable for a numerical solution are often generated from high-level modelling languages, based, e.g., on stochastic Petri nets or stochastic process algebras. For a significant class of systems, these models turn out to be infinite state, and need to be analysed by specific techniques, such as matrix-geometric methods.

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

This project aims to establish a cross-fertilization between (i) performance evaluation techniques for infinite-state systems and (ii) logic-based model-checking algorithms for
Markov chains. The goal is to develop algorithms and a prototype software tool for the specification and automated evaluation of performance measures for infinite-state Markov chains, and to apply these to case studies with realistic complexity. In particular, Markov chains with a regular structure will be investigated (Jackson QNs and Quasi-Birth-Death processes), and discrete event simulation techniques will be developed for model checking. These techniques are realized in the model checker MRMC.

**PROJECT: System and Software Co-Engineering: Performance and Verification**

PARTICIPANTS: A joint project together with the groups of Alessandro Cimatti (Fondazione Bruno Kessler, Centre for Scientific and Technological Research, Trento, Italy), and Xavier Olive (Thales Alenia Space, On Board Software Department, Cannes, France)

**FUNDING:** This project is funded by the European Space Agency, ESA

We develop a model-based approach to system-software co-engineering which is tailored to the specific characteristics of critical on-board systems for the space domain. The approach is supported by a System-Level Integrated Modeling (SLIM) Language in which engineers are provided with convenient ways to specify a.o. nominal hardware, as well as software operations, (probabilistic) faults and their propagation, error recovery and degraded modes of operation. This language is strongly based on AADL and its error annex which allows for the modeling of error behavior. A kernel of the SLIM language is equipped with a formal semantics that provides the interpretation of SLIM specifications in a precise and unambiguous manner. Systems are considered as a hierarchy of (hardware and software) components where components are defined by their type (interface) and implementation. Components communicate via ports allowing for message and continuous communication. The internal structure of a component implementation is specified by its decomposition into subcomponents, together with their HW/SW bindings and their interaction via connections over ports. Component behavior is described by a textual description of mode-transition diagrams. System reconfiguration is supported by mode-dependent presence of subcomponents and their connections. Error behaviour is described by probabilistic finite state machines, where error delays may be governed by continuous random variables.

Correctness properties, safety guarantees, and performance and dependability requirements are specified using requirement specification patterns which act as parameterized 'templates' to the engineers and thus offer a comprehensible and easy-to-use framework for requirement specification.

The properties are checked on the SLIM specification using formal analysis techniques such as model checking and probabilistic variants thereof. The precise character of these techniques and the SLIM semantics yield a trustworthy modeling and analysis framework for system and software engineers. The formal analysis is based on state-of-the-art model checking techniques such as bounded SAT-based and symbolic model checking, and extensions of model checking with numerical and simulative means to reason about quantitative requirements such as performance and dependability. The analysis facilities
The incorrect use of pointers is one of the most common sources of software errors. This especially applies to concurrent systems whose nondeterministic behavior rises additional challenges. 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 with dynamic thread creation and memory allocation that handle linked data structures which are potentially unbounded in their size. More concretely, two issues are addressed:

In a first phase, we concentrated on (possibly cyclic) singly-linked list data structures. We allow to express correctness properties of programs by combining a simple pointer logic for specifying heap properties with linear-time (LTL) operators for reasoning about system executions. To obtain a finitary representation of the system, we developed a technique which abstracts from non-interrupted sublists in the heap, resulting in a finite-state representation of the data space. In a second abstraction step, using an intermediate Petri-net representation, we also derive a finite-state representation of the control flow, which then allows us to employ standard LTL model checking techniques. Thus our approach stays within the realm of traditional (linear-time) model checking. This facilitates the usage of standard model checkers for validating temporal properties addressing absence of memory leaks, dereferencing of null pointers, dynamic creation of cells, and simple and position-dependent aliasing.

Next we extended our approach to analyze programs that handle more complex dynamic data structures. We developed a novel abstraction framework that employs graph grammars, more precisely context-free hyperedge replacement grammars, as an intuitive formalism for abstractly modeling dynamic data structures. The key idea is to use the replacement operations which are induced by the grammar rules in two directions. By a _backward_ application of some rule, a subgraph of the heap can be condensed into a single nonterminal edge, thus obtaining an _abstraction_ of the heap. By applying rules in _forward_ direction, certain parts of the heap which have been abstracted before can be _concretized_ again, which avoids the necessity for explicitly defining the effect of pointer-manipulating operations on abstracted parts of the heap. Altogether this method again allows to extend finite-state verification techniques to handle pointer-manipulating programs operating on complex dynamic data structures that are potentially unbounded in their size. We demonstrated how our framework can be employed for analysis and verification purposes by giving its instantiation for binary trees, and by applying this instantiation to the well-known Deutsch-
Schorr-Waite traversal algorithm. Our approach is supported by a prototype tool, enabling the quick verification of essential properties such as heap invariants, completeness, and termination.

**PROJECT: Equational Abstractions for Software Model Checking**  
PARTICIPANTS: M. Neuhäuser, Th. Noll, L. Haß, P. Tawiah

The combinatorial explosion of state spaces is the biggest challenge in applying model-checking methods to concurrent systems. The goal of this project is to develop a new state-space reduction technique that is tailored to system specifications in _Rewriting Logic_, a unified semantic framework for concurrency which is based on conditional term rewriting modulo equational theories. The idea is to hide “unimportant” details of the system’s behavior (such as internal computations) in the equations, and to represent only “interesting” state changes (such as communication operations) by explicit transitions. Our results show that this optimization can be implemented by transforming the Rewriting Logic specification, avoiding the intermediate construction of the full state space. The correctness of our technique can be established by proving that the original and the reduced system are weakly bisimilar. The usability of this approach was demonstrated by applying it to the concurrent functional programming language Erlang, which is designed for implementing open, distributed telecommunication software. The inherent complexity and nondeterminacy of such systems impedes the use of validation methods which are purely based on testing. Therefore we developed a formalization of this language in the Rewriting Logic framework, employing equations for defining abstraction mappings on the state space of the system. This specification was implemented in the _Maude_ system, and its model checker was employed to verify simple system properties.

**PROJECT: Formal Models of Microcontroller Systems**  
PARTICIPANTS: Th. Noll, G. Herberich, B. Schlich, C. Weise

Embedded systems usually operate in uncertain environments, giving rise to a high degree of nondeterminism in the corresponding formal models. This, together with other effects, leads to the well-known _state explosion problem_, meaning that the models of those systems grow exponentially in size as the number of components increases. Careful handling of nondeterminism is therefore crucial for obtaining efficient tools for analysis and verification. The goal of this project, carried out in close cooperation with the Embedded Software Laboratory of our department, is to develop formal computation models and state-space...
reduction techniques to tackle this problem. A first approach was taken by defining a general automata-based model for microcontrollers, taking into account both the hardware, the software, and the environment of the system. This model was used to prove the correctness of a particular abstraction method, called _delayed nondeterminism_, which resolves nondeterministic behavior only if and when this is required by the application code. More concretely, a simulation relation between the concrete and the abstract state space was established, thus showing the soundness of delayed nondeterminism with respect to “path-universal” verification logics such as ACTL and LTL.

Current efforts concentrate on extending the model to cover further abstraction techniques, and on the implementation of a tool component which automatically produces a state-space generator from the given microcontroller model.

PROJECT: Quasimodo
PARTICIPANTS: H. Bohnenkamp, J.-P. Katoen, D. Klink, H. Yue

Embedded systems are hidden computer components of many devices and appliances used in daily life: washing machines, air conditioners, cars, and GPS navigation systems, to name only a few. Embedded systems are highly complex, which poses a challenge for their design and implementation. In particular, such systems have to meet a multitude of quantitative constraints, such as available computation resources, power consumption, memory usage, communication bandwidth, arrival rates, timing constraints, QoS, availability, fault tolerance, etc.

Since January 2008, the MOVES group participates in the European research project ‘Quasimodo’’, funded by the European Commission under the IST framework programme 7 for Information and Communication Technology, ICT.

The objective of the Quasimodo project is to develop theory, techniques and tool components for handling quantitative (e.g. real-time, hybrid and stochastic) constraints in model-driven development of real-time embedded systems. Ultimate aim is to increase the competitiveness of European industrial companies which develop, implement and deploy embedded systems.

More specifically, the project aims are:

• Improving the modelling of diverse quantitative aspects of embedded systems.
• Providing a wide range of powerful techniques for analysing models with quantitative information and for establishing abstraction relations between them.
• Generating predictable code from quantitative models.
• Improving the overall quality of testing by using suitable quantitative models as the basis for generating sound and correct test cases.
• Applying the techniques to real-life case-studies and disseminating the results to industry.

Project partners are universities, research institutes, and companies in Germany, The Netherlands, Denmark, Belgium, and France.
The MOVES Group is currently working on a case-study for a sensor-network gossiping protocol, which is posed by one of the industrial partners.

**PROJECT: Model-Based Testing**

PARTICIPANTS: H. Bohnenkamp, E. Brinksma (ESI, NL), M. Stoelinga (Uni 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 w.r.t. 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.

- 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 non-deterministic safety timed automata.

- In timed testing, reaching a verdict depends on time measurements. The imprecision of measurements can lead to false positives (test fails although the implementation behaved 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.

**PROJECT: 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 M\nBIUS, a performance evaluation tool suite that has been developed at the University of Illinois at Urbana-Champaign, US. The MoDeST/Mobius tandem is currently used and constantly improved in the Quasimodo project case-studies.
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: FORMATS 08, SSV 08, DSN 08, QEST 07, SAVCBS 07, PERFORMANCE 07, Verify 07, DSN 07.
- Invited speaker at:
  - Summerschool GLOBAN 08, Warsaw, September 2008
  - IEEE/IFIP Symposium TASE 08, Nanjing, June 2008
  - International Conference FORMATS 07, Salzburg, October 2007
    - ARTIST2 Winterschool MOTIVES 07, Trento, March 2007
- Member of the IFIP Working Group 1.8 on Concurrency Theory.
- Member of the EPSRC Review College (Engineering and Physical Sciences Research Council), UK.
- Member of several external PhD committees.

Th. Noll

- Organizer of the 7th Workshop on Language Descriptions, Tools and Applications (ETAPS/LDTA 2007)
- Program committee member of the Software Engineering Track at the 23rd Annual ACM Symposium on Applied Computing (SAC 2008)
- Program committee member of the 2nd International Workshop on Harnessing Theories for Tool Support in Software (TTSS 2008)
- Program committee member of the 2nd IEEE International Conference on Secure System Integration and Reliability Improvement (SSIRI 2008)
- Member of the examination boards for Computer Science and Computational Material Science
- Student advisor for the following applied 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


Tingting Han: Counterexamples in probabilistic model checking. Talk, TACAS 2007 (Braga, Portugal), March 2007.

Tingting Han: Counterexamples in probabilistic model checking. Talk at the University of Birmingham (UK), March 2007.

Tingting Han: Providing evidence of likely being on time - Counterexample generation for CTMC model checking. Talk, VOSS 2 workshop (Dresden, Germany), Feb. 2007.

Tingting Han: Providing evidence of likely being on time - Counterexample generation for CTMC model checking. Talk, ATVA'07 (Tokyo, Japan), Oct. 2007.

Tingting Han: Time-abstracting bisimulation for probabilistic timed automata. Talk, TASE'08 (Nanjing, China), June 2008.


Joost-Pieter Katoen: Introduction to Probabilistic Model Checking. Talk at IFIP WG 2.2 Meeting, Nancy (France), Sept. 2007. Invited Presentation.


Joost-Pieter Katoen: *Principles of Model Checking*. Lecture Series at Tsinghua University, Beijing, June 2008.


Joost-Pieter Katoen: *Verifying Probabilistic Phenomena: Theory or Practice?*. Colloquium at the University of Konstanz, Jan. 2007. Invited Presentation.


**Publications**


Programming Languages and Verification

Staff

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

• Secretary:
  Elke Ohlenforst

• Research Assistants:
  Dipl.-Inform. Carsten Fuhs (since May 2007)
  Dipl.-Inform. Peter Schneider-Kamp (partially funded by DFG)
  Dipl.-Inform. Stephan Swiderski (funded by DFG)
  Dr. rer. nat. René Thiemann (until October 2007)

• Student Researchers:
  Clemens Adolphs
  Karsten Behrmann
  Marc Brockschmidt
  Thomas Dickmeis
  Fabian Emmes
  Christian von Essen
  Patrick Kabasci
  Andreas Kelle-Emden
  Lars Noschinski
  Carsten Otto
  Michael Parting
Martin Plücker
Matthias Raffelsieper
Ulrich Schmidt-Goertz
Matthias Sondermann
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 2007 and 2008, we held the first-year course on *Programming Concepts* for more than 500 students and lectures on *Term Rewriting Systems, Functional Programming*, and *Logic Programming*. We also offered seminars on *Advanced Programming Concepts in Java, Haskell, and Prolog*, on *Advanced Topics in Term Rewriting*, on *Verification Techniques*, and on *Automated Termination Analysis*.

Starting in May 2007, Carsten Fuhs joined our group of research assistants. On September 30, 2007, René Thiemann left our research group and took up a postdoc position at the University of Innsbruck, Austria. He defended his PhD thesis on October 24, 2007. Moreover, we had several guest researchers:

Raúl Gutiérrez from the UP Valencia, Spain (April – September 2007, March – August 2008), Beatriz Alarcón from the UP Valencia, Spain (September – December 2007), and Manh Thang Nguyen from the KU Leuven, Belgium (January – February 2007).
Research Projects

**AProVE: Automatic Program Verification Environment**

J. Giesl, C. Fuhs, P. Schneider-Kamp, S. Swiderski, R. Thiemann 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/
Satisfiability Checking for Termination Analysis and Termination of Java Bytecode

J. Giesl, M. Codish, A. Middeldorp, C. Fuhs, P. Schneider-Kamp, S. Swiderski, R. Thiemann

This project will be partially funded by the GIF and is a collaboration with the Ben-Gurion University, Israel, and the University of Innsbruck, Austria. Here, 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. The tremendous increase in efficiency will allow us to adapt termination methods from term rewriting also for new application areas like termination analysis of Java Bytecode.

Formal Methods in Signal Processing

B. Schmidt, S. Swiderski, D. Klink

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.

Termination Analysis for Context-Sensitive Rewriting


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 \textit{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.

\begin{center}
\textbf{Termination Proving for Systems with Integers}
J. Giesl, P. Schneider-Kamp, S. Falke, C. Fuhs, S. Swiderski, L. Noschinski, M. Plücker, D. Kapur
\end{center}

This project (funded by the DFG) is concerned with adapting termination methods from term rewriting in order to handle pre-defined data structures like integers. Such data structures are available in virtually all programming languages. However, the existing termination techniques from term rewriting do not support pre-defined data structures. Up to now, such data structures can only be handled by a naïve translation to terms. An appropriate adaption of the termination techniques from term rewriting is crucial in order to make them successfully applicable for real-life programs.

\begin{center}
\textbf{Connecting Termination Proving and Inductive Theorem Proving}
J. Giesl, S. Swiderski, P. Schneider-Kamp, C. Fuhs, M. Parting
\end{center}

There exist several natural algorithms whose termination proof requires the verification of a conjecture by mathematical induction. However, up to now all termination provers fail for such algorithms. The goal of this project is to connect termination proving and inductive theorem proving. To this end, one has to develop a method that detects suitable inductive conjectures during a termination proof and calls an inductive theorem prover. Moreover, one has to integrate this approach with other existing termination methods. In addition, we are also investigating the use of inductive theorem proving for proofs of non-termination.
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)* (until 2007)
- Vice-Chair of the *IFIP Working Group 1.6 on Term Rewriting* and participant of the *WG 1.6 meetings 2007 (Paris, France) and 2008 (Hagenberg, Austria).* Moreover, J. Giesl was the organizer of the meeting in 2008.
- Member of the Steering Committee of the *International School on Rewriting (ISR)* and lecturer at *ISR 2007 (Nancy, France)*
- Co-organizer and participant of the Dagstuhl Seminar *Deduction and Decision Procedures*, Dagstuhl, Germany, 2007
- Program Chair and participant of the *7th International Workshop on Reduction Strategies in Rewriting and Programming (WRS ’07)*, Paris, France
- PC-Member and participant of the *9th International Workshop on Termination (WST ’07)*, Paris, France, 2007
- PC-Member and participant of the *18th International Conference on Rewriting Techniques and Applications (RTA ’07)*, Paris, France, 2007
- PC-Member of the *7th International Workshop on Rewriting Logic and its Applications (WRLA ’08)*, Budapest, Hungary, 2008
- PC-Member of the *11th International Conference on Foundations of Software Science and Computation Structures (FOSSACS ’08)*, Budapest, Hungary, 2008
- PC-Member and participant of the *19th International Conference on Rewriting Techniques and Applications (RTA ’08)*, Hagenberg, Austria, 2008
- PC-Member of the *4th International Joint Conference on Automated Reasoning (IJCAR ’08)*, Sydney, Australia, 2008
- PC-Member of the *15th International Conference on Logic for Programming, Artificial Intelligence, and Reasoning (LPAR ’08)*, Doha, Qatar, 2008
- Participant of the *TeReSe workshops in Eindhoven, Aachen, and Amsterdam*
- Participant of *WAL ’07* (workshop on the occasion of Wolfgang Thomas’ 60th birthday), Aachen, Germany, 2007.
- Reviewer for several PhD theses: Stephan Schweitzer (TU Darmstadt, DE), René Thiemann (RWTH Aachen, DE), Adam Koprowski (TU Eindhoven, NL)
• Project Reviewer for the US/Israel BSF, the British EPSRC, the Dutch NWO, the Swiss NSF

• Reviewer for many international journals and conferences

C. Fuhs
• Participant of the First Workshop on Certification of Termination Proofs (WScT ’07), Nancy, France, 2007
• Participant of the TeReSe workshops in Eindhoven, Aachen, and Amsterdam
• Participant of the 10th International Conference on Theory and Applications of Satisfiability Testing (SAT ’07), Lisbon, Portugal, 2007
• Research Visits (funded by the DAAD) at the UP Valencia, Spain, June and November – December 2007
• Participant of the 18th International Conference on Rewriting Techniques and Applications (RTA ’07) and the 9th International Workshop on Termination (WST ’07), Paris, France, 2007
• Participant of WAL ’07 (workshop on the occasion of Wolfgang Thomas' 60th birthday), Aachen, Germany, 2007
• Participant of the 17th CIAO Workshop (CIAO-2008), Darmstadt, Germany, 2008
• Participant of the Second Workshop on Certification of Termination Proofs (WScT ’08), Leipzig, Germany, 2008
• Participant of the 19th International Conference on Rewriting Techniques and Applications (RTA ’08), Hagenberg, Austria, 2008
• Participant of the 3rd International School on Rewriting (ISR ’08), Obergurgl, Austria, 2008
• Participant of the 9th International Conference on Artificial Intelligence and Symbolic Computation (AISC ’08), Birmingham, UK, 2008
• Reviewer for several international journals and conferences

P. Schneider-Kamp
• PC-Member and participant of the 17th International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR ’07), Kongens Lyngby, Denmark, 2007
• PC-Member of the 7th International Workshop on the Implementation of Logics (IWIL 2008), Doha, Qatar, 2008
• Participant of the Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Koblenz, , 2007
• Organizer of the TeReSe workshop in Aachen (November 2007) and participant of the TeReSe workshops in Eindhoven and Amsterdam
• Participant of the 10th International Conference on Theory and Applications of Satisfiability Testing (SAT ’07), Lisbon, Portugal, 2007
• Research Visit (funded by the DAAD) at the UP Valencia, Spain, June 2007
• Participant of the 9th International Workshop on Termination (WST '07), Paris, France, 2007
• Participant of the 21st Conference on Automated Deduction (CADE '07), Bremen, Germany, 2007
• Participant of the 6th International Symposium on Frontiers of Combining Systems (FroCoS '07), Liverpool, UK, 2007
• Participant of the Dagstuhl Seminar Deduction and Decision Procedures, Dagstuhl, Germany, 2007
• Participant of WAL '07 (workshop on the occasion of Wolfgang Thomas' 60th birthday), Aachen, Germany, 2007
• Research Visit at Microsoft Research, Redmond (WA), USA, January – February 2008
• Research Visit at the KU Leuven, Belgium, April 2008
• Editor of the Department Of Computer Science Technical Reports of RWTH Aachen
• Reviewer for many international journals and conferences

S. Swiderski
• Participant of the First and Second Rolduc AlgoSyn Meeting, Rolduc, The Netherlands, 2007
• Participant of the TeReSe workshops in Eindhoven, Aachen, and Amsterdam
• Participant of the Dagstuhl Meeting of German Research Training Groups, Dagstuhl, Germany, 2007
• Participant of the 18th International Conference on Rewriting Techniques and Applications (RTA '07) and the 9th International Workshop on Termination (WST '07), Paris, France, 2007
• Participant of the 21st Conference on Automated Deduction (CADE '07), Bremen, Germany, 2007
• Participant of the Marktoberdorf Summer School on “Formal Logical Methods for System Security and Correctness”, Marktoberdorf, Germany, 2007
• Participant of the 14. Kolloquium Programmiersprachen und Grundlagen der Programmierung (KPS '07), Timmendorfer Strand, Germany, 2007
• Reviewer for several international journals and conferences

R. Thiemann
• Participant of the 2nd Austria - Japan Summer Workshop on Term Rewriting, Obergurgl, Austria, 2007
• Participant of the Dagstuhl Seminar Deduction and Decision Procedures, Dagstuhl, Germany, 2007
• Reviewer for many international journals and conferences
Talks and Publications

Talks


P. Schneider-Kamp: Panelist in Discussion "Sind unsere Deduktionssysteme praxistauglich?", Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Koblenz, March 2007.


P. Schneider-Kamp: *Termination Analysis of Logic Programs based on Dependency Graphs,*
Lehrstuhlseminar, RWTH Aachen, August 2007.

P. Schneider-Kamp: Termination Analysis of Logic Programs based on Dependency Graphs, 17th International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR '07), Kongens Lyngby, Denmark, August 2007.


P. Schneider-Kamp: Implementing RPO and POLO using SAT, Dagstuhl Seminar on Deduction and Decision Procedures, Dagstuhl, Germany, October 2007.


P. Schneider-Kamp: Automated Termination Analysis of Programs using Term Rewriting, Microsoft Research, Redmond, USA, January 2008.


S. Swiderski: Signal Processing and Railway Case Study, Dagstuhl Meeting of German Research Training Groups, Dagstuhl, Germany, June 2007.

S. Swiderski: Proving Termination by Bounded Increase, 9th International Workshop on Termination (WST '07), Paris, France, June 2007.

S. Swiderski: Proving Termination by Bounded Increase, 21st International Conference on Automated Deduction (CADE '07), Bremen, Germany, July 2007.


R. Thiemann: Disproving Innermost Termination, 2nd Austria-Japan Summer Workshop on Term Rewriting, Obergurgl, Austria, August 2007.


Publications


Staff

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

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

- Research Assistants:
  Dipl.-Inform. I. Armac (funded by DFG Graduate College SCS until April 2008, since May 2008 research assistant)
  Dipl.-Inform. S. Becker (DFG CRC 476, until March 2007)
  Dipl.-Inform. C. Fuß (until December 2007)
  Dipl.-Inform. T. Haase (DFG TC 61, until March 2008)
  Dipl.-Inform. T. Heer (DFG TC 61)
  Dipl.-Inform. M. Heller (DFG CRC 476, until April 2007)
  Dipl.-Inform. A. Körtgen (DFG TC 61)
  Dipl.-Inform. B. Kraft (funded by DFG, until March 2007)
  Dipl.-Inform. C. Mengi (funded by DFG Graduate College SCS, since March 2007)
  Dipl.-Inform. C. Mosler (funded by DFG Graduate College SCS, until November 2007)
  Dipl.-Inf. U. Ranger (until April 2008)
  Dipl.-Inform. D. Retkowitz
  Dipl.-Inform. E. Weinell
  Dipl.-Inform. R. Wörzberger
• Guest Researcher:
  Dipl.-Ing. M. Hassani (since January 2007)
  Dr. J. Su (from April 2007 until April 2008)

• Technical Staff:
  M. Breuer (part time 50%)
  A. Drews (part time 50% TC 61, until October 2007)
  R. Frotscher, Trainee (until August 2008)
  J. Hormes (part time 50% TC 61, until June 2008)
  Dipl.-Math. (RUS) G. Volkova

• Student Researchers:
  Q. Ali, C. Außem, Chr. Briem, T. Campmann, N. Dickmeis, A.
  Egners, N. Ehses, D. Evers, A. Fischer, K. Gruber, R. Grüßner,
  T. Hermes, N. Jansen, M. Kallenbach, S. Kulle, S. Kuz, T.
  Kurpick, T. Lake, I. Lazcanotegui, S. Leong, M. Look, F. Meyer,
  G. Oelmann, J. Olschewski, A.N. Perez, M. Pettau, M. Pienkos,
  D. Rose, A. Scheuermann, R. Seidel, M. Stegelmann, A. Weigelt,
  N. Wiechowski, C. Xue, R. Zimmermann
Overview

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

Application domains we are facing are software development, chemical process engineering, process control, telecommunication systems, multimedia applications, eHome, conceptual design of buildings, specification systems for visual modeling down to 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 years we have also studied concurrent and distributed systems in the embedded systems domain. Project types are new development, reengineering, and reuse projects.

Most projects aim at improving general and specific software engineering techniques, or facilitating engineering development processes to be applied to specific application fields. Internally, the projects apply specific forms of software engineering for constructing tools for these 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 within Priority Programme). Finally, some small cooperations with other institutes or with external companies have been carried out. Transfer projects are carried out in cooperation with AMB Generali Infomatik Services GmbH and innotec GmbH, a German engineering tool vendor.

Link to research activities of the group:
http://se.rwth-aachen.de/Research

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 Lab 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)

Link to education activities of the group:
http://se.rwth-aachen.de/Teaching0809
Research Projects

Semantical Support for Conceptual Design of Buildings
B. Kraft, M. Nagl, T. Kurpick

The project deals with conceptual design in Civil Engineering and its support by semantical tools. The latter means (i) that all constraints which apply for a conceptual design are obeyed, and (ii) that semantical units as rooms, areas etc. are regarded.

Two approaches were followed: (a) Specifying design knowledge and using this knowledge by prototyping tools to check designs. Thereby, a machinery for tool building of the group was used. (b) An existing industrial tool was extended by encoding the knowledge into the tool such that it can behave more semantically.

The dissertation project is finished, the doctoral examination was in 1/07 (s. chapter on dissertations).

DRAGOS: A Parameterizable Database For Development Environments
E. Weinell, M. Breuer, G. Volkova, Q. Ali, M. Kallenbach, I. Lazcanotegui, A. Scheuermann, R. Seidel

DRAGOS is a database system which is developed according to the requirements of software systems for special application areas. This includes integrated development environments, CASE tools, re- and reverse engineering tools, and other interactive applications using complex object structures.

Common to these applications is the necessity to handle different types of objects on different levels efficiently: Coarse- and fine-grained objects, hierarchical and non-hierarchical relations between them, and a vast number of differently sized attributes (chapter numbers and images). DRAGOS offers a rich graph model and an extensible architecture. Features not provided by DRAGOS itself can be realized by extension modules, e.g. graph versioning for undo/redo etc. DRAGOS comes with different graph storage implementations, which allow to store and access data from various sources, e.g. relational databases.

In 2007 and 2008, we extended DRAGOS towards becoming a universal platform to develop graph transformation tools. The basic idea of this approach is to support graph transformations by a basic, yet extensible set of language constructs. This graph transformation language is directly embedded into the graph database for seamless integration with its functionality. In contrast to common languages and tools for graph transformation, e.g. PROGRES, developers are free to compose a customized language using core constructs.
and extensions. Furthermore, they are free to implement completely new languages rapidly, which is a valuable contribution for so-called domain specific languages.

Work has been started to precisely define the core language in order to act as reference for developers. In parallel, we implemented the core graph language using two distinct approaches: First, we provided a so-called universal implementation, which solely operates on the DRAGOS API. This solution is not an optimal choice if DRAGOS is used to access relational databases, as it leads to severe efficiency problems due to a vast number of required database queries. Therefore, we conducted a second implementation which generates database queries for directly accessing the underlying database system. Whilst this is a more efficient choice, it is tied to the use of relational databases as storage backend, naturally.

Besides providing a core graph language, a methodology is required to specify graph transformations on top of it. For this purposes, we started the development of an according approach based on visual tools. Consequently, implementing a graph language can be carried out by step-wise transformation of an syntactic representation into executable rules of the core language. This transformation is conducted in a rule-based manner, carefully accounting for the source language's static and dynamic semantics.

In the future, we will continue to evaluate the followed approach by supporting conceptually different graph languages. Besides programmed graph transformations, we will also support specialized query languages, which can be easily and conveniently applied in existing software development projects. Furthermore, ways to support developers in creating correct language transformations need to be evaluated.

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

C. Fuß, C. Mengi, M. Nagl, N. Dickmeis, A.N. Perez, R. Zimmermann

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 manufacturer in Germany, 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, dissertation project Fuß) is a cooperative project of BMW Group and our group, which aims
at supporting the engineers in developing integrated models of functions, hardware and software by providing concepts and tools.

The conceptional work focuses on developing a component meta-model forming the common kernel of the above mentioned models, thus also building the greatest common denominator of all AUTOSAR meta-models.

Particular attention is paid to the communication in distributed systems, real-time requirements, and foremost model integration.

Tools are developed for editing models separately as well as editors for mappings between models, e.g. the deployment of software components to hardware units. All tools are based on the i-caramba meta-model kernel.

The experiences that we have gained during the cooperation have brought new open problems, so that we have decided to continue the project in our group (dissertation project Mengi). One main problem that we have identified, and which add an enormous complexity to the development of automotive software, is the handling of variants.

Today the automotive industry provides customers a lot of possibilities to individualize their products. For example, there exist different kinds of vehicle types: Touring, Coupé, Cabrio, Limousine, etc. Each type has different models, each model has different engines and so on. Beside of this, customers could also select from a huge set of optional fittings, e.g., parking assistant, rain sensor, and intelligent light system. This leads to an enormous number of product variants, which influence the whole software development process and which therefore have to be handled appropriately.

The challenges that we are dealing with are the classification of variants in the development process, and the variability modelling of functions, software and hardware with their integration in to the development process. For this purpose, the existing i-caramba tools will be extended with features for variant handling, so that a further step on reducing software complexity could be achieved.

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. Typical 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 and privacy aspects, just to name a few.

We analyzed the life-cycle of eHome services beginning from development and specification via configuration and deployment at the eHome until retirement. In the domain of low-cost eHome systems, it is essential to automate the configuration process. For this purpose we developed the eHome Tool Suite, which supports the eHome service life-cycle, and controls the eHome system at runtime. The mobility of users and devices require a dynamic and adaptive configuration. The eHome system has to adapt to the changing environment with as few user interactions as possible, nevertheless the user has to be in control at all times. To evaluate and demonstrate our tools, we developed an eHome software simulator, which allows simulating home environments with inhabitants and installed devices.

Extending the existing results to support dynamic adaptation we are working on supporting mobile users by personalizing multiple eHomes when moving from one eHome to another one. Our approach is based on users carrying mobile devices which store their profiles allowing them to release the personal data to eHomes on demand. Thus, eHome services can adapt their functionality to these preferences.

As a result, problems regarding security and privacy will arise. On the one hand, the privacy of the users has to be protected while personalizing eHomes. For doing this, we implemented an anonymous, negotiation-based authentication mechanism combined with identity management giving users control about what personal data to release to different eHomes. On the other hand, the eHomes have to be protected against malicious users and services. This is done by role-based access control techniques combined with anonymous credentials.

Furthermore, we are working on the semantic annotation of eHome services to address incompatibility problems that arise when composing heterogeneous services. An ontology-based approach allows for generating adaptor components automatically which are used to enable service composition. To support an efficient usage of restricted device resources, we are developing a mechanism for dynamic management of service bindings. This way, we can ensure that services can share resources they only need for specific time intervals.

<table>
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<th>Tools for Consistency Management between Design Products</th>
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<tr>
<td>A. Körtgen, M. Nagl, S. M. Becker, M. Brysch, T. Campmann, S. Heukamp, K. Schneider, R. Schmidt</td>
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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 T5 of the Transfer Center 61, a follow-up project of B2 from CRC 476. It is carried out in close
cooperation with our industrial partner innotec GmbH and aims in elaborating the results of B2 and in transferring them to industry.

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. The results of B2 were part of the dissertation of Simon M. Becker who graduated in summer 2007.

Focused on scenarios from chemical engineering, a large number of integrators were realized in 2007 and before, e.g., integrators for integrating flow sheets of different abstraction levels and simulation models, but also for integrating UML structure diagrams and source code to show the applicability of the developed concepts.

For transferring the results of B2 to industry, the system Comos PT of innotec plays a central role. It is used during all engineering phases, e.g. for the creation of flow sheets. In 2007 and 2008, a universal integrator platform for Comos PT was realized: it includes (i) the integrator framework, (ii) a nice user interface for configuring integrators by dragging and dropping documents on it from Comos, (iii) an editor for simplified modelling of integration rules by dragging an dropping parts of flow sheets from Comos on the editor and by hiding UML – concepts from the engineers, (iv) a wrapper to access the contents of the documents, (v) two graphical tools for managing all dependent documents of a development process and their integration documents and for managing rule collections for different scenarios which are both also tightly integrated with Comos.

An extension of the approach in 2007 and 2008 was concerned with re-integration of documents in cases once corresponding structures get inconsistent after changes have been performed on them. Different kinds of repair actions are derived dynamically for such structures and are proposed to the user re-establishing a rule-based state.

One major issue in supporting and accelerating the development of integrators - besides their configuration - concerns the integration rule modelling process. Usually, integration rules are modelled manually. We are following two approaches to generate integration rules: (i) find correspondences between existing documents, e.g. from preceding projects, and extract integration rules from these correspondences and (ii) find correspondences on document models, i.e., on type level, and derive integration rules from these correspondences for instance level. Both correspondence analyses need further rule language constructs when being applied with the integration approach to match similar structures and types.

Furthermore, there is a need to support relationships between rules, e.g., there are redundant parts modelled in multiple rules which have to be maintained. In 2009, we will specify the semantics of different relationship kinds and develop a tool supporting them. In addition, it will be analysed which influence relationships between rules can have on the integration process. At the time being, it is promising that they can help the user with decisions when rules are conflicting, which again would improve the usability of integrators.
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 underlying data structure, the specification comprises a graph schema representing the static structure of the prototype and a collection of declarative 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 modeling distributed systems, which is addressed by the project Vilendis.

In 2007, we have extended PROGRES by the ability to import Java methods into a PROGRES specification. These Java methods may be used within the PROGRES specification in the same way as locally defined graph transformations. For example, they may be called within graph transformations. Additionally, we have revised the super-language construct which has been introduced in PROGRES in the context of realizing the object-oriented programming paradigm in PROGRES. Thus, the super-construct may be used within graph transformations. Furthermore, we have been engaged with the maintenance and improvement of the comprehensiveness of PROGRES, which are still on-going tasks in such a complex environment.

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 2007 and 2008, we implemented support for functionality already being provided by the PROGRES generated code and the DRAGOS system, but which was not made available through the user interface up to that point. In particular, this includes support for object-oriented modeling of graph transformations, which now can be selected from a context menu from each node. Furthermore, we allow users to specify values for so-called type-in
parameters, which take another type as their value. For ease of use, the UI offers all valid types to the user, from which he may select a concrete one through a drop-down list.

Furthermore, import and export of graphs is now supported for the DRAGOS system which was introduced last year. Based on the GXL exchange format, UPGRADE prototypes can again be linked to other graph-based tools easily.

T6: Management of Dynamic Processes Based on Existing Systems

The T6-project is part of the Transfer Center 61 and continues work of the AHEAD-project (Adaptable and Human-centered Environment for the Management of Development Processes), which was part of the Collaborative Research Center 476. In the AHEAD-project, we developed tool support for the management of complex, highly dynamic, evolutionary development processes. These processes can span across multiple organizations. The support for different inter-organizational cooperation scenarios was the result of the dissertation of Markus Heller who graduated in February 2008.

The transfer of the research results of the AHEAD-project into industrial practice is the major objective of the current project T6. Furthermore, we broadened our research field by also considering time and cost related aspects of dynamic development processes as well as by extending our application domain to dynamic business processes. The T6-project is carried out in cooperation with two industry partners. We cooperate with innotec GmbH, a CAE-tool vendor for the plant engineering industries, and AMB Generali Informatik Services GmbH (AMB-Informatik), which is the IT-service provider for the Generali insurances group.

Together with the innotec corporation we extended their main product, the CAE-tool Comos by a full-fledged workflow management system based on the Windows Workflow Foundation to support individual engineers in executing recurring standardized tasks. We extended Comos by the main functionality of the AHEAD-prototype to provide explicit support for process management on a medium-grained level. This transfer work resulted in the prototype PROCEED (PROCess management Environment for Engineering Design processes). We coupled the developed WfMS with the PROCEED prototype to provide best possible process support by integrating the recurring workflows of individual engineers in the overall development process. To monitor and control the current state of the whole development project, we developed new concepts for the visualization of management data and extended the PROCEED prototype by according UI-functionality. Besides that, we also investigated and implemented the necessary functionality for resource management and access control. Currently we address the topic of time management and progress control in dynamic development processes, whereas the problem of measuring the progress of running workflow instances has already been partly solved and implemented.

Together with AMB-Informatik we extend the existing process management system IBM WebSphere Process Server (WPS). WPS mainly supports static business processes, i.e., processes which can be completely predefined in advance and remain structurally unchanged.
during execution. In order to support also dynamic processes, we have extended WPS by an additional layer, which simulates the capability for dynamic modifications in the process structure during process execution. Due to this extension, process fragments can now be inserted into other running processes, repeated because of prior erroneous executions, or skipped. Moreover, we have taken first steps towards a process model editor, which supports process participants in performing process modifications, which are correct from a technical point of view and reasonable w.r.t. laws or company-specific regulations. These regulations can be either explicitly defined in dedicated, graphical models or are inferred from other process models. In order to relief the process participant from the complexity of a certain process, process models are displayed in a condensed way.

Software Integration and Framework Development
Th. Haase, M. Nagl

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 and Transfer Center 61 (cooperation with Aachen Münchener Informatik Services), studies an approach to tool integration which puts strong emphasis on software architectures and model-driven development.

Integration was 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 studied a model-driven approach for constructing wrappers: Based on a formal meta-model a visual model of the wrapper was specified and the executable code for the wrapper was 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.

Based on the idea of service-oriented architectures, the modeling formalism to specify wrappers was extended to model an integrated business application as a loosely coupled set of interacting services. This extension was 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 was built up.

The dissertation project is finished. The thesis is nearly completed. The doctoral examination will take place around end of 2008.

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**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 2007 and 2008, we have developed concepts for defining abstract views on graph specifications. These views serve as interfaces for these specifications and abstract from internal implementation details. For example, a view may contain a node type which is composed of several node types of the internal specification. In this way, an application may export a simplified view upon its specification. Abstract views have been designed as updateable views in order to maximize their usability in other applications. Thus, other applications can import abstract views and use their elements within graph transformations. To apply the concept of abstract views in practice, we have implemented these concepts in the language and environment Fujaba. The dissertation project has been finished (see chapter on dissertation).
Other Activities

Prototype demonstrations

Armac, I.: *Protecting the Privacy of Mobile eHome Users, Prototype demonstration*, Workshop of German Computer Science Graduate Schools, Dagstuhl, Germany, May 2008.


Heer, T.: *Algorithm and Tool for Ontology Integration based on Graph Rewriting*, Applications of Graph Transformations with Industrial Relevance (AGTIVE 2007), Kassel, Germany, October 2007.


Weinell, E.: *Using PROGRES for graph-based program refactoring*, 4th International Workshop on Graph-Based Tools (GraBaTs 2008), Leicester, UK, September 2008.

Conference Activities and Academic Administration

I. Armac: Member of the organization committee of the 4ING conference 2008; Member of the search committee “Software Engineering”, Member of Faculty Council, Organizer of the RWTH Computer Science Soccer Tournaments 2007 and 2008.

T. Heer: Member of the organization committee of the 4ING conference 2008, July 2008; Member of the GI-Group „Flexible service- und prozessorientierte Informationssysteme”

A. Körtgen: Member of the organization committee of the 4ING conference 2008, Co-organizer of the “Girls Day” 2007 and 2008

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”

C. Mengi: Member of the organization committee of the 4ING conference 2008, July 2008; Member of the GI Research Seminar: „Modeling Techniques for Computer Networks Simulation”

M. Nagl: Speaker of Collaborative Research Center 476/Transfer Center 61; Member of the Board of “Forum Informatik” until 3/07; Member of the Board and Speaker Substitute of REGINA until 3/07; Member Substitute of RWTH Aachen University Senate; Additional Member of the Faculty for Electrical Engineering and Information Technology; Member of Faculty Council; Board Informatics Europe until 11/07; Chairman German Informatics Faculties Conference (Fakultätentag); Chairman of the Board of 4ING (Union of Faculty Conferences in Mechanical Engineering, Electric Engineering, Civil Engineering, and Informatics); SEI, Software Engineering 2007, Hamburg (Member of the PC); Intl. Workshop AGTIVE 2007 (Application of Graph Transformation with Industrial Relevance), Kassel (Member of the PC); SEI 2008, Software Engineering Conference 2008, Munich (Member of the PC); Intl. Conference on Graph Transformation ICGT 2008, Leicester, Great Britain
(Member of the PC); Fujaba Days 2008, Dresden (Member of the PC), Local Organizer 4ING Conference “Zukunft Ingenieurwissenschaften – Zukunft Deutschland” and the First Common Plenary Assembly of 4ING Faculty Conferences 2008; SEI 09 Software Engineering Annual Conference 2009, Kaiserslautern (Member of the PC)

U. Ranger: Co-organizer of the “Girls Day” 2007

D. Retkowitz: Member of the organization committee of the 4ING conference 2008, July 2008; Teaching assistant at the Thai-German Graduate School of Engineering (TGGS) at King Mongkut's University of Technology North Bangkok (KMUTNB), February 2008; Search committee member for the Ultra High-Speed Mobile Information and Communication (UMIC) research cluster, 2007-2008.

E. Weinell: Member of the organization committee of the 4ING conference 2008, Co-organizer of the “Scholar information days” for Computer Science, Member of the search committee “Algorithm-oriented code generation for high-performance computer architectures”.

R. Wörzberger: Teaching position at Aachen University of Applied Sciences; Member of the organization committee of the 4ING conference 2008; Chair of the working group “Project Management” of the Regionaler Industrieclub Informatik Aachen e.V. (REGINA); Member of the GI-Group „Flexible service- und prozessorientierte Informationssysteme”
Talks and Publications

Talks


Armac, I.: *Protecting the Privacy of Mobile eHome Users*. Workshop of German Computer Science Graduate Schools, Dagstuhl, Germany, May 2008.


Armac, I.: *Protecting Privacy of Mobile eHome Users*. Workshop of German Computer Science Graduate Schools, Dagstuhl, Germany, June 2007.


Heer, T.: *Algorithm and Tool for Ontology Integration based on Graph Rewriting*. Applications of Graph Transformations with Industrial Relevance (AGTIVE 2007), October 2007, Kassel, Germany.


Körtgen, A.: *Modeling Successively Connected Repetitive Subgraphs*, 3rd International Workshop on Applications of Graph Transformation with Industrial Relevance (AGTIVE'07), October 2007, Kassel, Germany


Körtgen, A.: *Correspondence Analysis for Supporting Document Re-Use in Development Processes*, 12th World Conference on Integrated Design & Process Technology (IDPT ’08), June 2008, Taichung, Taiwan


Mosler, C.: Reengineering of State Machines in Telecommunication Systems. 9th Workshop Software-Reengineering (WSR’07), 02-04 May 2007, Bad Honnef, Germany


Nagl, M.: One Year of 4ING or Has Informatics Europe to Become more Political?, Informatics Europe Conference ECSS ’07, Berlin, Germany, October 8th 2007


Ranger, U.: Defining Abstract Graph Views as Module Interfaces, 3rd International Workshop on Applications of Graph Transformation with Industrial Relevance (AGTIVE’07), October 19th 2007, Kassel, Germany

Ranger, U.: Ensuring Consistency within Distributed Graph Transformation Systems, 10th International Conference on Fundamental Approaches to Software Engineering (FASE’07), March 2007, Braga, Portugal

Ranger, U.: The Jury is still out: A Comparison of AGG, Fujaba, and PROGRES, 6th International Workshop on Graph Transformation and Visual Modeling Techniques (GT-VMT’07), April 2007, Braga, Portugal


**Publications**


Software Construction

Staff

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

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

- Research Assistants:
  Dipl.-Inform. Andreas Ganser
  (third-party funds position)
  Dipl.-Inform. Veit Hoffmann
  Dipl.-Inform. Alexander Nyßen
  (third-party funds position)
  Malek Obaid, M.Sc.
  (DAAD scholarship)
  Chayakorn Piyabunditkul M.Sc.
  (DAAD/NECTEC scholarship)
  Dipl.-Inform. Holger Schackmann
  (third-party funds position)

- Student Researchers:
  Philip Ritzkopf
  Oscar Mendoza
Overview

Our research focuses on the development of new and advanced methods, tools and techniques in the broad area of software construction. Thereby we always try to develop and deliver software engineering support that is applicable under industrial software development conditions.

Currently we are running a couple of research projects (details can be found in the corresponding section), most of them in close cooperation with industrial partners.

In the reporting period we started three new projects. The first aims to combine model driven development and service oriented architecture in the domain of life cycle software. In the second project we try to develop a use case based approach to early simulate functional requirements and to generate test suites. The third is in the area of process improvement where we define a light weight software process improvement approach that has to be especially applicable for small and medium software houses.

Furthermore we have successfully initiated the BugzillaMetrics open source project (hosted by sourceforge). BugzillaMetrics is a metrics tool that was developed in our group. Based on the experience gained with the first version of MeDUSA, the second edition of MeDUSA was released in 2008. Finally, in 2007 DASMA awarded a diploma thesis prize to Lars Grammel, one of our Diploma students, and a Design Pattern intense course was given at the University of Tartu, Estonia.
As the history of software engineering unveils, abstraction is the means to face complexity. While the 1970’s and 1980’s have been strongly based on functional and data abstraction, and while the 1990’s and early 2000’s have been dominated by object-orientation, model-based software development (MBSD) seems to be the predominant development paradigm of the present and upcoming decade.

Due to its increased capabilities in terms of abstraction, traceability and analyzability, it seems to be the in particular useful to address the very special constraints, being faced in the domain of embedded & real-time systems. However, as current surveys unveil, from a state-of-the-practice viewpoint, model-based software development does not seem to have penetrated the embedded & real-time domain yet. Tracing this back to domain-specific technical, economical and organizational constraints, not being properly reflected by current model-based approaches, it is the goal of this project to introduce modern model-based technology and techniques, being however constraint-adapted.

As only a common, integrated methodology, formed by a systematic and concise method, by profound supporting tools, and by underlying languages, being related via common concepts and principles, allows to unleash the full potential of model-based development, it is the central goal of this project to deliver the latter. Regarding the very special constraints, being additionally faced in the domain of small embedded & real-time systems, the approach should in particular be applicable to a domain, which has been very much elided so far.
Today, profitability and continuous adaptability with respect to business processes and corporate structure are major requirements to companies. Economics claim these goals are achievable only with corporate structure and IT structure collaborating tightly.

But, adjusting structures of companies and their IT is challenging since both exist independently and structures of IT are inflexible in general. Therefore, IT structures inevitably need to change towards well defined components with well defined interfaces. Many approaches have been developed and deployed in order to make IT better foster business processes. But these approaches were often tightened to technical details too much and left organizational aspects out of sight.

Service oriented architectures (short: SOA) are perceived as the silver bullets in that area our days. This is because SOA is an idea which regards business and IT likewise and hence fosters flexibility of the entire company. What's more, it demands loose coupling of components, here called services, and consequently it allows easy exchange of every service.

The IT related sub-discipline of SOA addresses software construction issues and belonging challenges with respect to design, processes, and evolution. These challenges emerge with more impact whenever legacy systems are involved. But SOA allows such systems conceptual and allows to integrate them since they rarely can be build from scratch again. But in most cases "software assets" do not adhere to every requirement of the new environment or the new environment simply adds requirements. Hence, SOA needs to deal with heterogeneous environments on the one hand and on the other hand it needs to tackle subsequent problems.

In the last few months we started our cooperation with Osthus GmbH and picked a topic for initial work in the area of SOA. We aimed for integration of legacy services into state of the art platforms by enhancing these services with extra functionality. Therefore we analyzed the environment thoroughly and built a conceptual model how integration and extension of these services might work. Though the conceptual model is intended to be generic, the guiding motivation is to add security functions to existing services. We did so because there are often existing services that have to be extended with some functionality leaving the source code untouched. This might be due to changes in the environment towards SOA. Finally, we came up with tool support with witch designer can arrange services and assign additional services by simply dragging and dropping existing services from repositories to a design black board.

But this tool support is rather rudimentary for now. This means there are a lot of things designers need to keep in mind during work. Therefore, we aim for better tool support how to warn designer when something is likely to go wrong or when components do not fit together. But the reasons why services might not work together are manifold. Hence, we need to find and extract best practices and condense them to patterns how designing is supposed to be done. In the long run the extracted patterns are intended to be used in model driven development to support model driven architectures.

Use cases are a widely accepted technique for the elicitation and specification of functional requirements. In practice Use cases often consist of tow parts: an overview diagram which
depicts the relations between the single use cases and a set of more or less detailed textual descriptions of the behaviour encapsulated by the single use cases. Although use cases have become a widespread technique, they still face several mayor acceptance issues. One of the major advantages of use case related techniques is the informal structure of the textual behaviour descriptions, which makes them easy to understand and thus a good means for communication especially between developers and customers.

This informality is at the same time their biggest drawback. Due to this lack of formality use case descriptions are difficult to maintain, since it is impossible to keep track of model completeness, as well as of consistency of the textual descriptions themselves and between textual descriptions and other requirement documents especially the use case overview diagrams automatically.

To overcome those issues our research group defined a formal meta-model for textual use case descriptions. This meta-model only affects the structure of textual behaviour descriptions, but does not restrict the language that can be used to describe the behaviour itself.

This keeps the enriched descriptions easy to understand even for readers that are unaware of the underlying meta-model, and at the same time enhances the manageability and quality of the descriptions.

Thus on the one hand the enriched descriptions remain simple enough to be usable as a communication means and on the other hand the application of the formal model enables tool support which leads more sophisticated, consistent use case descriptions. So the additional time the modeller has to spend during the specification of the behavioural descriptions is well worth the effort, especially since we think that the enriched descriptions may also be used to support the creation of other documents in the development process like test cases as well.

During the last year our research group created ViPER-NaUTiluS. ViPER-NaUTiluS adds integrated tool support for specifying, editing and analysing of enriched use case descriptions.
to the ViPER-IDE. Besides simple creation and editing of use case diagrams and textual descriptions the NaUTiluS-Editor provides a lot of context information which help the developers to create behaviour specifications with a high quality.

Furthermore the NaUTiluS framework includes a use case simulator for the specified behaviour descriptions. Thus NaUTiluS enables prototyping of the system behaviour very early in the development process. Use case simulation can for example be used for reviews with domain experts or for the analysis of the different scenarios described by the Use cases.

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**Generating System Test Cases based on Rich Use Case Models**

H.Lichter, M.Obaid

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UML (Unified modelling Language) is a widely used standard of definitions and concepts to structure the use cases modelling, which forms a basic step towards well-applied software development of software systems. Although UML notational diagrams are efficient formal way to model use cases on an abstract level, natural language descriptions that capture these use cases are still necessary and widely used for requirements. The aggregation of these both UML diagrams and the detailed descriptions form the complete use case model. In the previous described research on advanced use case modelling [V.Hoffman, H.Lichter], NaUTiluS tool provides an editor for the purpose of allowing behaviour specifications of use cases with natural language descriptions. Having a high quality use case model is beneficial to represent what the future system will do and how it will behave. Such a model does not only facilitate the next development phases, but also gives the possibility to have more beneficial features. Three of more important features are System Tests, Simulation, and Architecture. This research project will focus on the generation of system test cases out of use case models.

Having high quality system test cases is very important to verify system functionality, and the integrity of software systems. Generating system test cases from requirements models is helpful to save time, effort, and money. The research focus on generating system test cases based on use case models is against two important obstacles since generation of test cases based on natural language use case descriptions is not yet possible because the underlying use case model lacks information about the steps of a use case and the relationships to other use cases. On the other hand, using a strong formal description of use cases is not possible either, because we will then ignore the important widely used natural language descriptions of use cases, and generate test cases based on an incomplete and unreadable model. NaUTiluS needs to be validated for the use within the use cases modelling if it provides enough information for our research aim (generating test cases).

In summary, we want to use or develop a use case meta-model and corresponding tool support that allow both visual and natural language descriptions of use cases in a way that it contains enough information to generate system test cases. Then, to develop a generation approach for system test cases based on such use cases model and for this approach, a suitable tool support has to be provided too.
The development of a large portfolio of software projects raises several managerial challenges, like balancing resource allocation between different projects, and aligning development processes to the standards of the organization. Hence the project status and process quality characteristics, like planning precision or problem resolution speed, must be monitored continuously in order to identify development process weaknesses, and assess process improvements. Collecting the required data by regularly project status reporting can be expensive and intrusive, and furthermore ignores the past history of a process. This motivates mining data from routinely collected repositories like change request management (CRM) systems.

However existing CRM tools provide only a number of fixed metric evaluations and are limited in their adaptability. In order to support a flexible approach for the evaluation of metrics on CRM data, the tool *BugzillaMetrics* was developed at our group. It is based on declarative metric specifications. This enables concentrating the main effort on the model of the metric, not on its implementation.

In our ongoing work we are investigating how to apply this tool for the comparison of process quality characteristics within a project portfolio of open source projects, as well as in an industrial context.
Other Activities

- Design Patterns in Action, intense course, University Tartu, Estonia, May 21-25, H. Lichter
- Member of the award board “Hochschulpreis David-Kopf” 2007, H. Lichter
- Reviewer for dpunkt-Verlag Heidelberg and computing reviews, H. Lichter
- Organization of the Computer Science Department’s mentors program, H. Lichter
- Member of the Computer Science Department’s committee for Service-Lehre, H. Lichter
- Member of the examination board of Computational Material Science, H. Lichter
- Member of the program committee, “Modellierung 2008”, March 14-16, 2008, Berlin, H. Lichter
- Member of the program committee, SSIRI 2008, Second IEEE International Conference on Secure System Integration and Reliability Improvement, Yokohama, Japan, July 14-17, 2008, H. Lichter
- Member of the program committee, Software Engineering 2007, Hamburg, March 27-30, 2007, H. Lichter
- Member of the program committee, Software Engineering 2008, Munich, February 18-22, 2007, H. Lichter
- Member of the program committee, “Objektorientierung, Reengineering, Architektur - Evolution komplexer Softwaresysteme”, Bremen, September 2007, H. Lichter
- Organization of the Beginner’s Course in Computer Science 2007, H. Lichter, V. Hoffmann

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*
- Lecture *Managing Software Development Projects*
- Seminars and Practical Labs

Furthermore we are responsible for the Software Engineering lecture of the master program Software Systems Engineering at the Thai German Graduate School of Engineering, Bangkok, Thailand.
Talks and Publications

Talks


Publications


Staff

- Chairholder
  Prof. Dr. rer.nat. Dr. h.c. Otto Spaniol

- Secretariat
  Christiane Gelueck †
  Sabine Simon
  +49 241 80-21402
  Petra Zeidler
  +49 241 80-21401

- Research Staff
  Dipl.-Inform. Uta Christoph (since 1.12.08)
  Dipl.-Inform. Stephan Diepolder (until 31.3.07)
  Dipl.-Inform. Juan Miguel Espinosa Carlin
  Dr. Mesut Günes (until 30.6.07)
  Dipl.-Inform. Tobias Kölsch (until 31.5.08)
  Dipl.-Inform. Martin Krebs
  Dipl.-Inform. Karl-Heinz Krempels
  Dipl.-Ing. Jan Kritzner
  Dipl.-Inform. Sadeq Makram
  Dipl.-Inform. Ulrich Meis (since
  Dipl.-Ing. Kittisak Ormsup
  Dipl.-Inform. Andriy Panchenko
  Dipl.-Inform. Stefan Penz
  Dipl.-Inform. Dang Vinh Pham (until 29.2.08)
  Dipl.-Inform. Alexis Pimenidis
  Dr. Ulrich Quernheim
Dr.-Ing. Jürgen Rapp
Dipl.-Inform. Tim Seipold
Dipl.-Inform. Benjamin Schleinzer (since 1.4.08)
Thitinan Tantidham, M.Sc.
Dr. Dirk Thißen
Dipl.-Inform. Martin Wenig (until 29.2.08)
Dipl.-Inform. Ralf Wienzek (until 31.7.07)
Dipl.-Inform. Alexander Zimmermann

- Technical Staff
  Helen Bolke-Hermanns
  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

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://nets.informatik.rwth-aachen.de
Research Projects

Prior art analysis for patent infringement litigation
in cooperation with Software AG – Intellectual Property Department, Germany and Foley & Lardner LLP, USA.

Uta Christoph

The project comprised the analysis of prior art patents and articles with respect to claim evaluation for an infringement litigation in the U.S. Furthermore research on additional papers and articles was undertaken to support the intellectual property protection of Software AG.

Performance and Conformance Testing of a Service Delivery Platform for Converged Services

Juan Miguel Espinosa Carlín

The IP Multimedia Subsystem (IMS), defined by the 3rd Generation Partnership Project, is becoming the de facto overlay architecture for enabling service delivery in converged environments. In such scenarios, the QoS requirements of the delivered services vary from user to user, and from service to service. To cope with this feature, the IMS allows subscribers to personalize the QoS settings of the session that they want to establish.

In order to explore and further develop the service delivery mechanisms defined by the IMS, there is the need of enabling a reliable testing environment that allows to experiment with new approaches. Furthermore, this environment should help us understand the impact that the QoS parameters requested by the users have on the available network resources.

The first goal of the project consists on doing a conformance testing of the basic session control mechanisms of an IMS testbed. The second goal is aimed at showing how the SIP
signaling load in a core IMS network is affected when users change their QoS parameters when negotiating a session. Both the conformance testing and the performance evaluation with varying QoS parameters were done on a testbed based on the Open IMS Core implementation of the Fraunhofer FOKUS Institute at Berlin and on the IMS Client developed at the University of Cape Town.

Presence-based Runtime Service Composition of SIP Services
Juan Miguel Espinosa Carlín

The convergence-driven need to seamlessly deliver services, has forced operators to adopt new approaches, like the Intelligent Networks, Web Services API's, and, most recently, the IP Multimedia Subsystem (IMS). In the context of the IMS architecture, Java SIP Servlets are a suitable option to implement a SIP Application Server (AS).

With the goal of promoting software modularity and reuse, the Java Community Process specified the SIP Servlet API v1.1 under the Java Specification Request 289. In the application composition framework of this specification, the core entity is the Application Router (AR), to which the Servlet container communicates to know the sequence in which the applications have to be invoked. Although the AR is essential for the proper operation of the container, the specification only provides the definition of a Default AR (DAR), which has no processing logic besides the declaration of the order in which applications will be invoked; the implementation of more powerful AR's that make use of complex rules and diverse data repositories, are left to the container implementations.

With the goal of providing a richer component, this project is aimed at developing presents an AR that allows performing runtime composition, based on the Presence information associated to the users involved in a session.
The Internet, by design, lacks unified provisions for identifying who communicates with whom; it lacks a well-designed identity infrastructure (identifying endpoint of a communication by the IP address is not sufficient to identify single users). Instead, technology designers, enterprises, governments and individuals have over time developed a bricolage of isolated, incompatible, partial solutions to meet their needs in communications and transactions. The overall result of these unguided developments is that enterprises and governments cannot easily identify their communication partners at the individual level. Given the lack of a proper identity infrastructure, individuals often have to disclose more personal data than strictly required for real world transactions. The latter can often be conducted anonymously -- in many cases the service could be provided without any personal data at all. Over the long run, the inadequacy of the identity infrastructure affects individuals' privacy. 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. The availability of abundant personal data to enterprises and governments has a profound impact on the individual's right to be let alone as well as on society at large.

PRIME is the name of a 4-year project which was finished on May 31st, 2008. The objective of the project was 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. Information and communication technologies are increasingly intrusive allowing others more and more insight into the private sphere. One's right to privacy is thus increasingly at risk.

To preserve this essential right the individual's autonomy and control over personal information must be maintained. Current practice and trends in information technologies, however, show a widening gap. This undermines trust in domains where trust is critical, such as healthcare, banking, and even exercising one's democratic rights. PRIME solutions can close this gap. The project was focused on solutions for privacy enhancing identity management that supports end-users' sovereignty over their privacy sphere and privacy-compliant data processing of enterprises.

Conducted within the EU 6th Framework Programme, the PRIME consortium developed processes which could direct the current trend towards the use of identity management systems to strengthening of privacy protection as a whole. This requires that the design of data processing must start from maximum privacy and that privacy policies have to be trustworthily enforced. Therefore, the consortium developed solutions for users to gain control over their data. Following an interdisciplinary approach, the current social, legal and economic framework was analysed. Policy makers and other stakeholders were shown possibilities how to increase privacy and trust of citizens and customers.
Anonymous Communication
Alexis Pimenidis, Andriy Panchenko

With the growth of the digitized world privacy issues get more and more importance. While cryptography can be used to protect integrity and confidentiality of the data part of the packets, everyone along a route of packets can still observe the addresses of the communication parties. This is often enough to uniquely identify a person. Time, duration, and volume of communications can additionally be used to infer further information like e.g. a social relation between the communicating parties.

Anonymous communication deals with hiding relationships between communicating parties. It is a basic fundamental building block for privacy-friendly web browsing, any viable identity management system, privacy-aware eGovernment, eCommerce and eHealth technologies. Privacy-friendly communication is also necessary for providing freedom of speech, mind, and the achievement of democratic principles even in those countries that try to filter and censor access to information. Thus, strengthening privacy-enabled communication can be seen as a major goal from a social point of view.

The goal of this research is to enhance exiting and develop new methods of anonymous communication and provide a stable basis for a solid understanding of the topic. Topics of research and interest include, but are not limited to: performance of network layer anonymization, the limits of anonymization techniques, evaluation of attacks and their effectiveness, design of new protocols for anonymity and analysis of their properties, support for law enforcement in anonymous communication infrastructures, etc.

Standardising the Internet of Things
Kai Jakobs

Radio Frequency Identification (RFID), and succeeding technologies, will change people’s lives perhaps even more dramatically than Information and Communication Technologies (ICT) have done so far.

Technically, the ‘Internet of Things’ (IoT) or ‘Intelligent Dust’ will be realised through very small and ‘intelligent’ RFID chips that have the ability to communicate with each other. Yet, today’s networks are hardly equipped to deal with the amount of information to be exchanged, or to adequately accommodate the specific new communication patterns. Accordingly, new ICT systems (including new communication services and protocols) will need to be developed.

To deploy this technology beneficially for all stakeholders, internationally agreed standards will be a sine-qua-non. Yet, these technologies to be standardised will have an unprecedented
impact on the environment within which they will have to function. The standards setting process will need to reflect this in some way. As a consequence, it will become essential to identify new ways how to allow all interested parties to participate in this process, and to voice requirements and concerns. Accordingly, the standards setting process must not be limited to purely technical matters and to economic issues, but will also somehow have to take into account, for example, social and political aspects. To this end, new processes may have to be devised.

The overall objective of the project is to make initial recommendations on how to adapt the standards setting processes for the Internet of Things to stakeholders’ requirements. More specifically, the project will

- do a comprehensive state-of-the-art analysis with respect to current standards-setting processes and different stakeholders’ participation in these processes,
- identify the major stakeholders of the (future) IoT standards setting environment,
- develop typical sample application scenarios for the IoT,
- develop scenarios for the web of organisations setting standards for the IoT.

This project is part of RWTH’s Excellence Initiative, and funded under the Project House ‘Interdisciplinary Management Practice’ (IMP). The grant holders are Kai Reimers (Business Studies) and Kai Jakobs (Computer Science).

![China-EU-Standards](image)

Kai Jakobs

The China-EU-Standards project will promote research collaboration and engagement between research and policy in relation to Information Technology standardisation in China and Europe – a question that will have an important bearing upon their respective roles in the global economy in the 21st Century.

The People’s Republic of China has in recent years begun to be remarkably active in a number of areas of ICT interoperability standards. This raises a number of issues for China about standardisation processes: their standardisation strategy and its relationship with technology promotion policy. The outcome of these processes could have important consequences for the global ICT market and for the European economy and are flagged as being of particular interest to the FP7 Information Society Technologies programme.

This project brings together leading European and Chinese centres for research into ICT Interoperability Standards to undertake a comparative examination of ICT standardisation processes and associated policies between EU and China. The project will develop a knowledge network of leading players in the field, within Europe, China and beyond. The project will examine the new ICT standardisation activity emerging in China, apparently linked to its goals to promote indigenous technology. It will compare these emerging standardisation processes with those that have emerged and are being currently pursued by European players.
A set of empirical studies will focus upon 4th Generation Mobile Telephony and Audio-Visual Systems and Mobile Broadcasting. The studies will examine the standardisation approach adopted; the strategies of public policy, technical and industrial players in relation to standards. It will explore the likely implementation and uptake of standards and their outcomes for new technological innovation and markets. A particular interest is whether the outcomes will be open standards, alignment between regional economies, competitive standards processes leading to so-called “standards wars” or the fragmentation of global markets. Attention will be paid to processes of social learning by standardisation bodies, technology and industrial players and policy actors.

In addition to RWTH project partners include The University of Edinburgh, The University of Oslo, Vytauto Didžiojo Universitetas, Fraunhofer Institute for Systems and Innovation Research, Tsinghua University, The Chinese Academy of Science’s Institute for Policy and Management. The project is co-funded by the European Commission under the ‘Social Sciences and Humanities’ programme.

For further information please visit http://www.china-eu-standards.org.

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 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.

The UMIC research program is structured into four research areas A, B, C and D: The area B ‘Mobile Applications and Services’ area has its focus on demanding key application classes and their interplay with the wireless transport. This project is part of the sub area B1 ‘Future Mobile Internet Services’. The goal of this project follows the vision 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 and areas with low population density.

Wireless Mesh Networks are a suitable network technology to deliver reliable and affordable data and voice services with regard to cost for devices and deployment for this scenario. Service discovery will play an essential role in a future wireless network. This will especially be the case for rural areas and developing countries, which are expected to build their whole infrastructure on wireless networks like Wireless Mesh Networks (WMNs). Service and resource discovery mechanisms are able to provide rural communities with an easy way to share their devices and services among each other. However, our project is not limited to rural areas, it is also applicable to wireless city mesh networks which are expected to play a major part for ubiquitous computing.
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’.

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 by the MBMS (Multimedia Broadcast Multicast Service) framework. 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 has been defined.

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, 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 can be transmitted by the means of unicast transport protocols.

Especially the problem of switching delays has been analysed and improved. Many users of digital TV dislike the delay for switching channels they experience with DVB-T or DVB-S systems. Some methods have been proposed to reduce at least the perceived switching delay. This problem is not only relevant for mobile TV, but for the complete range of IP-based TV-services.

Channel Assignment and QoS-routing in wireless mesh networks
Sadeq Ali Makram

Wireless Mesh Networks (WMNs) are gaining growing interest as a promising technology for high speed network and Internet access. One of the challenges that still faces high performance WMNs is the capacity reduction due to interference of wireless links. In addition, efficient utilization of the limited resources (frequency channels) is one of the major challenges in WMN system design. Dynamic Channel Assignment (DCA) can be deployed for ensuring effective utilization of the available channels. The main contributions of our
research is to address the problem of assigning channels to the wireless links with the objective of reducing the overall network interference. Furthermore, to improve the capacity of wireless mesh networks, and the ability to reuse channels more efficiently by taking into account local propagation conditions and traffic loads. However, the proposed schemes of DCA do not consider the security issues from the exposed attacks which influence the channel assignment. Therefore the security vulnerabilities on DCA should be addressed in order to achieve the benefits of Multi-channel WMN.

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

Stefan Penz

Future mobile networks will become more and more decentralized and self-organized. In so-called Mobile Ad-hoc Networks, wireless devices will connect and communicate spontaneously directly without a fixed infrastructure. These networks require a flexible service management system that enables 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 access the service management should work transparently with a minimum of administration and configuration effort.

In the first phase of the project Informatik 4 developed a flexible service management system on the basis of the IETF Service Location Protocol (SLP). The second phase of the project dealt with the efficient assessment of Quality-of-Service parameters that are necessary for the appropriate selection of service providers. The work focused on the stability and the available bandwidth of a network connection.

Wireless Mesh-Networks are hybrid networks that offer a stationary infrastructure backbone, but parts of the network may consist of mobile nodes that spontaneously connect among each other and some of them also with access points to the backbone. Thus, the structure of these networks is vastly heterogeneous and so are the network connections to the service providers. Therefore, the network structure should also be considered for service provider selection. Therefore, the goal of the current project phase was the development of an assessment system that tries to derive the stable network substructure by statistically analyzing the overheard network traffic. This system does not impose any additional network traffic and does not require any modification to other network devices. So, it can be easily deployed in existing networks and offer the user applications valuable information about stable and instable substructures of the current network.

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/](http://www.tm.uka.de/forschung/SPP1140/).

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Flexibility in software systems is needed to allow adaption to increasing demands of users. To ease the development of flexible architectures several approaches are used, which often differ already on the conceptual grounds. Two of these paradigms are characterized by the strong underlying metaphors plugins and agents. Plugins emphasize on an extension relation between pairs of components where each component participates in a clearly specified role. Agents have a wide variety of attributes, such as mobility, autonomy, adaptability and pro-activeness. The general relationship of agents is that of peers mutually offering and using their services – higher organizational abstractions have to be implemented based on this service-oriented view. The goal of this project is to conjoin both paradigms of multi-agent systems and plugin systems, leading to the concept of a plugin-agent. Plugin-agents can be used in wireless ad-hoc networks where availability of online services or connection to the network is not always guaranteed. If services are mobile as proposed by the agent metaphor they can migrate to the portable device and be executed locally. With respect to the limited resources available on smaller mobile devices services are accessed using the plugin interface. The approach is unique as it handles both concepts on the same architectural level. To my knowledge, all other existing combinations of agents and plugins use one of the concepts to model or implement the other.

Data Service Continuation in Mobile Computing
Thitinan Tantidham

Since the rapid advance of mobile computing and communication technologies, the ratio of price to performance for mobile 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 the 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 and protect data loss in mobile computing, the techniques of checkpointing for a program re-execution at a break point and replicated data across multiple storages for ubiquitous access are required.

In recent researches, checkpointing and replication protocols in mobile computing have been developed on the basis of local storage limitations. These protocols employ a proxy server or a mobile station system for locating a persistent storage and functioning as a checkpoint and replication manager. It needs a link establishment between the system and a mobile device to save and to retrieve the checkpoints and the replica but it eases for consistency maintenance.
However, in real life due to high access cost and inadequate network coverage, while traveling, users are mostly in disconnection mode and work on their own local copy. To cope with this problem, a replication engine with facilitating of version control and data synchronization on the peripheral storage is introduced.

This research aims to investigate a replication framework for mobile computers and to design an optimum replication scheduling which is optimized between user workload, failure rate, and consistency management in the context of energy efficiency.

As the experimental results, it has been found that the lifetime of battery ranges from a few minutes to a few hours. It depends upon ages and power consumption of all elements of a whole computer system. A variety of USB storages like mobile hard disk, USB flash, SD and Microdrive with memory card reader have different characteristics of power consumption, performance, and capacity. Therefore, the replication scheduling is devised based on energy power sources: AC or battery. See Figure 1. Data replication profile and the descriptions of storage and system are pre-configured. The policy to select replicated data satisfies the constraints of storage capacity and energy and maximizes a profit function. The replication scheduling in battery-powered mode is classified into two policies: one dominated by fault tolerance aspect, another one is to save energy by maximizing power-saving in USB channel.

Simulations are a very appropriate way to study wireless and mobile networks since they offer a convenient combination of flexibility and controllability. However, their largest disadvantage is that the results are difficult to transfer into reality since not only the level of abstraction of the upper network layer is typically high, but also the environment of mobile and wireless networks is very complex.
During the last two years we developed UMIC-Mesh.net, a hybrid testbed approach that consists of real mesh nodes and a virtualization environment. On the one hand, the virtualization allows the development, and testing of software as if it were executed on real mesh routers, but in a more repeatable and controllable way. On the other hand, the results and conclusions can be easily transferred into reality, since the testbed offers a high degree of realism.

The UMIC-Mesh.net testbed is the building block that forms the basis for our further research. It provides an appropriate method and tool to study not only WMNs themselves, but also to develop and deploy new network protocols and application for them.
Publications


Jakobs, K.: *The ICT Standardisation Policy of the EU – Changes Ahead!*? To be published in: Proc. 2nd Int. Conf. on Standardisation of IT and Interoperability.


Penz, S.: SLP-based Service Management with QoS Server Selection in Mobile Ad-hoc Networks; Proceedings of the 9th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM'08), Newport Beach, CA, USA, June 2008


Tantidham, T.: Data Service Continuation for Battery-Powered Computers. The 3rd Balkan Conference in Informatics (BCI'07), September 2007.


Zimmermann, A.; Schaffrath, D.; Faber, M.; Wenig, M.; Günes, M.: Improving TCP Performance through Explicit Corruption and Route Failure Notification (ECRFN). In:
Distributed Systems

Staff

- **Faculty**
  
  Prof. Dr.-Ing. Klaus Wehrle

- **Office Administration**
  
  Ulrike May, Dipl. Verw.-Wiss.

- **Research Assistants:**
  
  Ismet Aktas, Dipl.-Inform. *
  Muhammad Hamad Alizai, MSc. *
  Jó Ágila Bitsch Link, Dipl.-Inform. *
  Stefan Götz, Dipl.-Inform. *
  Tobias Heer, Dipl.-Inform. *
  Georg Kunz, Dipl.-Inform. *
  Olaf Landsiedel, M.Comp.Sc. *
  Oscar Garcia Morchon, M.Eng. †
  Simon Rieche, Dipl.-Inform. *
  Raimondas Sasnauskas, Dipl.-Inform. †
  Florian Schmidt, Dipl.-Inform. *
  Elias Weingärtner, Dipl.-Inform. *
  Hanno Wirtz, Dipl.-Inform. *

- **Student Research Assistants:**
  
  Sebastian Agethen
  Dmitry Butenkov
  Rene Hummen
  Sebastian Jansen

* third party funded
† external PhD student
+ partially funded by tuition fees
Thomas Jansen
Hakan Karahan
Johannes Laudenberg
Jens Otten
Dongsu Park
Resit Sahin
Irfan Simsek
Michael Stahl
Tobias Vaegs
Nicolai Viol
Yanto Young

- **Guest Researchers**
  
  Dr. Andrei Gurtov (Helsinki Institute of Information Technology (HIIT))
  M.Sc. Miika Komu (Helsinki Institute of Information Technology (HIIT))
  Dr. Robin Sommer (Lawrence Berkeley National Laboratory & International Computer Science Institute, Berkeley)
  Dr. Christian Kreibich (International Computer Science Institute, Berkeley)

- **Visiting Undergraduate Students (via DAAD RISE)**
  
  Kate Harrison (Oregon State University)
  Matthew Tichenor (Auburn University, Alabama)
Overview

The vision of our research is the development of Flexible, Scalable & Resilient Communication Systems and the required Models, Methods and Tools to design, analyze, realize, and evaluate these systems.

The scope of considered systems spans from complex and massively distributed Peer-to-Peer-systems, via traditional Internet-based communication systems to highly mobile, ubiquitous devices, embedded systems and highly integrated Microsystems, such as sensor nodes.

With Flexibility, Scalability, Mobility and Resilience as key challenges in mind, we indentify three important research areas and mainly focus on them:

- **Protocol- and Systems-Engineering:**
  - Engineering of Resilient and Flexible Communication Systems
  - Structured Engineering of Protocols and (Embedded) Systems
  - Models, Methods and Tools for Protocol and Systems Development
  - Verification and Validation of Protocols and Communication 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
  - Infrastructure Services in/for Massively Distributed Systems

- **New Network Architectures:**
  - 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

A Flexible and Versatile Software Architecture
For Modular Protocol Development and Cross-Layer Adaptation
Ismet Aktas, Klaus Wehrle

Traditional protocol stacks that usually follow the rules of ISO/OSI divide the network task into layers and allow only the exchange of information between adjacent layers. The commonly used TCP/IP protocol stack is such an example, which follows these rules. So far, TCP/IP works well in wired environments since it was originally designed for such environments. But today’s networks not only consist of wired links but also include mobile and wireless networks where TCP has some weaknesses. In these highly dynamic environments, the resources are limited and vary over time. In addition, higher loss probability is an important issue to handle. One promising way to deal with these shortcomings is the exchange of information across layers, i.e., systematic cross-layer design.

As a result of this observation, the aim of this project is the development of a framework that enables flexible and versatile adaptation of protocols and communication sub-systems to the dynamic requirements and applications that wireless environments demand. Therefore, two major enhancements compared to today’s software architectures are needed. On the first hand, protocols have to be designed and implemented in a modularized way such that modules can be (re-)configured, exchanged, added or removed during runtime. On the other hand, the framework has to enable the coordination and collaboration of these protocol components in order to optimize the protocol stack behaviour as a whole. Accordingly, signalling mechanisms to allow coordination and collaboration between protocol components are needed. Moreover, an important point of interest is the integration of existing protocol implementations into this framework and additionally the guarantee of dynamic extensibility.

TimeTOSSIM: Enabling Time Accurate Simulation of Sensor Network Applications
Muhammad Hamad Alizai, Olaf Landsiedel, Klaus Wehrle
The rising complexity of data processing algorithms in sensor networks combined with their severely limited computing power necessitates a in-depth understanding of their temporal behavior. However, today only cycle accurate emulation and test-beds provide a detailed and accurate insight into the temporal behavior of sensor networks. In this project we extended TOSSIM – a TinyOS based simulator for sensor networks - to introduce fine grained, automated instrumentation of simulation models with cycle counts derived from sensor nodes and application binaries to provide detailed timing information. This approach bridges the gap between scalable but abstracting simulation and cycle accurate emulation for sensor network evaluation.

By mapping device-specific code with simulation models, we derived the time and duration a certain code line takes to get executed on a sensor node. Hence, eliminating the need to use expensive instruction-level emulators with limited speed and restricted scalability. Furthermore, the proposed design is not bound to a specific hardware platform, a major advantage compared to existing emulators. Our evaluation shows that TimeTOSSIM achieves a timing accuracy of 99% compared to emulation while adding only a small overhead. Concluding, it combines essential properties like accuracy, speed and scalability on a single simulation platform.

RatPack: Analysis of Animal Ecological and Social Networks
With Programmable Sensor Nodes
Jó Ágila Bitsch Link, Nicolai Viol, Klaus Wehrle (joint work with Tübingen University)

Natural behavior 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 behavior, the functioning of such behavior in natural environments is still only poorly understood. Efficient means of animal monitoring in the wild as well as tools for modeling complex systems are required for a deeper understanding of phenomena such as spatial cognition, optimal foraging, social behavior 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 underwater 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. Currently, advanced evaluation modules as well as a range of forwarding strategies are developed and evaluated.

**ADAPT: Integration and Adaptation of Legacy Applications, Systems, and Protocols With Mobile Ad-Hoc Networks**

Stefan Götz, Klaus Wehrle

Since September 2007, the German Research Society DFG funds the project "Adapt" at the LuFG Informatik 4. The goal of this research project is to enable the re-use of existing and established Internet applications in mobile ad-hoc networks. Based on a modular protocol framework, it focuses on mechanisms to provide Internet-based applications a runtime environment with Internet-like characteristics. Furthermore, its scope includes the development and demonstration of transparent extension of existing applications, services, and protocols for their specific use in mobile ad-hoc networks.

In such ad-hoc communication scenarios it remains desirable to employ existing applications which users are familiar with, and communication applications in particular. However, mobile ad-hoc networks inherently exhibit specific characteristics which break fundamental assumptions of Internet-based applications. These diverging prerequisites so far hamper or prevent to directly use existing Internet applications in mobile ad-hoc networks and require direct modifications that are time consuming and potentially prohibitively expensive.

Thus, Adapt builds on a protocol framework in which protocols and functional entities operate as uniform, exchangeable software components. However, this flexibility also poses the challenge how to compose individual protocol components into a functionally sound communication sub-system, based on the requirements of the execution environment, the application, and the user. On the one hand, today's approaches such as a classification of protocols into the small number of TCP/IP layers are too rigid and inflexible, on the other hand requiring user interaction for such configuration decisions is not an option. Thus, a main research focus in Adapt lies on the possibilities of extensible semantic descriptions of protocols and runtime parameters. With this approach, the composition of protocol components can be guided by functional and qualitative criteria instead of coarse-grained static classifications.

**PISA: The Peer-to-Peer Wi-Fi Internet Sharing Architecture**

Tobias Heer, Klaus Wehrle
The proliferation of broadband Internet connections has lead to an almost pervasive coverage of densely populated areas with private and commercial wireless access points. These access points can either operate in a coordinated or in an uncoordinated fashion. To leverage this coverage, sharing of access points as Internet uplinks among users has first become popular in communities of individuals and has recently been adopted as a business model by several companies.

However, existing implementations and proposals suffer from the security risks of directly providing Internet access to strangers. Access control at the wireless routers only solves part of the problem because as soon as un-trusted parties (e.g. subcontractors or private persons) operate part of the community network, privacy, confidentiality, and repudiation are hard to provide. Moreover, if the group of mobile users is dynamic (e.g. open access for everyone) legal issues arise for providers of the access points.

We are working on the P2P Wi-Fi Internet Sharing Architecture PISA, which eliminates these risks and drawbacks by introducing secure tunneling, cryptographic identities, and certificates as primary security concepts. PISA will offer nomadic users the same security that they expect from a wired Internet connection at home. Another design goal of PISA is flexibility in regard to user mobility, anonymity, service levels with different performance and availability characteristics, and different revenue models for operators. With this combination of key features, PISA can form an essential basis for secure Wi-Fi access in citywide or global Wi-Fi sharing scenarios.

Extended Communication Primitives for UMIC Applications
Tobias Heer, Klaus Wehrle

Modern networking applications require flexible and sophisticated ways of communication, such as multicast, anycast, service composition, and delegation. As a matter of fact, providing these communication services efficiently surpasses the capabilities of the traditional point-to-point communication paradigm prevalent in today's networks. Especially in networks that exhibit dynamic behavior, e.g. ad-hoc and hybrid wireless mesh networks (WMNs) providing these services is challenging.

Our aim is to provide five basic communication building blocks that allow the composition of many more complex communication services in UMIC. (1) Scalable management of multicast
paths and multicast groups is essential for various group communication and streaming applications, especially in ad-hoc- and mesh-networks. (2) Anycast allows location-based services and the selection of a service according to certain metrics like geographical closeness, delay, or available bandwidth. (3) Service composition allows connecting several different services in order to create a new service. (4) Delegation allows network entities to delegate certain tasks to other devices in the network. Firewalls or digital notary services are examples for such delegatable tasks. Moreover, (5) service discovery is a crucial supplement to these communication primitives. We use an indirection-based communication paradigm as basis for these forms of communication. However, our approach requires a network-wide lookup service as basis for the indirection functionality.

In this project we create a flexible and robust lookup service that is tailored for the challenging conditions in wireless mesh networks. The service is distributed amongst all wireless routers and can operate without centralized components. Therefore, it can be deployed easily without additional server infrastructure. The ultimate goal of this project is to enable new and flexible ways of communication in dynamic wireless scenarios without the performance, deployment, and scalability issues of centralized components.

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<tr>
<th>Accurate and Scalable Network Simulation</th>
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Within the area of network research, simulation is a widely used means for the evaluation of new concepts and approaches. This is due to a number of core properties such as repeatability, controllability and observability, which enable a deep insight into the system under investigation. However, the correctness of the evaluation results heavily depends on the accuracy of the models employed in the simulation. In particular in the increasingly important field of wireless networks, today's network simulators rely on highly abstract models due to performance and modeling reasons.

This project aims at the development of a new network simulation framework which features three core novelties: i) simulation of wireless networks using three novel levels of detail in the physical layer, ii) consideration of communication-related hardware effects such as energy- and time-consumption of the simulated system and iii) accelerating the execution speed of detailed wireless network simulation by parallelization of processing tasks.

By enhancing classic network simulation with detailed physical layer and hardware models, the scope of network simulation is significantly broadened. Based on the new framework, communication systems can be evaluated as a whole, hence allowing deeper and more detailed insights.
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 extensible communication systems and paradigms, as
from home appliances to airplanes all of them have a number of processors and commonly
network interfaces.

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 these 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 large set of heterogeneous systems ranging from tiny sensor nodes
with low-power radio communications to high performance cluster computers with
communication bandwidth in the order of several GBit/s. This heterogeneity requires
implementation, evaluation and maintenance for each platform, resulting in implementation
overhead, increases the risk of security leaks and interoperability problems. 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
(re)configure communication protocols to meet changing application and user needs at
development and run-time. Furthermore, we develop a platform independent abstraction
layer, allowing building blocks to be used in various operating systems and network
simulators.

Wireless medical sensor networks enable ubiquitous health monitoring of patients during their
everyday life. Security is a key requirement to guarantee safety and privacy of users.
However, the resource-constrained nature of the sensor nodes and the operational
requirements of MSNs hinder the use of traditional security solutions.
We focused our attention on polynomial-based alpha-secure systems as our preferred solution for key agreement in MSNs. We carried out simulations to validate the advantages of distributed alpha-secure-based key agreement approaches regarding delay or packet losses in large medical sensor networks. A multidimensional alpha-secure key establishment scheme was developed exploiting deployment- or feature-based distribution of keying material to enhance system security. Further research into key establishment includes the assessment of the resource requirements depending on the finite field size and the definition of segment diversification techniques to increase network resiliency.

Additionally, we introduced lightweight digital certificates allowing us to cryptographically link information to keying material. This approach offers a lightweight signature and verification algorithm making possible new security functionalities such as distributed access control without requiring expensive public-key cryptography or access to a central online trust center. The performance and security of the proposed system was extensively analyzed describing optimal configuration parameters.

Current work concentrates on the management of the patient area network security domains regarding their security architecture as well as access control methods, handshakes and policies based on alpha-secure technology.

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 retrieval, the very nature of hash tables allows only exact matches, e.g. a file is stored under HASH(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.
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 the P2P network.

Modern communication protocols are complex and difficult to implement correctly. In addition to their informal and ambiguous specifications the nature of protocol software (concurrent execution, node and network failures) leads to subtle errors, whose detection is an arduous and costly task. Especially in mission-critical deployment areas, e.g. wireless sensor networks, the need of protocol correctness drew recently many developers’ attention. Hence, it is essential to utilize effective software analysis methods throughout the protocol development cycle to ensure its reliability, security and performance.

The goal of this project is to develop practical methods and tools for automatically verifying protocol stack’s correctness requirements. In first step we checked the dependencies between interconnected protocol modules within a particular stack composition using static code analysis. As communication protocols are highly data flow oriented, the correct exception handling at full coverage is a challenging task. Hence, in second step we employed symbolic software execution techniques to explore possible memory flaws for any possible network input. Finally, new techniques for distributed protocol debugging should be devised to enable extensive protocol behavior testing.
Enhancing the Quality of VoIP with Cross-Layer-Iterated Soft Information
Florian Schmidt, Klaus Wehrle

Voice over IP (VoIP) has in recent years become a main contender for audio-visual communications, and its widespread use is anticipated to supplant a sizable amount of classical telecommunication via phone lines. Of special importance is the use in wireless devices, and how to improve the quality of communication, from a user point of view in respect to voice quality as well as from a provider point of view in respect to efficient communication.

In current systems for wireless IP transmission of audio-visual signal, residual bit errors on a wireless link are detected by CRC on the physical layer and erroneous packets are discarded. While packet headers of the used protocols (IP, UDP, RTP) generally have to be error-free, it is possible to make use of data with bit errors, especially in combination with reliability information from the channel decoder, i.e. probabilities of every bit to be correct. Being able to use partly corrupted data is a vital point in enhancing the quality of VoIP communication, especially over wireless links, where bit errors are much more common.

This project will expand on earlier proposals of cross-layer communication, i.e. exchange of information between protocol layers to facilitate more efficient cooperation between different parts of the network stack. The goal is to design a system that manages cross-layer information on a per-connection basis; previous approaches have only discussed global information. To reach this goal, a framework has to be created that allows for efficient yet flexible exchange of information between network stack layers, to maintain its extensibility, but at the same time make it usable on handheld devices, without noticeably impairing the performance. In a second step, this framework will then be used to create and integrate network protocol extensions that allow for soft-state information, such as link quality on the PHY layer, to be exchanged and used to establish more efficient voice communication.

Synchronized Network Emulation
Elias Weingärtner, Klaus Wehrle

The goal of the Synchronized Network Emulation project depicted in the figure below is the creation of a new performance evaluation methodology in the field of distributed systems and computer networks, building on top of the paradigm of network emulation. This concept relies on the integration of real-world prototypes, which are typically constituted by a software program, and a simulation that models the context of the prototype.
But why combine network simulations with software prototypes? Network simulations allow one to conduct experiments in a simulated network in a flexible way. Simulation parameters can be easily changed, and a global picture of the entire network is steadily available. However, while network simulations mostly abstract from the detailed system behavior, such observations are possible with a real prototype in place. Here, it is possible to study performance metrics, such as memory and energy consumption as well as timing needs. Bringing both together combines the advantages of both approaches.

Our work on Synchronized Network Emulation finally enables the utilization of arbitrarily complex network simulations. Simulations of complex ad-hoc networks, for example in the context of UMIC, require the simulation of networks with thousands of nodes and very complex simulation models. Hence, the simulation may execute slower than a potential software prototype does, and a synchronization component is required to drive the set-up properly through the time of the virtual experiment. So far, we have build a fully functional implementation of this so-called synchronized network emulation methodology, which relies on the popular OMNeT++ network simulator, a synchronization component and a virtualization platform for the software prototypes. The virtualization is required for synchronization purposes. This work has been published at ACM HotMetrics 2008, a workshop focusing on "hot" topics in the ACM SIGMETRICS community. Additionally, the topic has been awarded the "Best Student Thesis Panelist" award during the main SIGMETRICS conference.
Other Activities

P2P ‘08
From the 8th to the 11th of September 2008, the Distributed System Group, headed by Prof. Dr. Klaus Wehrle, hosted the major P2P’08 conference. P2P’08 is the eighth conference in a series of annual conferences concerned with overlay network technologies and massively distributed systems and applications. The conference raised a large interest in the research community, with over 150 attendees from all over the world. 161 papers were submitted to the conference, from which less than 20% were selected for the conference program. The high number of submissions and the selectivity proves the importance and the reputation of the conference series.

Following its name, the main focus of the conference is peer-to-peer (P2P) systems. P2P systems benefit from and share the resources owned by systems that are distributed around the Internet. Examples of such technologies include peer-to-peer applications and grids, and in general, any large-scale distributed system characterized by decentralization and sharing of resources. Recently, interesting applications of P2P technology have begun to emerge, together with new platforms for application development. The conference program involved papers that reflected such experiences with practical applications in this field and explored new application areas. Furthermore, many key issues, like scalability, robustness, and security were addressed in the presented publications.

Fachgespraech "Wireless sensor networks" of the GI / ITG-section on "Communication and Distributed Systems"

Wireless Sensor Networks (WSN) is a promising technology to monitor and influence events in the real world. Autonomous sensor nodes adopt these parameters of the environment through sensors and react by activating actuators. Many such autonomous, resource constrained nodes cooperate by means of wireless communication. The properties of these nodes and networks present a multitude of new research challenges.
“Fachgespräch” is a workshop that aims to invite scientists from the field of sensor networks for an informal exchange of ideas and to establish cooperation in this multidisciplinary research field. The Distributed Systems Group arranged this workshop at RWTH Aachen University on 16-17 July 2007. A total of 29 paper submissions were accepted for talks and poster presentations. This workshop covers WSN research issues ranging from hardware and operating systems, communications, data and signal processing, programming paradigms, system architectures, and applications and integration of sensor networks in existing systems.

**Childrens’ University “How does the Internet work?”**

Since 2007, the RWTH Aachen University has taken part in the “Kinderuniversität” (children’s university) program. This program aims at opening the university to children of ages 8 and up, by presenting scientific topics in a way to raise their interest in the world of science. This way of opening the universities, their staff and society to the outside world has recently been met with much acclaim.

In September 2007, Prof. Klaus Wehrle of the Distributed Systems Group held his lecture on “How the Internet works” as opener for the childrens’ university winter semester 2007/2008. About 900 young students attended the lecture and learned about the versatility of the Internet, and why it is possible to use it for many different application scenarios, about data encoding, and about sending and receiving data, as well as answering the lecture’s main question: In theory during the lecture, and afterwards in practice by means of a game, the children learned how data is encapsulated in packets and routed through the Internet by means of DNS, IP addresses and routing tables.

**GI-Dagstuhl-Seminar: Modeling Techniques for Computer Network Simulations**

In cooperation with Prof. Mesut Günes of Freie Universität Berlin and Prof. James Gross of RWTH Aachen University, the Distributed Systems Group has hosted a GI seminar on "Modeling Techniques for Computer Network Simulations" at Schloss Dagstuhl. In the course of the seminar, more than 30 researchers from 10 German universities presented and discussed different approaches to network simulation design. Core aspects of the discussion focused on how to increase the credibility of network simulation results and how to establish best-practices among researchers.

The goal of the seminar is to compile the outcome of the discussions as well as the individual expertise of the participants into a book that is to be published at Springer in early 2009. Eventually, the book should act as a guide to network simulation for advanced students and PhD candidates who start to design and conduct own network simulations.
At its core, the book covers modeling aspects of the entire network stack, beginning at the physical layer, over the network and transport layer, up to P2P protocols and applications. Additionally, architectural facets of network simulation frameworks such as the integration of real-world software, parallelization or simulation of hardware effects are considered.

**Miscellaneous**

Klaus Wehrle is a member of the steering board of “GI-Beirat der Informatikprofessoren (GIBU)”, and the steering committee of the GI/ITG board on “Kommunikation und Verteilte Systeme (KuVS)”. He also is an active reviewer for several journals, publishers, and boards. In 2007/2008, he also served as a member of the program committees of the following conferences and workshops:

- PC Member of ACM SIGCOMM 2008
- PC Member of IEEE GLOBECOM 2008
- PC Member of Intern. Workshop on Mobility in the Evolving Internet Architecture 2008 (MobiArch’08)
- PC Member of 15th International Conference on Telecommunications (ICT’08)
- PC Member of European conference on Wireless Sensor Networks (EWSN 2008)
- PC Member of MobileP2P’08
- PC Member of OMNeT++ Workshop 2008
- PC Member of IEEE GLOBECOM 2007
- PC Member of ACM SIGCOMM 2007
- PC Member of ITU Conference on Next Generation Networks 2007
- PC Member of 6th International Workshop on Peer-to-Peer Systems (IPTPS’07)
- PC Member of Seventh IEEE International Conference on Peer-to-Peer Computing (P2P 2007)
- PC Member of 5th International Workshop on Databases, Information Systems and Peer-to-Peer Computing (DBISP2P)
- PC Member of 4th European conference on Wireless Sensor Networks (EWSN 2007)
- PC Member of IEEE Local Computer Networks 2007 (LCN 2007)
- PC Member of IEEE MobileP2P’07
- PC Member of KiVS 2007 (Kommunikation in Verteilten Systemen)
- General Chair of "Eighth IEEE International Conference on Peer-to-Peer Computing (P2P’08)”, Aachen/Germany, September 2008
- Travel-Grant Co-Chair ACM SIGCOMM 2008, Seattle, USA, August 2008
- Travel-Grant Co-Chair ACM SIGCOMM 2007, Kyoto, Japan, August 2007
- Program Co-Chair of "Seventh IEEE International Conference on Peer-to-Peer Computing (P2P 2007)”, Galway/Ireland, September 2007

In December 2007, Dr. Andrei Gurtov and Dr. Dimitry Korzun from the Helsinki Institute on Information Technology (HIIT) and from Helsinki Technical University visited our group for some weeks.

In November and December 2007, Dr. Robin Sommer and Dr. Christian Kreibich from the International Computer Science Institute (ICSI) visited our group on invitation by UMIC and held a lecture on the topic of Intrusion Detection.

Together with Informatik 4, our group organized the first KuVS symposium for PhD students in Bonn, from May 31st to June 1st 2007. Its goals were not only to learn, present and discuss important skills that help PhD students to master their thesis, but also foster the communication between the participants, during the symposion and afterwards by giving the opportunity to create and maintain contact with other PhD students, as well as professors.
Prof. Wehrle was awarded “Nachwuchswissenschaftler des Jahres 2007” (Junior researcher of the year 2007) by DIE ZEIT and Deutscher Hochschulverband. The committee explained their choice by his important work in the field of Internet protocols and standardization, his engagement of supporting junior researchers, as well as his commitment to raising younger people’s interest in science and especially computer science.

Prof. Wehrle was selected as associate member of the foundation "Neue Verantwortung". The foundation serves as a highly interdisciplinary think tank of selected young potentials from academia, economics, politics, art and sports, with the ambition to develop new ideas and pragmatic solutions for the upcoming challenges of today’s society. To this end, the foundation brings together leading researchers and professionals, that contribute, based on the work on interdisciplinary projects, to the public discourse concerning the future of Germany.
Talks and Publications

Talks

Klaus Wehrle, Towards a (Practical) Convergence of Multiple Network Architectures, Telekom Laboratories, TU Berlin, April 2007

Klaus Wehrle, Massively Distributed Systems Research: Challenges and Solutions, Philips Lab Aachen, May 2007

Elias Weingärtner: Hybrid Sensor-Vehicular Networks in the context of next-generation networking, Joint EuroFGI and ITG Workshop on Visions of Future Generation Networks (EuroView2007), Würzburg, Germany, July 2007


Klaus Wehrle, Wie funktioniert das Internet?, Lecture on occasion of RWTH Aachen Children’s University, September 2007

Klaus Wehrle, Mobiles und adaptives Internet – Chancen, Probleme und neue Ansätze, Kompetenzzentz IT/Informatik Aachen REGINA, Aachen, September 2007

Klaus Wehrle, Cross-Layer Coordination for highly mobile devices, UMIC Day 2007, RWTH Aachen, October 2007


Klaus Wehrle, Peer-to-Peer-based Information Management in Massively Distributed Systems, Sino-German Center for Research Promotion, Beijing, November 2007

Klaus Wehrle, Hot Topics in Distributed Systems and Mobile Internet Research, Ericsson Research Lab Aachen, November 2007


Klaus Wehrle, Attraktivität Deutschlands für rückkehrwillige deutsche Wissenschaftler Workshop Perspektiven und Chancen für Nachwuchswissenschaftler, Bonn University, June 2008


Alexander Becher: Towards Short-Term Wireless Link Quality Estimation, 5th IEEE Workshop on Embedded Networked Sensors (IEEE HotEmNets 2008), Charlottesville, USA, June 2008
Klaus Wehrle, Mobile Internet – Mobile and Distributed Internet Access with PISA, Invited Talk, Google Engineering Lab, München, August 2008

Klaus Wehrle, Mobile ACcess – Mobile and Distributed Internet Access with PISA, UMIC Day 2008, RWTH Aachen University, October 2008

Klaus Wehrle, Mobile and Distributed Internet Access with PISA, Informatik Kolloquium, TU Braunschweig, October 2008

Publications


Elias Weingärtner, Frank Kargl: Hybrid Sensor-Vehicular Networks in the context of next-generation networking, Joint EuroFGI and ITG Workshop on Visions of Future Generation Networks (EuroView2007), Würzburg, Germany, July 2007


Ralf Steinmetz, Nicolas Liebau, Klaus Wehrle: Peer-to-Peer-Systems (Editorial), it - Information Technology, 49 (2007) no. 5, pp. 269-271

Olaf Landsiedel, Tobias Heer, Klaus Wehrle: MHT: A Mobility-Aware Distributed Hash Table, it - Information Technology, 49 (2007) no. 5, pp. 298-303


Elias Weingärtner: Synchronized Network Emulation, ACM SIGMETRICS 2008 Student Thesis Panel (awarded with ACM SIGMETRICS Best Student Panelist Award), Annapolis, USA, June 2008


Tobias Heer, Stefan Götz, Elias Weingärtner, Klaus Wehrle: *Secure Wi-Fi Sharing at Global Scales*, In Proceedings of 15th International Conference on Telecommunications, St. Petersburg, Russian Federation, June 2008


Simon Rieche, Klaus Wehrle, Marc Fouquet, Heiko Niedermayer, Timo Teifel, Georg Carle: *Clustering Players for Load Balancing in Virtual Worlds*, Accepted for publication in the International Journal of Advanced Media and Communication (IJAMC) 2008

**Conference Proceedings**


**Contribution to Internet Standardization**


Samu Varjonen, Tobias Heer: *HIP Certificates*, draft-varjonen-hip-cert-00, Internet Draft, HIP Working Group, IETF, February 2008


Staff

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

• Secretary:

  Gabriele Hoeppermanns
  
  Tel: (0241) 80-21501, Fax: (0241) 80-22321
  E-mail: sekris@dbis.rwth-aachen.de
  WWW: http://dbis.rwth-aachen.de

• Researchers:

  Sebastian Brandt
  Yiwei Cao
  Mohamed Amine Chatti
  Sandra Geisler (since 02.06.2008)
  Anna Glukhova (since 15.10.2007)
  David Kensche
  Dr. Ralf Klamma
  Xiang Li (since 01.05.2007)
  Dr. Erika Linz (until 30.09.2007)
  Dominik Lübbers (until 31.08.2008)
  Michalis Miatidis (until 30.04.2007)
  Zinayida Petrushyna (since 03.03.2008)
  Dr. Christoph Quix
  Marcus Raddatz (until 31.03.08)
  Khaled Rashed (since 01.10.2007)
• Researchers continued:
  
  Dr. Marc Spaniol (until 29.02.2008)
  Dr. Satish Srirama
  Elisabeth Birk (since 01.04.2008)

• Visiting Lecturers:
  
  Dr. Andreas Becks, Fraunhofer FIT
  Dr. Wolfgang Broll, Fraunhofer FIT
  Stefan Hirschmeier, Fraunhofer FIT
  Jessica Huster, Fraunhofer FIT
  Dominik Schmitz, Fraunhofer FIT
  Dr. Christian Seeling, Fraunhofer FIT

• Technical Staff:
  
  Tatiana Liberzon
  Reinhard Linde
  Eric Heder (until 29.08.2008)
  Daniel Plötzer (since 03.09.2007)

• Student Researchers:
  
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; in fall of 2007, Prof. Jarke was also appointed Deputy Chairman of the Fraunhofer ICT group with 16 institutes and over 2000 researchers. 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 March 2008, a new B-IT Research School for doctoral training has been approved by the NRW state government which will start its operations in the fall of 2008 under the coordination of Prof. Jarke and Prof. Cremers (Bonn).

The years 2007-2008 were a very active period for the Information Systems group. In terms of new projects, the main emphasis was on getting our projects in the new Excellence Cluster in Ultra-Highspeed Mobile Information and Communication Systems (UMIC) started and to coordinate its research area “Mobile Web Services and Applications”. Prof. Jarke also served on the steering committee of the successful university-wide Future Concept proposal “RWTH 2020: Meeting Global Challenges” and is presently responsible for its subarea “International Recruiting”. In addition, the DFG approved a research project group on context-adaptive interaction (CONTICI) we are conducting jointly with groups from the universities of Siegen, Duisburg-Essen, and Hagen. In the summer of 2008, we were also successful in the application for a new large-scale Integrated Project in the field of technology-enhanced learning (ROLE) which will start in early 2009 as a follow-up to the European Network of Excellence PROLEARN. The BMBF-funded project MERKOFER in which some results of our former SFB 476 (IMPROVE) have been further developed for practice innovation, was successfully completed in 2007.

In teaching, a major challenge was the switch from the traditional German diploma system to the new Bachelor program which, among others, more than doubled the number of students taking our Introduction to Databases class to about 300. International teaching cooperations such as the EU-funded European Master of Informatics (EuMI) scholarship program, the Cairo University eLearning Center (CUELC) project, and especially the start of a new, RWTH-supported German University of Technology (GUtech) in Oman – supported by Prof. Jarke as temporary Inaugural Dean of the Applied Information Technology curriculum – were also major fields of activity.
Informatik 5 was also very active in **conference organization**. Together with the Informatik 9 group of Prof. Seidl, we organized the 12th GI Conference on Business, Technology, and the Web (BTW 2007) in Aachen in March 2007 which was attended by almost 300 participants. In addition, R. Klamma served as Program Co-Chair of the First European Conference on Technology-Enhanced Learning held in Iraklion, Greece, in September 2007 with over 200 participants. Together with other members of Informatik 5 and externals, he also chaired several PROLEARN-related workshops, summer schools, and doctoral consortia. Y. Cao and M. Spaniol co-organized workshops of standardization committee meetings in the field of Data Management and Exchange (DIN NI-32) and Multimedia Metadata (MPEG-7/21).

The group of **people** at Informatik 5 has developed an unusual diversity, with research assistants from eight different countries, not counting numerous further countries among our student assistants. In the reporting period, four doctoral theses were completed in 2007 (Christian Seeling, Marc Spaniol, Carla Valle, and Andreas Zimmermann), another four until September 2008 (Emmanuel Nayo, Gertraud Peinel, Martin Sedlmayr, Satish Srirama). In addition, over 30 diploma and master theses were completed under supervision of professors from Informatik 5. In December 2007, Prof. Jarke completed an eight-year term as Board Member of the Gesellschaft for Informatik (GI) e.V., the last four years as President. In this role, he also participated in the BMBF working group of the IT Summits conducted by Chancellor Angela Merkel in 2006 and 2007, following the Informatics Year 2006.
UMIC: Ultra High-Speed Mobile Information and Communication


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 participate 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 to support the demanding applications of the next-decade mobile Internet.

Based 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 Applications and Services” which is coordinated by Prof. Jarke. This research area focuses on mobile multimedia processing and environmental information processing. The concepts of UMIC were successfully presented at the CeBIT 2007.

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.

In 2007, the Virtual Campfire scenario has been further developed as mobile social software to bridge media and communities across 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 and prototypes were successfully demonstrated on a number of international conferences and workshops, as well as other events such as UMIC Day 2007, RWTH Transparent. We also maintain the Bamiyan Community (http://www.bamiyan-development.org) that brings together international researchers, governmental and administrative officers for the conservation work in Bamiyan, Afghanistan.
Mobile Web Service Provisioning
Intelligent phones as web service providers 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, quality of service issues like security and scalability, application and usability analysis strategies for mobile web service providers were published. Currently the project is being funded by Ultra High-Speed Mobile Information and Communication (UMIC).

Mobile and Wearable P2P Information Management in Health Net Applications
Informatik 5 cooperates with the institute for textile technology (ITA), the Philips Chair for Medical Information Technology (MEDIT), and Informatik 9 (Data Management and Exploration, T. Seidl). 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.

As a first result, the groups have created a prototype for a shirt which includes an ECG sensor and acclerometer. The sensor information is processed by a device which sends the data to a mobile client (e.g. a PDA or a mobile phone). The client may forward the patient’s data to a server where health experts can analyse the data in detail. To avoid sending of a huge amount of data, the data is pre-classified on the mobile client according to normal and emergency situations. In normal situations, only a highly aggregated summary of the data will be sent; if an emergency situation is suspected, detailed information will be sent to the server.
The device level scheme for mobile and wearable P2P information management within the UMIC project

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.

**Metadata and Cooperative Knowledge Management**

*M. Jarke, C. Quix, S. Geisler, D. Kensche, X. Li, M. Jeusfeld (Uni Tilburg, NL), R. Linde, S. Chaiyakul, C. Schwering, T. Siegbert, 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. Version 7.1 of the system was released in May 2008. In this version new functional and arithmetic expressions have been added, the use of the underlying Telos language has been made easier, the support for meta-level formulas has been improved, and a number of bugs have been corrected.

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. Based on the generic role-based meta model *GeRoMe*, the group developed the generic model management *GeRoMeSuite* which includes support for model management operations such as schema matching, composition of mappings, schema integration, and model transformation. A first prototype of the tool has been shown at the 33rd International Conference on Very Large Data Bases (VLDB) in Vienna.
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. These community information systems are designed and applied meeting communities’ real needs. With the emerging Web 2.0 paradigm, the connection between user communities and information systems is even tight. A new DFG cluster project Context Adaptive Interaction in Cooperative Knowledge Processes (CONTICI) was started in October.

Several international cooperation activities are carried out. Cooperation with Prof. Nalin Sharda from Victoria University, Melbourne has been further fostered, while he gave lectures and a workshop at his three-month sabbatical stay at Informatik 5 from August to November, 2007. Experiences on developing multimedia information systems have been shared with the group of Prof. Baltasar Fernández Manjón at Universidad Complutense, Madrid, Spain. In addition, many academic events took place within our international Multimedia Metadata Community (http://www.multimedia-metadata.info) in 2007. Research results have been collected in the book “Multimedia Semantics – The Role of Metadata” published by Springer.

Metadata are based on international standards in different domains like Audio-visual Media, E-Learning, Cultural Heritage, Music Information Retrieval, and Geographical Information Systems. Central for our approach is the reflective conceptual architecture ATLAS which incorporates a set of (self-)monitoring tools for the community members and the repository/community middleware. Communities can assess their community needs and evolve the community through the development and change of the community information systems. The monitoring tools allow the measurement, analysis and simulation of community aspects with methods from the semantic web, information retrieval & visualization, data/text/media mining, geospatial database querying, social network analysis, transcriptive algorithms etc.

On the database/repository level we use and develop further scalable state-of-art
database technologies for the management of mass data and metadata for community systems. On the middleware level we realize scalable community hosting services like single-login, variable and fine-granular access control, mobility support, multimedia management, multimedia annotation, interoperable search and retrieval, matching, data/text/media mining etc. The following projects have been worked on from 2007 to September 2008:

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

After having organized the successful symposium in 2006 the research in 2007 concentrated on the finalization of our support environment ATLAS for communities of practice in the humanities. M. Spaniol defended successfully his thesis about this topic and several diploma and master projects were conducted. The LAS environment also serves as an application server for the Virtual Campfire demonstration scenario in UMIC. The monitoring environment MediaBase was extended to work with new Social Software media like blogs and wikis. We demonstrated the approach in a colloquium of the SFB and on several international and national conferences. A journal publication was submitted and accepted for publication.

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

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 and user-friendly 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 2007 we developed a prototype that analyzes community-based similarity relationships (like Amazon’s “customers who bought this item also bought this one”) and tries to mimic them on the basis of automatically extracted audio-based features thereby eliminating the well-known new item problem for music items. Furthermore we started a project which investigates the usefulness of expert and customer reviews on music for its application as a similarity source.

**i* Wiki** ([http://istar.rwth-aachen.de](http://istar.rwth-aachen.de))

Since September 2005, Informatik 5 is hosting the i* Wiki, a platform for researchers
CONTICI: Context Adaptive Interaction in Cooperative Knowledge Processes

M. Jarke, R. Klamma, A. Glukhova, A. Goer, G. Hackenberg, C. Hocken, Z. Zhu

CONTICI is a new project funded by the Deutsche Forschungsgemeinschaft (DFG). The aim of this project is research and development of context adaptive systems for non-well structured knowledge processes. Thereby the adaptivity of cooperative systems to dynamic users requirements presents a main scientific question of this research. CONTICI is a cooperation of four German universities and thus is a cluster project. Beside RWTH Aachen University the project partner are Duisburg-Essen University, Siegen University and FernUniversitaet in Hagen.

Traceable Cooperative Requirements Engineering for Communities-of-practice

The research area of our group in scope of this project covers traceable cooperative requirements engineering for communities-of-practice. During the project evolution models of context, process and cooperation models created by the other project partners have to be established. Hereby, a framework for tracing model changes during the project life has to be developed. This step is followed by the design of the methods for qualitative and quantitative analysis of traces, which will allow the extraction of the best practices out of the executed requirement engineering processes. For analysis and navigation purposes the environment for visualization and management of the collected data has to be created. Next, the tracing results should also be applied as learning materials about the system state and its evolution history.

CUELC: EU Tempus Cairo University E-Learning Centre

M. Jarke, R. Klamma, M.A. Chatti, Z. Petrushyna, D. Kensche, C. Bicer, N. Drobek, M. Fayek (Cairo University), K. Maillet (INT Evry)

CUELC aims to bridge the currently existing gap between the advanced, technology enhanced teaching and learning methods in Europe and Egypt. In 2007 students of Cairo University and RWTH Aachen University jointly evaluated learning materials for a data structure and algorithms course in Moodle. The three best performing students from RWTH Aachen University were sent to Cairo University to discuss their E-Learning experiences with their Egyptian fellow students.
Teachers and students from Cairo University came to Aachen to participate in intercultural workshop in August, 2008.

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**PROLEARN: EU Network of Excellence**

M. Jarke, R. Klamma, Y. Cao, M.A. Chatti, M. Spaniol, Z. Petrushyna, M. Bachwerk, M. Frericks, X. Li, A. Martini, M. Moers, N.F. Muhammad, A. Moyano Sánchez, 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.

Dr. Klamma was the program chair of the Second European Conference on Technology Enhanced Learning (EC-TEL 2007), one of the major events. Also the doctoral consortium at EC-TEL 2007 was organized by the chair. Even after the end of the funding period the chair co-organised the PROLEARN summer school in Ohrid, Macedonia, 2008. The summer school brought together PhD students, teachers, and academics for PhD training and network events. Around 50 PhD students have successfully attended the summer school.
ERASMUS MUNDUS European Master in Informatics (EuMI)

M. Jarke, G. Lakemeyer, R. Klamma, J. Enderle (i9), A. Ferrein, P. Selders

In winter term 2004/2005 the first students were enrolled in this pan-European master program 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 program is accompanied by a scholar program 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.

MErKoFer

Identification and Reuse of Experience Knowledge in Rubber Extrusion Processes

M. Jarke, S.C. Brandt, M. Schlüter, M. Raddatz, 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 Gummierwerke 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. As analytical models exist only for small parts of such processes, experience continues to play an important role here.

In the project’s approach, knowledge about the extrusion processes is captured by ontology-based traceability mechanisms for both direct process support of extrusion operators, and for process analysis and improvement based on an integration of data mining techniques. The accumulated knowledge assists in ensuring defined quality standards and in handling production faults efficiently and effectively. The approach was experimentally implemented and evaluated at the industrial partners site. Some generalizable parts of the environment were taken up by aiXtrusion GmbH in their
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. Several workshops on .NET or related technologies such as Microsoft Office Sharepoint Server have been given for customers from industry and academia. Furthermore, .NET technologies have been introduced in lectures such as a lab course on developing web applications with .NET. Other activities include the maintenance of the website with several documents (tutorials, white papers, and case studies) on .NET technologies. The website contains also a glossary for terms and acronyms being frequently used in the context of .NET. In addition, the website offers sample code and sample online applications such as the DBWorld Map, which is an interactive map of events related database research based on the Microsoft Virtual Earth.

In 2007, RWTH Aachen University signed a treaty with the Ministry of Education and some investors from the Sultanate of Oman concerning the founding of a private Technical University GUtech in the capital, Muscat. RWTH Aachen University supports the scientific start-up of the university and will provide continuous quality assurance. In addition to private funds, GUtech is supported by scholarships from the Sultanate and by a quality assurance project from DAAD. GUtech initially offers five study programs one of which is called Applied Information Technology (AIT). We helped GUtech...
design their Bachelor program in AIT, assisted with the accreditation, and organized the recruiting process for the first faculty positions. Prof. Jarke was appointed Inaugural AIT Dean for up to two years until a permanent dean has been hired locally. In mid-2007, the first AIT students entered a Foundation Year. The Bachelor Program itself starts in October 2008. Dominik Lübbers of Informatik 5 will spend the academic year 2008–2009 in Muscat to assist in the set-up phase and take over some of the first-year teaching.

Other Activities

Service

Prof. Jarke’s major administrative and service activities in 2007 included:

- Executive Director, Fraunhofer FIT, Birlinghoven
- Deputy Chairman, Fraunhofer Group Information and Communication Technology
- Founding Director, Bonn-Aachen International Center for Information Technology (B-IT)
- Inaugural Dean, Applied Information Technology, German University of Technology in Oman (GUtech)
- Coordinator, B-IT Research School Proposal
- President, GI German Informatics Society (2004–2007)
- Member, BMBF Working Group of IT Summit 2007, Potsdam
- DFG elected reviewer for practical computer science (2000–2007)
- Member, Working Group “Hightech Strategy for the Information Society”, First Nationale IT Summit of Chancellor Merkel, Potsdam
- Scientific advisory board, Faculty of Informatics, University of Vienna, Austria
- Scientific advisory board, Learning Lab Lower Saxony (L3S), Hannover
- Scientific advisory board (Chair), OFFIS, Oldenburg
- Scientific advisory board, Beta Research School, Eindhoven/Twente, the Netherlands
- Scientific comission, Free University of Bozen, Italy
- Reviewer, Enterprise Software Initiative Baden-Württemberg and LOEWE Excellence Initiative, Hessia
- Supervisory, curatory and scientific advisory board, IBFI, Schloss Dagstuhl
- Jury member, Wissenschaftspreis Stifterverband der Deutschen Wirtschaft
- Jury member, Campus Online competition, Stifterverband der Deutschen Wirtschaft
- Chairman, GI Fellow selection commission
- Jury chair, GI-Innovationspreis
- Second reviewer, doctoral theses in mechanical engineering (Tobias Valtinat) and electrical engineering (Guido Gehlen)
Dr. R. Klamma is a substitute member of the PROLEARN executive board. Dr. Klamma served as advisor of the ERASMUS Mundus master program 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
- Information and Management
- Journal of Universal Computer Science
- Requirements Engineering Journal
- Wirtschaftsinformatik
- Journal of Intelligent Information Systems
- International Journal of Cooperative Information Systems
- Organizational Computing and Electronic Commerce Intelligent Information Systems
- Group Decision and Negotiation
- International Journal of IT Standards and Standardization Research

R. Klamma serves as associate editor on IJASS, IJTEL, and IJHSC. He is editing a special issue for IEEE Transactions on Learning Technologies.

M. Spaniol serves as an associate editor of the Journal of Distance Education Technologies (JDET).

W. Prinz served on editorial boards:
- Computer Supported Cooperative Work: The Journal of Collaborative Computing
- i-com Zeitschrift für Interaktive Medien und kooperative Medien

**Conference Organization**

Y. Cao co-organized the DIN NI-32 “Data management and data exchange” meeting on April 24, 2008 at Informatik 5 and the 1st Intl. Workshop on Story-telling and Educational Gaming (STEG’08) on September 16, 2008, Maastricht, the Netherlands. She was member of the program committee of the I-Know’07 special track KVD’07, M3A Workshop at I-Media’07, MONET’07, and MapISNet’07, ACM/IEEE CSTST’08, M3R’08, Monet’08, I-Media’08 special track CPASW’08, I-Semantics’08 special track OLM, SIRTEL’08 at EC-TEL, STEG’08 at EC-TEL, and MIMIC’08.

A. Glukhova co-organized the 1st Intl. Workshop on Story-telling and Educational Gaming (STEG’08) on September 16, 2008, Maastricht, the Netherlands, and the workshop on “Mobile and Contextualized Learning”, Prolearn Summer School, Ohrid, Macedonia, June 18, 2008.


E. Linz was a member of the program committee of the conference “Medienbewegungen. Praktiken der Bezugnahme”, SFB/FK 427, Aachen, April 25-27, 2007.

Z. Petrushyna was an co-organizer of the intercultural workshop “Challenges for Intercultural Virtual Campus Systems”, Evry, France and Aachen, Germany, August 27 – August 30, 2008, and of the workshop on “Mobile and Contextualized Learning”, Prolearn Summer School, Ohrid, Macedonia, June 18, 2008.

C. Quix served as a member of the program committee of the International Workshop on Semantic Web Architectures For Enterprises (SWAE), Regensburg, Germany, Sep-
tember 2007. He was chair of the organizing committee of the “12. GI-Fachtagung für Datenbanksysteme in Business, Technologie und Web (BTW)”, Aachen, Germany, March 2007.

T. Rose is chairman of demonstration program at BTW 2007, Aachen.

M. Spaniol is a steering committee member of the MPEG-7/21 Community Conference/Workshop Series and is Publicity Co-Chair of the International Conference on Web-based Learning (ICWL) event series. He was member of the program committee of the IADIS Intl. Conf. on Web Based Communities 2007, the 6th MPEG-7/21 Community Workshop, ICWL’07, I-Know’07 special track KOST’06, M3A at I-Media’07, EC-TEL’07, SIRTEL 2007 at EC-TEL’07, and the Workshop „What is missing in Social Software? Current collaborative practices in social software“ at ECSCW’07, i-TCE’08, M3R’08, IDET’08, and ICWL’08.

Software Demonstrations

- Virtual Campfire, the 9th Learning Management Congress, Berlin, Germany, June 20, 2008.
- Virtual Campfire, UMIC area B meeting, Aachen, Germany, June 17, 2008.
- Virtual Campfire, RWTH Transparent, Aachen, Germany, January 25, 2008.
- Virtual Campfire – A Mobile Social Software for Cross Media Communities, Workshop on Multimedia Metadata Applications (M3A) at Conference I-Media’07, Graz, Austria, September 5, 2007.
- Mobile Mining and Information Management in HealthNet Scenarios, the 9th International Conference on Mobile Data Management (MDM 2008), Beijing, China, April 29, 2008.
- GeRoMeSuite, 33rd International Conference on Very Large Data Bases (VLDB’07), Vienna, 2007.
- Mobile Mining and Information Management in HealthNet Scenario, Forum Gesundheitswirtschaft Region Aachen, AGIT Aachen, May 2008. · MobSOS and Mobile NMV of Virtual Campfire, the workshop on ”Mobile and Contextualized Learning”, Prolearn summer school, Ohrid, Macedonia, June 18, 2008.
Talks and Publications

Talks

T. Berlage: *Challenges and new solutions for data and image analysis*, The Application of Molecular and Cellular Imaging in Drug Discovery, Zurich, Switzerland, Oct. 18, 2007


Y. Cao: *Collaborative Storytelling in the Web 2.0*, the First International Workshop on Story-Telling and Educational Games (STEG’08) at EC-TEL 08, Maastricht, the Netherlands, September 16, 2008

Y. Cao: *Virtual Campfire*, The 9th Learning Management Congress, June 19-20, 2008, Berlin, Germany


Y. Cao: *Multimedia Community Information Systems Reload on Web 2.0*, Seminar talk at School of Computer Science and Mathematics, Victoria University, Melbourne, Australia, January 9, 2008

Y. Cao: *Media and Communities: Concepts and Systems*, Invited colloquium talk at Department of Computer Science, Hong Kong Baptist University, Hong Kong, China, December 18, 2007

Y. Cao: *Media Shape/Change Community!*, 16th CIDOC CRM SIG Meeting, Nuremberg, Germany, December 5, 2007


Y. Cao and Z. Petrushyna: *Getting to “Know” People on the Web 2.0*, International Conference on New Media Technology, Special Track on Cross-Platform Aspects of the Social Web (CPASW ’08), Graz, Austria, September 3, 2008


Y. Cao: *Spatiotemporal Knowledge Visualization and Discovery in Dynamic Social Networks*, 7th International Conference on Knowledge Management, Graz, Austria, Sept. 5-7, 2007


A. Glukhova and A. Hahne: *Non-linear Story-telling in a Mobile World*, International Conference on Knowledge Management and New Media Technology, Graz, Austria, September 4, 2008


S. Hackenbracht: *Online Gaming as Tool for Career Development*, First International Workshop on Story-Telling and Educational Games (STEG’08) at EC-TEL 08, Maastricht, the Netherlands, September 16, 2008


M. Jarke: *Agent modeling and community information systems*, Keynote Talk, CAiSE Workshop on Agent-Oriented Information Systems (AOIS 07), Trondheim, Norway, June 11, 2007

M. Jarke: *Fraunhofer-Institut für Angewandte Informatik FIT*, Presentation on the Occasion of the visit of Minister Pinkwart to Fraunhofer Institute Center Birlinghoven Castle, June 28, 2007


M. Jarke: *IKT Management*, Modul im Executive MBA Technology Management, Aachen International Academy, October 1-5, 2007

M. Jarke: *Informatics and Innovation – The Fraunhofer ICT Group at the Junction Between Research and Innovation*, Invited Talk, European Computer Science Faculties Symposium (ECSS 07), Berlin, October 8, 2007


R. Klamma: *Virtual Intercultural Campus: CUELC after 1 year + ?*, Joint Workshop FK 427/CUELC Aachen, August 27, 2008

R. Klamma: *Dynamic Network Analysis of Wikis*, I-Know’08 and I-Media’08, International Conferences on Knowledge Management and New Media Technology, Graz, Austria, September 3, 2008


R. Klamma: *Social Software und Community Informationssysteme*, Invited Talk, Institute of Psychology, University of Graz, Austria, December 6, 2008


R. Klamma: *Social Software and Community Information Systems*, Invited Talk at SCOOP Workshop, Jacobs University, Bremen, August 30, 2007


W. Prinz: *Keynote: Do we need CSCW 2.0 to overcome our current communication problems?*, Pragmatic Web Conference 2008, Tilburg, NL, October 22-23, 2007


W. Prinz: *Keynote: E-Collaboration – die neue Welt interner und externer Zusammenarbeit im Unternehmen*, COMPUTERWOCHE Executive Program Collaboration, October 9, 2007


C. Quix: *Generic Schema Merging*, 19th International Conference on Advanced Information Systems Engineering (CAiSE), Trondheim, Norway, June 2007


D. Renzel and M. Spaniol: *MobSOS – A Testbed for Mobile Multimedia Community Services*, 9th International Workshop on Image Analysis for Multimedia Interactive Services (WIAMIS ’08), Klagenfurt, Austria, May 7-9, 2008

D. Renzel and M. Spaniol: *Community-Aware Semantic Multimedia Tagging - From Folksonomies to Commsonomies*, Workshop on Multimedia Metadata Applications (M3A) at Conference I-Media’07, Graz, Austria, September 5, 2007

D. Schmitz: *Requirements Engineering for Control Systems Development in Small and Medium-Sized Enterprises*, 16th IEEE Requirements Engineering Conference (RE08), Barcelona, Spain, September 10, 2008

D. Schmitz: *Telos: Representing Knowledge about Control Systems?*, 1st Int. Workshop on Managing Requirements Knowledge (MaRK), RE08 workshop, Barcelona, Spain, September 8, 2008


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M. Spaniol: *Watching the Blogosphere: Knowledge Sharing in the Web 2.0*, Conference Weblogs and Social Media, Boulder, Colorado, USA, March 27, 2007

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M. Spaniol: *Web-Based Learning in Cultural Science Communities: Information System Support for Transcription, Localization and Addressing*, Invited Talk at Special ICWL Workshop 2007, Jinhua, China, August 28, 2007


**Publications**

**Books and Edited Volumes**


M. Jarke, K. Neunast (eds.): *Informatiktag 2007 – Fachwissenschaftlicher Informatik-Kongress, 30.-31.3.2007, B-IT Bonn. GI Lecture Notes in Informatics, 2007*


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A. Aleksandrowicz, D. Kensche, S. Kim, P. Kranen, E. Müller, C. Quix: Mobile and Wearable P2P Information Management in HealthNet Applications, Annual Symposium of the IEEE/EMBS Benelux Chapter 2007, Heeze, the Netherlands


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J. Huster, C. Hesselmann, A. Becks: *A Guideline for Modelling and Supporting Information Access Processes*, Proceedings of I-KNOW ’07, 7th International Conference on Knowledge Management, Graz, Austria, Sept. 5-7, 2007, pp. 8-15


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S. Kim, S. Leonhardt, N. Zimmermann, P. Kranen, D. Kensche, E. Müller, C. Quix: Influence of Contact Pressure and Moisture on the Signal Quality of a Newly Developed Textile ECG Sensor Shirt, 5th International Workshop on Wearable and Implantable Body Sensor Networks (BSN 2008), Hong Kong, China, June 2008


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S. Srirama, M. Jarke, W. Prinz: Mobile Web Service Discovery in Peer to Peer Networks, 5th International Workshop on Ubiquitous Mobile Information and Collaboration Systems, UMICS 2007, a CAiSE’07 workshop, June 11-12, 2007


Other Publications (Selection)


Knowledge-Based Systems & Cognitive Robotics Group

Staff

- **Faculty**
  Univ.-Prof. Gerhard Lakemeyer, Ph. D.
  lakemeyer@informatik.rwth-aachen.de
  http://kbsg.rwth-aachen.de/

- **Secretaries**
  Gabriele Hoeppermanns
  Phone: +49 241 80 21501
  Fax: +49 241 80 22321
  sekris@i5.informatik.rwth-aachen.de

- **Research Assistants**
  Dipl.-Inform. Daniel Beck (since October 2006)
  Vaishak Belle, MSc (since July 2008, funded by DFG)
  Dipl.-Inform. Laurent Calmes (until September 2008, funded by DFG)
  Dipl.-Inform. Jens Claßen (funded by DFG)
  Dr. rer.nat. Alexander Ferrein (funded by DFG)
  Dipl.-Inform. Stefan Schiffer (funded by DFG)

- **Student Researchers**
  Masrur Doostdar, Tim Niemüller
  Viktor Engelmann (former), Martin Liebenberg (former)

- **Visiting Researchers**
  Prof. Yongmei Liu, Ph.D., Sun Yat-Sen University, China
  (May - August 2008)
  Prof. Yves Lésperance, Ph. D., York University, Canada
  (June 2007 and April–May 2008)
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-robot 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.

Figure 1: The pictures above illustrate the adaptation of the former soccer robot (left) to the requirements of the @Home league (center, 2006, and right, 2008).

To validate our approach in the framework of RoboCup, we apply it to both the simulation league and real robots in the so-called Middle 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.

Cognitive Service Robotic Systems and Applications
Stefan Schiffer, Gerhard Lakemeyer

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 “AllemanniACs” RoboCup Team participated in the soccer competitions with the initial robot platform for several years. Since the platform initially developed for soccer was designed with also other applications in mind from the beginning, we could easily enter the service robotic competition. We participate in the RoboCup@Home league since the first competition in 2006.

To be successful in RoboCup@Home 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.

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 annual tournament is structured in several specific tasks called tests, that each check for one or more important abilities of the robot. In a so-called Open Challenge and in the Final teams can freely demonstrate whatever they think is their robot’s most noteworthy functionality.
In the last three years we continuously enhanced our robot’s abilities both in soft- and in hardware. We installed a six degree of freedom manipulator and a stereo camera to better perceive and to manipulate things in the environment. The control software now features a generic object detection and recognition module, robust and flexible speech recognition used to command the robot, and further a new approach to face detection, recognition, and learning which is indispensable for any human-robot interactive application. After winning the world championship in 2006 and 2007 we became vice world champion in the 2008 competition in Suzhou, China. Furthermore, we won the RoboCup German Open in 2007 and in 2008.

**RoboCup Middle-size Soccer Robots**

Daniel Beck, Alexander Ferrein, Gerhard Lakemeyer

Contrary to other RoboCup soccer leagues the robots in the Middle Size League are completely autonomous and self-contained which means that they carry all the necessary sensors and computational devices on-board. Recent changes in the rules for the Middles Size League and the overall progress in the league made it difficult to compete with a general purpose robotic platform as we did since 2002 (cf. Fig. 1). The most prominent changes are the increase of the field size which is 18 x 12 m, now, and the removal of any colored markings on the field which makes the two halves now identical.

Thanks to a grant of the Bonn-Aachen Institute of Technology and the support from the Chair of Computer Science 5 we were able to develop a new, specialized robot platform for the RoboCup soccer competitions. In the design of the new robots we followed the de-facto standard in the league by integrating a omni-directional drive system and an omni-vision camera system. An omni-directional drive system allows the robot to move into arbitrary directions without any constraints. The omni-vision camera system consists of a hyperbolic mirror that is mounted atop of a camera at the top of the robot (cf. Fig. 2). The images obtained from the camera depict the complete surroundings of the robot. Additionally, the robots are equipped with a stereo-camera which delivers a three-dimensional reconstruction of the objects in front of the robot. The construction and manufacturing of the robots was accomplished in collaboration with the chair for Engineering Design led by Prof. Dr.-Ing. Jörg Feldhusen.

With the support of Festo Didactic GmbH we developed a new multi-actuator kick system for the robots. It is driven by two pneumatic muscles and a pneumatic cylinder which can be triggered individually. Such a kick system allows to vary the intensity with which the ball is kicked over a large range. This leads to more possibilities to pass the ball to a team-mate and will hopefully enhance the passing game between the robots.

For the new robots we developed a new framework for the robot control software. Major design goals were low latencies, support for multi-core CPUs, clearly structured flow of data, good scaling properties and a high degree of portability. The success of the last two goals is made clear by the fact that the control software for our soccer robots as well as for the humanoid Nao robots is developed on basis of the same framework.

Since the new platform strongly deviates from the old one certain key modules of the control software had to be adapted or newly developed, respectively. The new drive system required
to implement new motion and navigation modules. Since the new robots are not equipped with a laser-range finder (LRF) as the old ones we needed a new localization module that solemnly works on visual information retrieved from the omni-vision camera.

Currently, we are working on integrating the new components and implementing the basic behaviors. The high-level control will again be implemented in the ReadyLog framework which we are currently extending by means of explicit communication and inductive policy learning, among others.

Figure 2: The pictures above show a CAD model of the robot and its real counterpart in a late prototype stadium. Clearly visible are the omni-directional wheels, the newly developed kick mechanism, the omni-vision camera on top of the robot, and the stereo camera mounted below.

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

Jens Claßen, Gerhard Lakemeyer, Bernhard Nebel, Gabriele 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. In the first project phase, we are for this purpose 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. Experimental evaluations have shown that combining a GOLOG system with an PDDL-based planner is beneficial in terms of savings in the computation time needed by the overall system. 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.

The second project phase will tackle the problem that available GOLOG systems as well as planners currently lack an efficient and expressive way of representing incomplete world
knowledge. For means of efficiency, they usually rely on the closed-world and domain closure assumptions, which are not realistic in practice. Therefore, both GOLOG systems and PDDL-based planners are to be extended with the possibility of using incomplete knowledge in a tractable manner. Another aspect to be studied is how to speed up the execution of GOLOG programs in those situations where there actually is complete information about the current world state. Instead of only calling a PDDL planner and providing it with the translation of the primitive actions of the GOLOG domain, entire GOLOG programs (that contain valuable control information in the form of macro actions that restrict the space of possible plans) shall be efficiently translated into PDDL problems that can then be solved by a planning system. A further aim is to not only embed domain-independent PDDL-based planners into GOLOG, but to do so also with systems such as TLPlan or TALplanner that possess the ability to consider domain knowledge to drastically reduce their search space. For that purpose it is necessary to identify sublanguages of the situation calculus that correspond to those planners’ underlying input logics. Finally, the newly developed systems and methods shall be evaluated on mobile robots and appropriate benchmark problems.

Self-Aware Humanoid Robots in the RoboCup Standard Platform League

Alexander Ferrein, Gerhard Lakemeyer

This project is a research co-operation between the University of Cape Town, South Africa, the Technical University Graz, Austria, and the Knowledge-Based Systems Group, and is funded by the International Bureau of the BMBF. It aims at developing the control software for a humanoid robot that is not only able to reason about its environment or the next course of actions to take, but also about itself. The robot platform deployed for this project is the new Nao, manufactured by the French company Aldebaran. The robot is a 58 cm tall biped humanoid robot with 25 degrees of freedom (see Fig. 3).

Figure 3: The robot platform Nao
The idea is that already developed and deployed methods (cf. the RoboCup project) are applied to the humanoid platform. The interesting question here is, how complex reasoning methods can be down-scaled to the restricted computational power of the humanoid robot. Moreover, this project aims at developing models of the robot itself. With these models the robot will be enabled to detect execution failures of primitive actions more easily. The Standard Platform League is a new robotic soccer league under the roof of the RoboCup federation and succeeds the Four-Legged League. At the RoboCup 2008 competitions, 16 teams were allowed to participate in this league out of 24 applications. Our project was selected as one of the 16 and we participated in the RoboCup 2008 in Suzhou, China with our international team.
Other Activities

Best Student Paper Award
Masrur Doostdar, Stefan Schiffer, and Gerhard Lakemeyer received a best student paper award at the International RoboCup Symposium in Suzhou for their paper “Robust Speech Recognition for Service-Robotics Applications”.

Program Committees
Gerhard Lakemeyer was PC member of numerous international conferences, including ECAI 2008 (Area Chair) and AAAI 2008 (Senior PC member). He is on the Editorial Board of Computational Intelligence and the Journal of Applied Logic, and a member of the Advisory Board of the Journal of Artificial Intelligence Research.
Stefan Schiffer was a PC member of the RoboCup Symposium in 2008 and of the ERLARS Workshop in 2008.

Research Visits
• In 2007 and 2008 Prof. Yves Lеспérance from York University, Toronto, visited our research group for a total of two months. Prof. Lеспérance is well known for his work in cognitive robotics and multi-agent systems.
• In 2008 Prof. Yongmei Liu from Sun Yat-Sen University in China visited the group for three months as an Erasmus Mundus Scholar. Her research interests include reasoning about action and tractable reasoning.
• Funded by the National Research Foudation of the Republic of South Africa and in co-operation with the International Office of the Federal Ministry of Education and Research, Alexander Ferrein visited the Meraka Institute, Pretoria, South Africa from July–September 2007. The aim of this stay was to prepare the ground for bilateral research projects between Germany and South Africa in the field of robotics and AI research. During his stay, he gave talks in Cape Town, Stellenbosch, Durban, Bloemfontain, and Pretoria about the robotic soccer activities. Together with colleagues from the Meraka Institute, a propsal for a governmental funding programme was prepared. This proposal was presented to the Department of Science and Technology, South Africa, and is by now approved.
• Gerhard Lakemeyer visited the University of Toronto in March 2007, September 2007, February 2008, and September 2008 to continue the collaboration with Prof. Hector J. Levesque in the area of reasoning about action.

Tournaments and Competitions
RoboCup German Open 2007.
In April 2007, we participated in the RoboCup German Open 2007 which took place at the Hannover Fair for the first time. The RoboCup competitions were located in the pavilions on the fair ground gaining attention from industry and visitors. In the first RoboCup@Home competition held at the German Open, we, the “AllemaniACs”, were able to win the tournament.
RoboCup 2007.

We participated with our team “AllemaniACs” at the Eleventh RoboCup World Championships in Atlanta, USA in the RoboCup@Home league. RoboCup@Home is league established in RoboCup in 2006 to foster service robotics applications. Besides capabilities like safely maneuvering and localizing in an apartment like scenario human machine interaction is of special interest, that is, the communication between man and machine in a natural way.

With the AllemaniACs team we advanced to the finals. In the final round the AllemaniACs’s robot showed that it could retrieve a particular out of several cups from another room and bring it to the kitchen therein avoiding dynamic obstacles and recovering from other distractions. With the overall sound performance we could successfully defend our World Champion title in RoboCup@Home.

RoboCup German Open 2008.

In April 2008, we participated in the RoboCup@Home league at the RoboCup German Open, which were held at the Hannover Fair. With several technological innovations we experienced an intense week of real-life testing and competition with other teams. A further complication was a whole new set of tests that were introduced with the annual rule changes. Nevertheless, we could successfully defend our title and win the tournament.

RoboCup 2008.

In July 2008, we participated in the RoboCup@Home league with our team “AllemaniACs” at the Twelues RoboCup World Championships in Suzhou, China. At the very beginning we were already confronted with major hardware problems which rendered our robot unfunctional for the first day. After taking the first tests with a workaround we finally managed to organize spare equipment. We could regain most of the lost time until the final round and made it into the final. With the other finalists also showing high-quality performances we were glad to become Vice World Champion in RoboCup@Home in the end.

Science and Trade Fairs

Hannover Fair 2007.

Besides our participation in the RoboCup German Open, we were also present at two booths at the “Hannover Fair 2007” in Hannover in April 2007, the largest industrial fair. We demonstrated our 2006 champion service robot at the joint booth of North-Rhine Westphalia, explaining its main functionality to visitors and other interested exhibitors. Furthermore, we showcased the first prototype of our new soccer robots at the booth of Festo Didactic who supported us in the development of a new kicking devices.


In the time between July 24 – 29, 2007, we participated in a special exhibition at the Science Tunnel which was located in Johannesburg, South Africa. Together with colleagues from the Technische Universität Darmstadt, we gave interactive soccer robot demonstrations. While the interested audience could remote control two of our new Middle-size soccer robots, our colleagues from the Technische Universität Darmstadt demonstrated their humanoid soccer robots. The participation was supported by the International Bureau of the Federal Ministry of Education and Science.
Soccer-Ex 2007.

Upon an initiative of the foundation Germany – Land of Ideas e.V. within their campaign “Research in Germany” we participated in the German Area of the Soccer-Ex 2007 in Johannesburg, South Africa, again with our colleagues from the Technical University Darmstadt. The Soccer-Ex is the world-largest soccer-related business-to-business fair. With respect to the 2010 FIFA World Championships, which will be held in South Africa, the Soccer-Ex gives an adequate business platform. We were supported by the International Bureau of the Federal Ministry of Education and Science to present our research co-operation in the field (soccer) robotics and AI.

INSITE 2008.

On behalf of the Ministry of Science and Education, the German Academic Exchange Service organized the third edition of largest science fair on the African continent, the INSITE 2008. In 2006 we presented our domestic robotics projects, while this time we showed our humanoid soccer robot project at the INSITE. The fair took place from September 15 – 17, in Sandton, South Africa.

Tag der Technik 2008.

With our champion robot Caesar we participated at the "Tag der Technik" 2008 which is being held under the patronage of Germany’s Federal President Horst Köhler. Initiated by the Verein Deutscher Ingenieure (VDI), this nationwide collection of events is meant to give insights and to foster fascination for technology, to elate young kids and teenagers for technical careers. Specifically, Caesar served as an assistant at the "Manege der Innovationen" in Sankt Augustin, helping moderator Helge Haas known from TV shows such as "Kopfball" in guiding through a show that took place in a circus tent right next to Schloss Birlinghoven at the Fraunhofer IZB.
Publications


Alexander Ferrein: *Towards Applying Soccer Moves in the RoboCup Standard Platform*


Human Language Technology and Pattern Recognition

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
  R. Linzenich
  J. Kikum

- Academic and Research Staff
  Dipl.-Inform. O. Bender
  Dipl.-Inform. J. Bungeroth
  Dipl.-Inform. T. Deselaers
  Dipl.-Inform. P. Dreuw
  Dipl.-Inform. C. Gollan
  Dipl.-Inform. S. Hahn
  Dipl.-Inform. S. Hasan
  Dipl.-Phys. G. Heigold
  Dipl.-Inform. B. Hoffmeister
  Dipl.-Inform. M. Huck
  Dipl.-Phys. P. Lehnen
  Dipl.-Inform. G. Leusch
J. Lööf, M. Sc. Engineering Physics
Dipl.-Inform. E. Matusov
Dipl.-Inform. A. Mauser
Dipl.-Inform. M. Nuβbaum
Dipl.-Inform. C. Plahl
Dipl.-Ing. M. Popovifá
Dipl.-Phys. M. Ratajczak
Dipl.-Inform. D. Rybach
Dr. rer.nat. R. Schlütter
Dipl.-Inform. C. Schmidt
Dipl.-Inform. D. Stein
Dr. rer.nat. V. Steinbüü
Dipl.-Ing. D. Vilar Torres
Dipl.-Inform. J. Xu
Dipl.-Inform. R. Zens
Y. Zhang, M. Comp. Sc. Tech.

- **Technical Staff**
  S. Koltermann
  T. Schuhmacher

- **Visitors**
  Vicente Alabau, Universidad Politécnica de Valencia
  Jesus Andres Ferrer, Universidad Politécnica de Valencia
  Mei-Yuh Hwang, University of Washington, USA
  Danju Lu, Southwest Forestry University, China
  Naveen Parihar, Mississippi State University, USA
  Zoltán Tüske, Budapest University of Technology & Economics, Hungary
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:

Speech Recognition = Acoustic--Linguistic Modelling + 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:

Language Translation = Linguistic Modelling + 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
  o large vocabulary recognition
  o multi--lingual speech recognition
  o speaker independent and adaptive speech recognition
  o 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 and international projects (see below). In addition, there are bilateral research projects with companies. In the projects, various operational prototype systems have been set up, such as the Image Retrieval Engine FIRE (Flexible Image Retrieval Engine); see also http://www-i6.informatik.rwth-aachen.de\ deselaers/cgi\_bin/fire.cgi

**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 refSMT_Arch). 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.

![Architecture of a Statistical Machine Translation System](image-url)
At ‘Lehrstuhl für Informatik 6’, the following research directions related to the main topics of machine translation were pursued in 2007:

- The phrase-based translation system (PBT) was improved with a focus on search organization, including new knowledge source and better coupling with automatic speech recognitions systems.
- 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, baseforms of words and compounds) 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 continued 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.

**Speech Recognition**

Architecture of an automatic speech recognition system

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 \ref{fig:SR_Arch}) 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:

- The acoustic analysis which parameterizes the speech input into a sequence of acoustic vectors.
- Acoustic models for the smallest sub-word units, i.e. phonemes which usually are modeled in a context dependent way.
- 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.

(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 2007:

- 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.

• 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 \textit{it} 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.

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 2007, we developed a tagging system based on Conditional Random Fields and compared it to our current machine translation systems and the maximum entropy framework developed in former years with respect to their performance in natural language understanding. Including tagging results from other systems in the Luna project, we carried out research in system combination of these systems.

**Image Recognition and Retrieval**

The experiences gained in human language technology and statistical pattern recognition are applied to the recognition of objects in images. So far, the main emphasis has been put on recognition of single objects using appearance-based methods (examples are shown in Figures refcaltech_fig and refUSPS_fig). 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 2007, 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.

Examples of single objects to be recognized (Caltech database)
Sign Language and Gesture Recognition

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 2007, 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 5 and 6) by combining different data sources, suitable language modelling, temporal contexts, and model combination.
Research Projects

CLEF/ImageCLEF Image Retrieval Evaluation 2007

In 2007, 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.

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.

Examples from the IRMA Database
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.

PASCAL Visual Object Classes Challenge 2007

In 2007, 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.

DFG Project Statistical Methods for Written Language Translation

This project aimed at the development and improvement of statistical machine translation. The following problems were 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.

Data Mining Cup 2007

In 2007 and 2008 students from the ‘Lehrstuhl für Informatik 6’ were very successful in the Data Mining Cup organized by the Chemnitz University of Technology, and prudsys AG. While achieving ranks 1-2, 4-5, and 7-8 among others in 2007, students from ‘Lehrstuhl für
Informatik 6’ submitted the 8 best solutions in 2008. Most additional participants were ranked within the top 20

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’ contributes 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 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.

IWSLT 2007 and 2008 (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 many other research groups in the translation directions Chinese to English, Japanese to English and Arabic to English and achieved good results in translation quality in all input conditions and language pairs.

spoken Language UNderstanding in multilingual communication systems (LUNA)

The LUNA project addresses the problem of real-time understanding of spontaneous speech in the context of advanced telecom services.

In commercial telecom services the quality of human-computer interaction is still far from being effective. In Luna the processing from the spoken utterance up to the input to a dialog
manager is realized with a pipeline approach starting with an automatic speech recognition system (ASR), followed by a word lattice annotation module (WP2), a semantic composition module (WP3), and a context sensitive validation module (WP4) and ending in the dialog manager.

The first module (WP2) extracts information presented as basic concepts ("yes" is a "response"), while the second module (WP3) integrates knowledge about the concept level to get a higher level interpretation.

The last module (WP4) takes the dialog state into account and omits all hypotheses that are not possible in this dialog state. Between the modules the hypotheses are transmitted using lattices.

The dialog system in LUNA will be multilingual and support the languages French, Italian, and Polish. ‘Lehrstuhl für Informatik 6’ contributes mainly to the word lattice annotation module (WP2). This component is the most important one for all dialog systems. In some applications like call routing it is satisfactory as input to the dialog manager. ‘Lehrstuhl für Informatik 6’ applies ongoing research in the fields of Conditional Random Fields, positional wise normalized log-linear models and machine translation to the word lattice annotation process. Using system combination, the already good performance of the best single best system could be further improved.

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: the project targets at speech recognition, machine translation, and speech synthesis. It spans the time from 2004-2007.

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 modeling 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’ has been involved in several work packages of this project. We have built the European Parliament Plenary Session (EPPS) corpus for speech-to-speech translation.
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 have been involved in research on innovative translation methods, use of human-supplied knowledge, and on the integration of machine translation and speech recognition. We have been work package leader and have developed 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.

R&D Project TRAMES (Traduction Automatique par Méthodes Statistiques)

The aim of TRAMES was to develop an automatic translation system capable of processing Arabic or English documents from various domains, such as written text or radio/television and conversational speech transcripts, and produce corresponding French translations. A data-driven machine-translation system developed at RWTH/i6 was interfaced with a graphical frontend (developed by Bertin Technologies) that displays the MT system output, such as n-best translation hypotheses, word alignments, confidence measures etc. A large-scale translation engine was designed to cover Arabic-French as primary language pair.

The system has successfully participated in the second CESTA evaluation campaign. In the second phase of the project, the main focus was to adapt the translation engine to automatic speech recognition output in order to produce a fully automated processing chain from recognition of audio streams (such as Arabic television broadcast news) to translation of the recognized output into French.

R&D Project TRANSTAC (Spoken Language Communication and Translation System for Tactical Use)

Within the TRANSTAC project, RWTH/i6 builds machine translation systems for colloquial Iraqi Arabic to English and vice versa. The systems are optimized for real-time operation. The trained models are then integrated into SRI's IraqComm system, a ruggedized, mobile, spontaneous translation system. Additionally, SRI participates at various evaluations with systems delivered by RWTH/i6. Rapid development of new MT systems is tested in a special surprise language track where the researchers have limited time to set up a complete translation pipeline, e.g. for Malay (Bahasa Malaysia) to English and vice versa. The focus here is on Speech-to-Text translation systems.
Quaero is a collaborative research and development program, centered at developing multimedia and multilingual indexing and management tools for professional and general public applications such as the automatic analysis, classification, extraction and exploitation of information.

The research aims to facilitate the extraction of information in unlimited quantities of multimedia and multilingual documents, including written texts, speech and music audio files, and images and videos.

Quaero was created to respond to new needs for the general public and professional use, and new challenges in multimedia content analysis resulting from the explosion of various information types and sources in digital form, available to everyone via personal computers, television and handheld terminals.

Since the official start of the program in May 2008, the ‘Lehrstuhl für Informatik 6’ contributes to the projects by developing and supplying technologies and corpora for Machine Translation, Automatic Speech Recognition and Image Recognition.
Talks and Publications

Publications


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. Ingo Felscher
  Dipl.-Inform. Michael Holtmann
  Dipl.-Inform. Florian Horn
  Dipl.-Inform. Wong Karianto
  Dr. Christof Löding
  Dipl.-Inform. Daniel Neider
  Dipl.-Inform. Frank Radmacher
  Dipl.-Inform. Michaela Slaats
  Dipl.-Inform. Alexandra Spelten
  Dr. Nico Wallmeier

- Technical Staff:
  
  Rolf Eschmann
Overview

The research area of the group is automata theory and logic in connection with the specification, automatic verification, and automatic synthesis of programs. The focus of our present research is the evolving algorithmic theory of infinite graphs, with applications to model-checking, and the study of infinite games in various forms, e. g. as a model of reactive systems.

During summer semester 2007, W. Thomas spent a three months’ sabbatical at the University of Cambridge, UK (upon invitation of Robinson College, Cambridge). During this time C. Löding took over lecture duties and many items of organization.

Major projects in which our group participated are the following:

- DAAD project “Finitely Presented Infinite Graphs: Structure, Behavior, Algorithms” with the group of D. Caucal (Rennes), which – besides the research results – led to a one year stay of Arnaud Carayol on a teaching position of our chair.
- DFG-Graduiertenkolleg AlgoSyn (“Algorithmic synthesis of reactive and discrete-continuous systems”)
- Excellence Cluster UMIC (“Ultra High-Speed Mobile Information and Communication”) of Wissenschaftsrat and DFG
- Project AutoMathA (“Automata Theory: From Mathematics to Applications”) of the ESF (European Science Foundation)
- Project GASICS (“Games in analysis and synthesis of interactive computational systems”) of the ESF (European Science Foundation), launched in September 2008.

Other Highlights:

- In February 2007, the group was organizer of the European conference STACS 2007, 24th International Symposium on Theoretical Aspects of Computer Science, in which about 150 participants gathered for a top-level scientific program with 56 contributed papers out of 400 submissions.
- In December 2007, a colloquium “Logic and Automata: History and Perspectives” was held on the occasion of the 60th birthday of Wolfgang Thomas. More than 140 guests from many countries participated in this event.
- The diploma thesis of Daniel Neider (“Lernverfahren für Automaten über linearisierten XML-Dokumenten”) was selected as best theoretical thesis at the “GI-Informatiktage” in Bonn (June 2008); a short description was invited as an article in the national journal “Informatik-Spektrum”.

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Research Projects

Automata Theory and Infinite-State System Verification

J. Altenbernd, I. Felscher, C. Löding, M. Slaats, A. Spelten, W. Thomas
Funding: ESF (European Science Foundation)

The research in this field was done in different cooperations and spans a rather broad spectrum:

- **Model Transformations and Decidability**
  In work with B. Morcrette (ENS de Cachan), who worked in our group for his “stage” from June to August 2008, a new method of generating infinite structures with a decidable MSO-model-checking problem was developed. The idea is to construct models that participate in each level of the so-called Caucaal hierarchy and thus – as limit models – are located outside this hierarchy. The results were included in the invited plenary lecture of W. Thomas at the conference CSL 2008 (see [25]).

  In joint work with T. Colcombet (Rennes/Paris) C. Löding introduced a powerful formalism of model transformation called “set interpretation” [6]. This mechanism allows to construct structures with a decidable first-order theory from structures with a decidable monadic second-order theory. Starting from the Caucaal hierarchy this allows to construct a rich hierarchy of structures with decidable first-order theory. The methods developed in [6] allow, for example, to separate the levels of this hierarchy.

- **Tagged Word Rewriting Systems**
  In the dissertation work of J. Altenbernd, generalized rewrite systems over words are studied as generators of infinite graphs (where the vertex set is a regular language and the edge relation is induced by the one-step-rewriting of words). Extending previous work on prefix rewriting and mixed prefix-suffix rewriting, it turned out that the decidability of the derivability relation can be guaranteed for quite more general systems in which also infix rewriting next to special tag symbols is allowed. Moreover, it was possible to clarify the expressive power of these graphs as acceptors (infinite automata). A preliminary version of the results was presented at the conference LATA 2008 [2].

- **Model-Checking over Product Structures**
  Extending results of A. Rabinovich, I. Felscher exhibited new cases where the model-checking problem for a product model can be reduced to the component...
models, following the “Feferman-Vaught composition technique”. It was shown that the modal logic enhanced by the reachability modality can still be be extended (namely, by counting conditions) and nevertheless shares a composition property. The work was presented at the International Workshop on Reachability Problems (Liverpool, 2008), see [10].

**Infinite Games**

*A. Carayol, M. Holtmann, F. Horn, C. Löding, M. Slaats, W. Thomas, N. Wallmeier*

*Funding: DFG, ESF (European Science Foundation)*

Much of this research was carried out in the framework of the DFG Research Training Group AlgoSyn; other parts were supported by the European Science Foundation.

- **Construction of “optimal” winning strategies**

  In an invited lecture at the international conference SOFSEM, W. Thomas gave an overview of the current challenges in shifting the synthesis problem for infinite games from a qualitative viewpoint (“Is there a winning strategy?”) to a qualitative one (“How to construct an optimal strategy?”).

  In [11] a new approach to the synthesis of finite-state controllers was proposed, which optimizes finite-state controllers for certain infinite games with respect to the memory size.

- **Request-Response Games**

  This aspect is important in the synthesis of controllers that win so-called “request-response games”: Here the winning condition requires the visit of a certain state after the visit of the corresponding “request state”, and the time lag between the two visits should be minimized. Nico Wallmeier obtained in his dissertation [26] results on the synthesis of corresponding controllers that satisfy such an optimality criterion.

  This work was extended and presented at the conference ATVA in the paper [12]. For this work, Florian Horn joined the team in the framework of his French-German dissertation project (“Co-Tutelle”) and came to Aachen during the winter semester 2006/2007.

- **General Theory**

  In two papers of a more tutorial character [22,24], the synthesis problem for regular infinite games was discussed – referring to its first formulation by A. Church
50 years ago (“Church’s Problem”). A streamlined solution was presented, emphasizing the analogy between the solutions for so-called “weak” and “strong” games.

- **Higher-Order Pushdown Systems**

  In diploma thesis work, M. Slaats (supervised by A. Carayol) developed algorithmic solutions for infinite games over higher-order pushdown graphs. For a finite representation of the (“regular”) winning regions and winning strategies an approach due to A. Carayol was pursued. The research work resulted in a paper [5] which was presented at the international conference MFCS 2008.

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**Tree Automata**

*W. Karianto, C. Löding, F. Radmacher, A. Spelten, W. Thomas*

*Funding: DFG*

The research activities were divided in two branches, concerning (1) automata over finite trees (and their relation to the specification of semistructured data such as XML documents), and (2) automata over infinite trees, as a difficult and powerful background theory for program verification and synthesis.

- **Automata over Unranked Trees**

  The goal of our research, partly 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.

  - In [13], 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 dealing with data values in XML documents, which 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 allow not only the comparisons of input subtrees, but also of the output trees of a transducer. Another extension of unranked tree automata is obtained by allowing (a restricted use of) counters.

  - In her diploma thesis, 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. The results are published in [16].

– A chapter on the theory of automata for unranked trees and their applications to XML has been contributed by C. Löding to the electronically available book *TATA: Tree Automata Techniques and Applications* [9].

• **Star-Height of Regular Tree Languages**

In [8] the star-height problem for regular tree languages has been solved by adapting and extending techniques that have been used to solve the star-height problem for regular word languages. The solution is based on an extended model of tree automata whose algorithmic analysis includes new aspects compared to the case of word automata, for example the use of game theory. In an ongoing collaboration with T. Colcombet (Paris) this model of tree automata is studied in further detail.

• **Rational Tree Relations**

Frank Radmacher developed (in his diploma thesis) an automata theoretic characterization of the rational tree relations, and singled out special cases where undesirable properties (like nonregular unary relations that are nevertheless rational) can be avoided. The work was presented at SOFSEM 2008 (see [18]).

• **Automata on Infinite Trees**

In [4] automata on infinite trees are used to give a simple proof of a theorem of Gurevich and Shelah stating that there is no choice function on the infinite binary tree that is definable in monadic second-order logic.

The paper [7] deals with the complexity of regular languages of infinite trees. Using an extension of automata on infinite trees similar to the one used for deciding the star-height problem (see above), it is possible to open a new way of tackling the difficult open problem of deciding the number of priorities needed by a parity tree automaton for accepting a regular language of infinite trees.

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**A Game Theoretic Approach to Dynamic Networks**

*F. Radmacher, W. Thomas*

*Funding: DFG (Excellence Cluster UMIC)*

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This project is a contribution to the Aachen Excellence Cluster UMIC (“Ultra high-speed mobile information and communication”). Starting from the paradigm of “sabotage games”, we introduce several models of dynamic networks in a game-theoretic framework. For example the users of a network play against a scheduling unit by blocking and allocating connections. The two antagonistic parties are also called the destructor and the constructor (of vertices or edges). The construction of winning strategies for constructor amounts to the synthesis of a scheduling policy that can adapt to any (even hostile) behavior of the users. Preliminary results were presented in [20]. Continuing diploma thesis work of D. Klein, we presently extend the results to a probabilistic setting.

Other Activities

W. Thomas

- Speaker of the DFG-Graduiertenkolleg 1298 “Algorithmische Synthese reaktiver und diskret-kontinuierlicher Systeme” (since July 2006)
- Member of Academia Europaea
- Member of Conseil Scientifique d’ Ecole Normale Superieure de Cachan
- Representative of the Faculty of Mathematics, Computer Science, and Natural Sciences for the organization of doctoral studies.
- Member of the university committee for the supervision of the budget from student fees
- 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 (until 2007)
- 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 the Steering Committee for the conference STACS (“Symposium on Theoretical Aspects of Computer Science”)

• Program Committee Co-Chair and Chairman of organizing committee of STACS 2007 (24rd International Symposium on Theoretical Aspects of Computer Science), Aachen

• Member of the program committees of MFCS 2008, ICALP 2008 (Track B).

• 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 Aachen Competence Center for History of Science

C. Löding

• Student Counselor for Curricula for Minor Subjects and for Teachers’ Curricula

• Member of the program committees of INFINITY 2007 and STACS 2008.

Talks and Publications

Talks
J. Altenbernd: Reachability over Tagged Infix Rewriting Systems, Automata: from Mathematics to Applications (AutoMathA 2007), Mondello, Italy, June 2007

J. Altenbernd: Word Rewriting and Infinite-State System Verification, Tag der Informatik, Aachen, Germany, December 2007

J. Altenbernd: Reachability over Word Rewriting Systems, Workshop on Algorithmic Model Theory, Freiburg, Germany, February 2008


I. Felscher: The compositional method and regular reachability, Arbeitsgemeinschaft Logik und Automaten, Aachen, Germany, August 2008

I. Felscher: The compositional method and regular reachability, 2nd Workshop on Reachability Problems, Liverpool, UK, September 2008


M. Holtmann: Memory Reduction for Strategies in Infinite Games, Conference on
Implementation and Application of Automata, Prague, Czech Republic, July 2007

M. Holtmann: *Memory Reduction for Strategies in Infinite Games*, Workshop on Games and Automata for Synthesis and Validation, Lausanne, Switzerland, September 2007


W. Karianto: *Unranked tree automata with sibling equalities and disequalities*, Arbeitsgemeinschaft Logik und Automaten, Aachen, Germany, July 2007

W. Karianto: *Unranked tree automata with sibling equalities and disequalities*, 34th International Colloquium on Automata, Languages and Programming, ICALP 2007, Wrocław, Poland, July 2007


C. Löding: *Games*, Tutorial at the summer school MoVeP 2008 (Modelling and Verifying Parallel Processes), Orleans, France, June 23–27, 2008


C. Löding: *Tree Automata with Subtree Comparisons*, Dagstuhl Seminar Beyond the Finite: New Challenges in Verification and Semistructured Data, Dagstuhl, Germany, April 2008


C. Löding: *MSO on the Infinite Binary Tree: Choice and Order*, Dagstuhl Seminar Algorithmic-Logical Theory of Infinite Structures, Dagstuhl, Germany, October 29,


W. Oberschelp: *Farewell Addresses to Graduates*, Sommerfest Informatik, June 22, 2007 and June 27, 2008


F. Radmacher: *A Game Theoretic Approach to the Analysis of Dynamic Networks*, First Workshop on Verification of Adaptive Systems, Kaiserslautern, Germany, September 2007

F. Radmacher: *An Automata Theoretic Approach to Rational Tree Relations*, 17. Theorietag Automaten und Formale Sprachen, Leipzig, Germany, September 2007

M. Slaats: Regular strategies for higher-order pushdown parity games, Workshop on Algorithmic Model Theory, AlMoTh 2008, Freiburg, Germany, February 2008


W. Thomas: Automata Theoretic Foundations of Infinite Games, Colloquium on New Perspectives on Games and Interaction, Royal Dutch Academy of Science, Amsterdam, the Netherlands, February 2007

W. Thomas: Church’s Problem on the Synthesis of Nonterminating Programs, Computer Laboratory Wednesday Seminars, University of Cambridge, UK, April 2007

W. Thomas: Infinite-State System Verification via (Tree-)Automata, Computer Laboratory Logic and Semantics Seminar, University of Cambridge, UK, May 2007

W. Thomas: Das Church’sche Problem zur Synthese nicht-terminierender Programme, Kolloquium des Instituts für Informatik, Universität Kiel, Germany, July 2007

W. Thomas: Perspectives of Algorithmic Model Theory, Invited lecture at the 13th International Congress of Logic, Methodology, and Philosophy of Science, Beijing, China, August 2007

W. Thomas: Constructing Winning Strategies in Infinite Games, Invited talk at the 7th International Tbilisi Symposium on Language, Logic, and Computation, Tiflis, Georgia, August 2007

W. Thomas: Logical Refinements of Church’s Problem, Computer Science Logic, CSL 2007, Lausanne, Switzerland, September 2007

W. Thomas: MSO-Properties over Infinite Graphs, Dagstuhl Seminar Algorithmic-Logical Theory of Infinite Structures, Dagstuhl, Germany, October/November 2007

W. Thomas: Church’s Problem after 50 Years, Invited lecture at Workshop L s, V |= 10y, 10 Years of Verification in Cachan, Cachan, France, November 2007


W. Thomas: Perspectives of Theoretical Computer Science, Dagstuhl Advisory Board Meeting, Dagstuhl, Germany, April 2008

W. Thomas: Infinite Games in Synthesis and Verification, Dagstuhl Seminar Topological and Game-Theoretic Aspects of Infinite Computations, Dagstuhl, Germany, June/July 2008


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**Publications**


F. Horn, W. Thomas, N. Wallmeier: *Optimal strategy synthesis for request-response games*,


Mathematical Foundations of Computer Science

Staff

- Faculty
  Prof. Dr. Erich Grädel

- Secretary
  Marianne Kuckertz

- Research Assistants
  Dr. Vince Bárány (until 9/2007)
  Dr. Dietmar Berwanger
  Dipl.-Inform. Diana Fischer (since 10/2007)
  Dipl.-Inform. Tobias Ganzow
  Dr. Łukasz Kaiser
  Dipl.-Math. Bernd Puchala (since 10/2008)
  Dipl.-Inform. Roman Rabinovich (since 10/2008)
  Dipl.-Inform. 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 7 (Prof. Wolfgang Thomas).

The main research areas of the group are mathematical logic and the theory of infinite games, with particular emphasis on algorithmic issues in logical systems, computational model theory, fixed point logics, and strategy construction and definability in infinite games.

Research Projects

Games for Design and Verification (GAMES)

GAMES is a Research Networking Programme funded by the European Science Foundation (ESF). It was launched in March 2008 for a duration of five years and is directed by Erich Grädel.

The GAMES network proposes a research and training programme for the design and verification of computing systems, using a methodological framework that is based on the interplay of finite and infinite games, mathematical logic and automata theory. This ESF networking programme is the continuation of the European Research Training Network Games and Automata for Synthesis and Validation (GAMES) that had been funded under the Fifth Framework Programme of the European Community from 2002 to 2006, but it is scientifically broader and more ambitious. It includes about 150 researchers throughout Europe.

URL: www.games.rwth-aachen.de

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, D. Fischer, 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 study algorithmic and definability issues on various classes of infinite structures that are presentable by automata and logical 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)**
E. Grädel, 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).
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.

URL: www.algosyn.rwth-aachen.de

**Algorithmic Strategies in Multi-Player Games**

E. Grädel, D. Berwanger, Ł. Kaiser

The goal of this project is to develop theoretical concepts and algorithmic methods for the analysis of interactive non-terminating systems. The focus is on state-based systems which can be modelled as multi-player games on graphs. Traditionally, research in this area has concentrated on situations of conflict between two agents (e.g., system and environment) yielding a rich and effective theory for two-player zero-sum games of infinite durations. Our objective is to extend this theory to incorporate the potential of cooperation which arises when two or more agents interact in situations that are not necessarily conflicting.

For interactive behaviour over a finite duration of time, the corresponding model of non-zero-sum games is well established in classical Game Theory. To cope with non-terminating behaviour, however, we need to extend fundamental solution concepts and make them accessible to algorithmic treatment. Aside with games of perfect information, we investigate games of imperfect information with different sources of uncertainty. One particular task is to combine logical and algebraic approaches with methods from artificial intelligence to obtain tractable algorithmic solutions.

**Logic for Interaction (LINT)**

E. Grädel, D. Berwanger, B. Puchala, R. Rabinovich.

LINT is a Collaborative Research Project (with partners from Amsterdam, Gothenburg, Helsinki, Oxford, and Paris) inside the ESF Eurocores Programme LogICCC, aiming at developing mathematical foundations for interaction. Intelligent interaction involves agents in complex scenarios like conversation, teamwork, or games. Contours of a broad mathematical description are starting to emerge today, based on several individual research developments that shall now be brought together.

Our contribution to this project will focus on uncertainty and partial information. The investigation is directed at the following broad objectives:
(1) to achieve a systematic classification of games with natural patterns of information uncertainty;
(2) to devise logical characterisations for the fundamental elements of dynamics in such games;
(3) to develop algorithms for analysing and solving games with partial information;
(4) to establish effective abstraction techniques for interactive systems.

Other Activities

Erich Grädel

- Programme Chair of the ESF Research Networking Programme GAMES
- Editorial Board of the Journal of Symbolic Logic
- Editorial Board of the Bulletin of Symbolic Logic
- Editorial Board of Logical Methods in Computer Science
Talks and Publications

Talks


**Publications**


E. Grädel and Ł. Kaiser. *What kind of memory is needed to win infinitary Muller games?* In Interactive Logic (J. van Benthem, B. Löwe, and D. Gabbay, Eds.), vol. 1 of Texts in Logic and Games. Amsterdam University Press, 2007.


Computer Graphics and Multimedia

Staff

- Faculty:
  Prof. Dr. rer. nat. Leif Kobbelt
  kobbelt@cs.rwth-aachen.de
  http://www.rwth-graphics.de/
  Prof. Dr. Bastian Leibe
  Bastian.Leibe@umic.rwth-aachen.de
  http://www.umic.rwth-aachen.de/multimedia

- Secretary:
  Silke van Betteraey/Dorothee Degen, M.A.
  Tel: +49-241-80-21801
  Fax: +49-241-80-22899

- Research Assistants:
  Dipl.-Inform. David Bommes (funded by DFG)
  Dipl.-Inform. Ellen Dekkers
  Dipl.-Inform. Martin Habbecke (funded by DFG)
  Dipl.-Inform. Alexander Hornung
  Dipl.-Inform. Jan Möbius
  Dipl.-Inform. Darko Pavić (funded by Innovaris GmbH)
  Dipl.-Inform. Torsten Sattler (funded by DFG)
  Dipl.-Inform. Arne Schmitz (funded by DFG)
  Dipl.-Inform. Dominik Sibbing (funded by DFG)
  Dipl.-Inform. Henrik Zimmer

- Artist in Residence:
  M.F.A. Matthew Sloly
Student Researchers:
Overview

The Computer Graphics and Multimedia group at RWTH Aachen is focussing on research projects in the areas of Geometry Processing, 3D Reconstruction, Mobile Multimedia, Computer Vision, and Interactive Visualization but it is also active in related areas such as High Quality Image Synthesis and Global Illumination. 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. 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.

We have recently 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). In the context of the Mobile Access initiative we are collaborating with the communication systems group in order to develop the basic functionality for mobile multimedia applications in a WLAN-based city network.

The processing of 3D geometry data is becoming more and more important in industrial product design and development. Typical applications go 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 reach 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 inauguration in Aachen in 2003 is now established as the major international forum specialized in 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 one part in the winter term and the other part 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, we offer the practical course "Virtual Aachen Project". The aim of this course is the development of a processing pipeline, which enables the automatic creation and photo-realistic real-time visualization of complex virtual city models from simple 2D city maps and height fields. On the undergraduate level we offer an introductory seminar and practical exercises on topics in Computer Graphics.

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 quite a few innovative research papers on internationally recognized conferences and journals in Computer Graphics.
Research Projects

Augmented Reality Applications On Mobile Devices
Torsten Sattler, Leif Kobbelt

Although augmented reality has been an active area of research for many years, only few augmented reality applications are in practical use outside of scientific research environments. One main reason for the lacking widespread adoption is that most of these applications require special hardware that is either expensive or bulky. However, the improvement in computational power and camera quality of today's mobile phones now seem to constitute a mass-market hardware base that is capable of running augmented reality applications, resulting in the newly emerging research area of mobile augmented reality.

The focus of our project is two-fold: One part of the project deals with the computational hardware of mobile devices. We search for ways of accelerating already existing, sophisticated methods, developed for high-end PCs, to enable their use on the low-end hardware of mobile phones. Examples of such methods are the extraction of feature points from images and the matching of feature points between image pairs.

The other part of the project deals with the networking capabilities found in mobile phones. While the storage capacities of mobile devices are very limited, using server-client infrastructures combined with a wireless network allows the handling and processing even of large data sets. This allows to run sophisticated applications such as augmented reality tourist guides for entire cities, where the multimedia data is not stored on the mobile phone itself but is streamed on demand from a server. The left figure shows an image and the features extracted from it. By matching this feature set with a database of feature-annotated images, a relation between the image and a database containing geo-referenced multimedia content can be established. As a result, additional information can be superimposed onto the original image, as shown in the right figure.
In geometry processing research, the extraction and modeling of smooth curves which are embedded into the surface of a geometric object is of great interest since such curves often define the essential design characteristics of the object. Reconstructing a network of curves that sketch the main features of a raw (e.g. laser scanned) input geometry forms the basis for further processing stages, such as segmentation, freeform editing or shape morphing.

In this project, we developed a set of interactive tools for the extraction of smooth characteristic feature curves from car body shapes. The typical problems arising in this setting include the lack of consistency in the input data, the distinction of detail from the overall underlying geometry, the identification of regions of interest as well as curve-on-surface optimization with regard to a variety of application dependent criteria such as surface curvature, normal orientation and so on.

Our algorithm is able to process a variety of input data types such as CAD models or laser scanned data, each imposing specific challenges to our algorithms. While CAD data exhibits a regular mesh structure it often suffers from non-manifold configurations, whereas laser-scanned geometry is noisy and often contains holes in occluded surface regions. Additionally, we developed robust criteria to distinguish between local detail like e.g. molding or handgrips and the global geometry.

In our interactive modeling system, the designer roughly sketches a curve in a region of interest on the input shape using standard curve editing functionality. Our system supports the user by automatically "snapping" the sketch curves to the most likely feature location. A graph cut based optimization process shifts the curve to regions of maximum curvature or certain surface normal directions, thereby minimizing the approximation error and satisfying smoothness requirements. The optimization criteria as well as positional constraints for selected points on the curve can be modified by the designer interactively. The feature curve then adopts itself to the new constraints in realtime.

The images show a typical input car model and a network of feature curves that outline the car's characteristic geometry.
Animated 3D Characters From Uncalibrated Video
Alexander Hornung, Ellen Dekkers, Leif Kobbelt

The creation and animation of human characters is an intensively investigated field in Computer Graphics and Vision research. One particularly promising direction in this discipline is the generation of dynamic 3D character models directly from images or video.

We develop a new method for extracting and rendering animated 3D character models from video sequences. The main contribution lies in the fact that the reconstruction can be performed from a single uncalibrated video of a moving articulated figure. We show that this problem can be transformed into that of 3D character reconstruction in a temporally synchronized multi-camera setup by enforcing a pose synchronization of the character across the frames of the input video.

In a first step, we align the projections of a 3D template model to selected frames of the character in the input video. The required camera calibration is derived from the character's skeleton. The changes in shape and pose are then tracked throughout the video using a mesh-based approach, which supports the complex occlusion handling necessary for accurately tracking articulated motion of a character. These tracked shapes are then deformed to establish a consistent, temporally synchronized character pose, which allows for a subsequent 3D shape refinement of the initial template model by multiview stereo techniques. Our method scales with the number and quality of available input images, and can handle a variety of character shapes and acquisition scenarios.

The result of our reconstruction technique is a fully animated 3D character model which can be rendered realistically using view dependent texture maps extracted from the input video.

The images show two exemplary input frames and a frame from the corresponding animated 3D reconstruction generated by our algorithm.
Avatar faces are widely used in the design of stimuli which are needed to investigate brain disorders like schizophrenia and autism. Emotional expressions like happiness, sadness, fear, anger or disgust are typically generated by adjusting facial action units or by using free form deformation techniques like the ‘harmonic coordinates’. This process is most often very time consuming and requires a good knowledge about the facial anatomy.

In this project we investigate a low budget and markerless facial animation system. Instead of modeling the anatomy of the human face explicitly, we extract it from a large number of samples by statistical analysis.

In collaboration with the Human Modeling and Simulation Department at UPENN in Philadelphia we process the data (texture and geometry) obtained by laser-scanning, extract a shape model by applying a principal component analysis to a large set of test data and then synthesize human faces from this resulting shape model. The principal component analysis requires the data to be in one-to-one vertex correspondence. We establish this correspondence by fitting a multi-resolution template mesh to each of the scans. For the multi-view stereo reconstruction, we have to deal with camera calibration issues. Here, we exploit the shape model to stabilize the stereo reconstruction which is usually very sensitive to image noise.

In this figure one can see a synthetic example: left shows the pointwise optimization of vertex positions. Stabilizing the process by using the shape model leads to a smooth surface (middle) which deviates only slightly from the ground truth surface (right). In a second stage of this project we will extend our capture system to acquire video data from dynamically moving faces. Tracking natural facial features in time and between views of a multiview stereo system will enable us to perform markerless facial motion capture.
Interactive Pixel-Accurate Free Viewpoint Rendering
Alexander Hornung, Leif Kobbelt

Photorealistic image synthesis is one of the central challenges in computer graphics and vision. In the last years, research on view-morphing and image-based rendering has shown great potential with immense impact on practical applications such as free viewpoint TV of sport events and movies, or simply a realistic 3-dimensional visualization from pictures of the last holiday trip. The basic idea in image-based rendering is to synthesize novel output views of a scene directly from a given set of input images. But although the imaging process has been researched extensively, the goal of real-time, virtually unconstrained free viewpoint rendering of arbitrary and unstructured scenes is still very challenging.

To achieve these goals, we have presented an integrated and scalable system which handles all required processing steps. We developed a generic particle-based scene representation in combination with a flexible multi-view stereo formulation which allows for the creation of geometric proxies from a set of input views for arbitrary scene types. The particle shapes used for generating the proxy are sensitive to depth discontinuities at object silhouettes and enable a proper handling of occlusions in the input images.

Our algorithm is implemented using a special parametrization of the view-space and an efficient continuous optimization framework. In combination these techniques support the generation of 3D proxies even for complex scenes and unconstrained camera setups. In the rendering phase we compute a pixel-accurate camera blending field for a photo-realistic reproduction of the scene appearance from a large number of input views. Our method is optimized for an entirely GPU-based implementation resulting in high performance rendering with unconstrained and interactive 3D user navigation.

This figure shows two exemplary input images and a novel output view rendered in real-time with our system for image-based free viewpoint rendering.
The computation of geodesic distances on a triangle mesh has many applications in geometry processing, ranging from segmentation and low distortion parametrization to motion planning and tool path optimization. In most cases the true geodesic distance field is approximated by some fast marching method which leads to acceptable results on nicely structured meshes and away from singularities of the distance transform. However, such simple propagation schemes tend to become numerically unstable on not-so-nice meshes as they often occur in practical applications. Moreover, since they use the same mesh structure as a representation for the input geometry as well as the distance field, the precision is limited by the mesh resolution.

Recently presented methods allow for the robust computation of exact geodesic distance fields. However, in these algorithms, the distance computation is initialized by one or more isolated points on the mesh and the distance is propagated from them.

Unfortunately, for many practical applications this is too restricted. In general one would like to be able to compute the geodesic distances with respect to a curve on the surface, e.g., a polygon defined on a triangle mesh since this allows us to take arbitrary boundary conditions into account. Moreover, it is unavoidable to upsample the resulting explicit distance field representation to obtain the necessary accuracy for practical applications, especially near the geodesic medial axis.

We developed an efficient and robust algorithm to solve both tasks by observing that the geodesic distance field on a triangle mesh is piecewise linear and by accordingly decomposing the geodesic field into its linear pieces over which the distance field can be represented exactly. The isolines of two highly accurate distance fields computed with our novel method are depicted below. Notice the well-resolved shocks in concave regions of the geodesic iso-contours.
Computing the exact lighting of a scene is of high relevance not only for engineering, design and architectural purposes. Global illumination is also used in movie production, advertisement, video games, art, and many other areas. In fact every computer generated photorealistic picture uses global illumination in some way.

In our work we show that with today's highly parallel multi-core CPUs and GPUs it is possible to implement an interactive system for diffuse global illumination using simple and efficient computations on custom PC hardware. We concentrated on NVIDIA's CUDA, since it is the first already available general purpose computing platform and it supports the highest degree of parallelization. Our implementation allows for rapid light exchange, using data structures that fully exploit the power of many-core compute platforms. Moreover we have achieved to maintain interactivity in deformable scenes, with moving, non-rigid objects and with moving light sources. This enables our system to be used both in interactive relighting applications as well as in future game engines. Although we use the CUDA platform, our system is general enough to be easily ported to other parallel compute platforms such as the Cell architecture, as well as other upcoming systems.

Besides the simulation of light in the visible spectrum which is used for image synthesis, we can simulate other kinds of electromagnetic radiation as well. Most notably we compute the propagation of radio waves for mobile communication systems. By using quite similar algorithms and techniques as they are known from computer graphics, we achieve high performance and good accuracy for a full 3D estimation of the radio field including estimates of the delay spread. This can be used for optimized antenna placements, network simulations and network analysis.

(a) and (b) Global illumination makes computer generated images more realistic with effects like diffuse interreflections and caustics. (c) Ray tracing approaches not only work for visible light, but also for the simulation of radio wave propagation.
Recent evaluations of several techniques for multi-view stereo reconstruction have shown that the quality and speed of most multi-view stereo algorithms depend significantly on the number and selection of input images. In general, not all input images contribute equally to the quality of the output model, since several images may often contain similar and hence overly redundant visual information. This leads to unnecessarily increased processing times. Yet, a certain degree of redundancy can help to improve the quality of the reconstruction in more "difficult" regions of a model.

In this project we have proposed an image selection scheme for multi-view stereo which results in improved reconstruction quality compared to uniformly distributed views. Our method is tuned towards the typical requirements of current multi-view stereo algorithms and is based on the idea of incrementally selecting images so that the overall coverage of a simultaneously generated proxy is guaranteed without adding too much redundant information. Critical regions such as cavities are detected by estimating the local photo-consistency and are improved by adding additional views. Our method is highly efficient, since most computations can be out-sourced to the GPU. We evaluated our algorithm using four different methods participating in a standard benchmark (Middlebury Multi-View Stereo Evaluation) and showed that in each case reconstructions based on our selected images yield an improved output quality while at the same time reducing the processing time considerably.

The above figure shows a sequence of images selected by our algorithm and the surface quality estimates on an iteratively refined proxy model. Blue areas correspond to a high surface confidence, while red areas represent regions in 3D space which have not been covered sufficiently by the input images.
While many techniques for the 3D reconstruction of small to medium sized objects have been proposed in recent years, the reconstruction of entire 3D scenes is still a challenging task. This is especially true for indoor environments where existing active reconstruction techniques are usually quite expensive and passive, image-based techniques tend to fail due to high scene complexities, difficult lighting situations or shiny surface materials.

To fill this gap we have developed a novel low-cost method for the reconstruction of depth maps using a video camera and an array of laser pointers mounted on a hand-held rig. Similar to existing laser-based active reconstruction techniques, our method is based on a fixed camera, moving laser rays and depth computation by triangulation. However, unlike traditional methods, the position and orientation of the laser rig does not need to be calibrated a-priori and no precise control is necessary during image capture. The user rather moves the laser rig freely through the scene in a brush-like manner, letting the laser points sweep over the scene's surface. We do not impose any constraints on the distribution of the laser rays, the motion of the laser rig, or the scene geometry except that in each frame at least six laser points have to be visible.

Our main contributions are two-fold. The first is the depth map reconstruction technique based on irregularly oriented laser rays that, by exploiting robust sampling techniques, is able to cope with missing and even wrongly detected laser points. The second is a smoothing operator for the reconstructed geometry specifically tailored to our setting that removes most of the inevitable noise introduced by calibration and detection errors without damaging important surface features like sharp edges.
Offset surfaces play a very important role in geometry processing and especially in various CAD/CAM applications. Since all commercial CAD systems are able to handle polygonal meshes or at least provide import and export routines for them, polygonal meshes can be seen as the universal geometry representation for data exchange.

We have developed a new algorithm for the efficient and reliable generation of offset surfaces for polygonal meshes. The algorithm is robust with respect to degenerate configurations and computes (self-)intersection free offsets that do not lose small and thin components. The results are correct within a prescribed $\varepsilon$-tolerance. This is achieved by using a volumetric approach where the offset surface is defined as the union of a set of spheres, cylinders, and prisms instead of surface-based approaches that generally construct an offset surface by shifting the input mesh in normal direction. A simple but effective mesh operation allows us to detect and include sharp features (shocks) into the output mesh and to preserve them during post-processing (decimation and smoothing). The problem of limited voxel resolutions inherent to every volumetric approach is avoided by breaking the bounding volume into smaller tiles and processing them independently. This allows for almost arbitrarily high voxel resolutions on a commodity PC while keeping the output mesh complexity low.

From left to right: Morphological opening operation on the Bunny model by computing the inner offset of an outer offset of the original surface. The offset surface generated for a CAD cogwheel model and our volume tiling approach is visualized on the offset surface of the Buddah model.
Today there exists a large variety of different 3D modeling software applications and libraries. Most of them are proprietary or they do not provide all the features required to establish an open platform for research projects in geometry processing. In order to simplify the iterative process of implementing and testing new algorithms for software developers and to provide a common and open platform for 3D geometry processing, we developed a flexible 3D geometry modeling framework called OpenFlipper.

This framework provides many features required for 3D modeling like a flexible rendering environment supporting a large number of different visualization modes, a highly customizable graphical user interface, 3D user interaction metaphors and data management. Additional functionality can be added easily by a powerful plugin API. This includes not only algorithmic extensions but also user interface elements or support for new file formats and content types.

As the framework itself is open source, developers can easily contribute to the extension of a growing modeling framework by adding plugins with new functionality. On the other hand, users can explore and test new techniques with one unified graphical front end on many different platforms and operating systems including Windows and Unix based systems like Linux or Mac OS.

In the current version, OpenFlipper already includes many algorithms for the processing of triangle and polygonal meshes. Some examples are decimation and refinement of meshes for adjusting the complexity. To provide mesh editing operations, we developed plugins for smoothing/filtering, holefilling, multi-resolution deformation, mesh repair and many others.

Among other features, OpenFlipper offers an easy to use scripting language. Almost the entire functionality can be accessed through this language. Using the scripting option we can run computations and tests in batch mode without user interaction or, by using the modeling features of OpenFlipper, generate high quality 3D animations.
Parametric descriptions of 3D objects, i.e., continuous and bijective mappings from a 2D parameter domain to the 3D positions on an object's surface are fundamental for many tasks in Computer Graphics and Geometry Processing.

For example, the optimization of a polygonal mesh representation for some 3D model can be performed easily in the 2D domain and then be lifted to the surface by simply evaluating the parametrization. However, for this procedure to produce high quality results, the parametrization has to satisfy certain requirements, most importantly, the iso-parameter lines of the mapping have to be oriented locally according to the field of principal directions on the surface and specific parameter values have to be set in order to guarantee a proper alignment with sharp surface features (in order to avoid alias errors).

Using an image of a 2D integer grid as texture, the parametrization can be visualized as a quad grid on the surface (left). If the corresponding quad mesh is extracted explicitly, the wrong orientation and alignment of the parameterization leads to severe meshing artefacts (right).

In this project we develop new techniques for global parametrization and quad meshing which allow us to take directional and positional constraints into account. The interpolation of such constraints is achieved by allowing the individual quads to stretch and deform slightly. However, the overall result typically captures the underlying geometric structure of the input object much better than previous techniques.
Generating high quality 3D content for animations, image synthesis or other applications can be a time consuming task. This is particularly disturbing when a large number of different individual objects of a similar type have to be generated. One approach to speed up this task is to reuse existing components or objects and recombine them to new ones.

For the creation of humanoids, we can, e.g., use a collection of hands, arms, legs, heads, and many other parts. To create such a database, the designer needs to have a set of tools which can cut objects into smaller pieces, deform existing parts and recombine them to larger ones. Additionally a powerful database system is required to organize and find parts created during the modeling process.

We developed an interactive system where 3D geometry can be organized, cut, and recombined with very little effort in user interaction. These geometric tools are implemented as plugins to the OpenFlipper framework. The first tool can cut 3D geometry at arbitrary polygonal lines. Such segment boundaries can be defined either manually or automatically by various geometric criteria. The resulting parts are stored in a database system implemented in a second plugin. During this operation a potentially large number of parts can be created depending on the complexity of the original model and in how many segments each object is split.

To make part retrieval from the database easier for the designer we add semantic information to each part created. Using a semantic search database we can not only retrieve objects from the database containing a specific search term in their description or name but also objects whose descriptions are semantically related. For example if one part could be anatomically attached to another one in the database then there is a semantic relation (arm, hand, finger). This also enables the system to pro-actively suggest parts the designer might want to add to the model.

During all stages of this process the designer has the possibility to edit and change the shape of each part and therefore create new content beyond what is already stored in the database. The chosen parts are then recombined to create a final model like shown in the example below.
Virtual 3D models of entire cities become more and more important in applications like digital city guides, geographic information systems or large scale visualizations. Moreover, they play an important role in the planning process of wireless networks and the simulation of noise propagation or other environmental phenomena. However, generating 3D city models of sufficient quality with respect to different target applications is still an extremely challenging, mostly manual and hence time consuming and costly process. To improve this situation, we have presented a novel system for the rapid and easy creation of 3D city models from 2D land registry data and terrain information, which are commonly available in digital form for many cities.

In order to deal with the extreme complexity of a city model, our system is able to continuously vary the resulting level of correctness, ranging from fully automatically generated models with simple geometry and plausible appearance to landmark building models with correctly and individually textured facades and highly detailed geometry which are generated in a semi-automatic manner.

While our main target application is the high-quality, real-time visualization of complex, detailed city models, the models generated with our approach have successfully been used for radio wave simulations as well. To demonstrate the validity of our approach, we show an exemplary reconstruction of the city of Aachen.

The above figure shows a bird's eye view of our Aachen model and a close-up on the cathedral, both rendered in real-time despite the complex geometry and visual effects. The right image depicts a simulation of GSM network field strength based on our model.
We develop semi-interactive methods for advanced video processing and editing. The basic idea is to partially recover planar regions in object space and to exploit this minimal pseudo-3D information in order to make perspectively correct modifications. Typical operations are to increase the quality of a low-resolution video by overlaying high-resolution photos of the same approximately planar object or to add or remove objects by copying them from other video streams and distorting them perspectively according to some planar reference geometry. The necessary user interaction is entirely in 2D and easy to perform even for untrained users. The key to our video processing functionality is a very robust and mostly automatic algorithm for the perspective registration of video frames and photos, which can be used as a very effective video stabilization tool even in the presence of fast and blurred motion. Explicit 3D reconstruction is thus avoided and replaced by image and video rectification. The technique is based on state-of-the-art feature tracking and homography matching. In complicated and ambiguous scenes, user interaction as simple as 2D brush strokes can be used to support the registration. In the stabilized video, the reference plane appears frozen which simplifies segmentation and matte extraction.

In this example, the original painting from the input video stream (upper left; the used matte as inset) is replaced using the other two shown images (lower left). For each case two frames from the output stream are shown.
Other Activities

Committees and Organizations:

2008:

- Member of the ACM SIGGRAPH 2008 papers committee
- Member of the international program committee Eurographics 2008
- Member of the international program committee of Pacific Graphics 2008 (PG ’08)
- Member of the international program committee for the Symposium on Interactive 3D Graphics and Games I3D 2008, February 2008
- Member of the international program committee of the ACM SIGGRAPH/Eurographics Symposium on Geometry Processing, SGP 2008
- Member of the international program committee, European Conference on Computer Vision, ECCV 2008
- Member of the international program committee, 5th ACM Symposium on Point-Based Graphics, PBG 2008
- Member of the technical program committee for the Brazilian Symposium on Computer Graphics and Image Processing, SIBGRAPI 2008
- Member of the international program committee Shape Modeling International 2008 (SMI ’08), June 2008, New York, USA
- Member of the international program committee ACM Symposium of Solid and Physical Modeling 2008
- Member of the program committee, 5th GI workshop on Virtual and Augmented Reality, 2008 (Workshop VR/AR 2008)
- Member of the international program committee, 4th International Symposium on Visual Computing, ISVC 2008
- Member of the Günter Enderle Award committee, Eurographics Conference 2008
- Member of the program committee for the 4th International Symposium on 3D Data Processing, Visualization, and Transmission (3DPVT 2008)
- Member of the international program committee, 16th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision, WSCG 2008
- Member of the international program committee of the seventh conference on "Mathematical Methods for Curves and Surfaces", Toensberg, Norway, 2008
- Member of the international program committee of Geometric Modeling and Processing 2008 (GMP 2008), April 23-25, Hangzhou, China

2007:

- Member of the international program committee: Eurographics 2007
- Member of the international program committee, Pacific Graphics 2007 (PG ’07)
- Member of the international program committee of the IEEE Conference on Computer Vision and Pattern Recognition, CVPR 2007
- Member of the international program committee: ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games 2007, Seattle
• Member of the international program committee of the ACM Symposium on Solid and Physical Modeling 2007, Beijing, China
• Member of the international program committee: Eurographics/ACM Symposium on Geometry Processing 2007, Barcelona, Spain
• Member of the international program committee of the ACM SIGGRAPH/Eurographics Symposium on Point-Based Graphics 2007, Prague
• Member of the international program committee of the Brazilian Symposium on Computer Graphics and Image Processing SIBGRAPI 2007
• Chair of the 2nd Tsinghua Workshop on Geometry Processing, Tsinghua University, Beijing, June 2007
• Member of the international program committee, Conference on Vision, Modeling and Visualization, VMV 2007, Saarbrücken, 2007
• Member of the program committee, 4th GI workshop on Augmented and Virtual Reality, 2007
• Member of the international program committee of the 3rd International Symposium on Visual Computing (ISVC 07) Lake Tahoe, USA
• Member of the international program committee for the workshop on New Advances in Shape Analysis and Geometric Modeling (NASA-GEM) at the Cyberworlds 2007 conference
• Member of the international program committee 6th IFIP International Conference on Entertainment Computing 2007 (ICEC 2007), Shanghai, China
• Member of the international scientific committee of the SIAM Conference on Geometric Design 2007, San Antonio, USA
• Member of the international program committee: WSCG 2007: International Conferences in Central Europe on Computer Graphics, Visualization and Computer Vision
• Member of the international program committee: Shape Modeling International Conference 2007, Lyon, France
• Member of the international program committee: 11th IMA Mathematics of Surfaces conference, Sheffield, UK, September 2007

Offices:
• Department Chair of the Computer Science Department at RWTH
• Deputy Member in the RWTH Senate
• Fellow of the Eurographics Association
• Member of the Editorial Board of the Computers & Graphics Journal
• Member of the Editorial Board, Journal of WSCG (ISSN 1213-6972)
• Co-Editor of the Springer book series “Geometry and Computing” (Computer Science & Mathematics)
• Member of the Pacific Graphics Steering Committee (sole non-Asian member)
• Vertrauensdozent der Studienstiftung des deutschen Volkes
• Member of the Center for Computational Engineering Science (CCES)
• Scientific Advisor, German-Israeli Foundation for Scientific Research and Development
• Chair of the GI-Fachgruppe “Geometry Processing”
• Member of the Scientific Board at the Virtual-Reality Center Aachen (VRCA)
• Head of the Steering Committee: Symposium on Geometry Processing
• Organizational Member of the Eurographics Association
• Member of the regional industry club REGINA e.V.
• Member of the Society for Industrial and Applied Mathematics SIAM
• Director of the Steinbeis Transfer Center for “Geometry Processing and CAGD”

• Martin Habbecke: Student Advisor, main study period computer science

**Participation in Major Research Grants**

“Ultra High-Speed Mobile Information and Communication” (UMIC)
Excellence Research Cluster, 2006-2011, German Research Foundation (DFG), principal investigator and member of the steering committee

“Aachen Institute for Advanced Studies in Computational Engineering Sciences” (AICES)
Excellence Graduate School, 2006-2011, German Research Foundation (DFG), principal investigator

“Software for mobile communication systems”
Research Training Group (= graduate school for top Ph.D. students), 2000-2009, German Research Foundation (DFG), principal investigator

“Brain-Behavior Relationships of Emotions in Schizophrenia and Autism”
Research Training Group (= graduate school for top Ph.D. students), 2006-2010, German Research Foundation (DFG), principal investigator

“B-IT Research School for Applied Informatics”
Talks and Publications

Invited Talks:

2008:

L. Kobbelt: *Local Feature Size Adaptive Mesh Generation*
General Motors R&D Department Detroit, USA, August 2008

L. Kobbelt: *Pre-Processing of Polygonal Models*
Seoul National University, Seoul, Korea, July 2008

L. Kobbelt: *Recent Topics in Computer Graphics*
Korea University, Seoul, Korea, July 2008

L. Kobbelt: *Geometry Processing in Medical Applications*
Ehwa University, Seoul, Korea, July 2008

2007:

L. Kobbelt: "New Trends in Mesh Processing and Repair", General Motors R&D Department, Detroit, November 2007


A. Hornung: *Image-based Rendering and Reconstruction*, ETH Zürich, Switzerland, November 2007


Conference presentations:
2008:

L. Kobbelt, M. Botsch: ITMAN / SGP 2008 Course in Geometry Processing, Technical University of Denmark, June/July 2008, two full days

L. Kobbelt: *Geometry Processing in Industrial Design*, SIAM Annual Meeting 2008, San Diego, USA


C. Manthei, J. Krassnigg: *City Virtualization*, 5th Workshop der GI-Fachgruppe VR/AR, Magdeburg, Germany, September 2008


2007:

M. Botsch, M. Pauly, L. Kobbelt, B. Levy, P. Alliez: *Geometric Modeling Based on Triangle Meshes* SIGGRAPH 2007 course, full day

D. Bommes: *Accurate Computation of Geodesic Distance Fields for Polygonal Curves on Triangle Meshes*, VMV Konferenz, Saarbrücken, November 2007

E. Dekkers: *Character Animation from 2D Pictures and 3D Motion Data*, Tweenwork Award 2nd prize, Stuttgart, May 2007


A. Schmitz: *Blender in Research & Education*, Blender Conference, Amsterdam,
Netherlands, October 2007

Publications:

2008:

J. Huang, M. Zhang, J. Ma, X. Liu, L. Kobbelt, H. Bao: *Spectral Quadrangulation with Orientation and Alignment Control*, to appear at SIGGRAPH Asia 2008


M. Botsch, M. Pauly, L. Kobbelt, B. Levy, P. Alliez: *Geometric Modeling Based on Polygonal Meshes*, Eurographics 2008 tutorial, full day


2007:
Data Management and Exploration

Staff

- Faculty
  Univ.-Prof. Dr. rer. nat. Thomas Seidl
  E-mail: Seidl@informatik.rwth-aachen.de
  http://www.dme.rwth-aachen.de

- Secretary
  Hedi Klee

- Technical Staff
  Detlef Wetzeler

- Academic and Research Staff
  Dr. rer. nat. Ira Assent
  Dr. rer. nat. Christoph Brochhaus
  Dr. rer. nat. Ralph Krieger
  Dipl.-Inform. Christian Beecks
  Dipl.-Inform. Jost Enderle
  Dipl.-Inform. Stephan Günneumann
  Dipl.-Inform. Philipp Kranen
  Dipl.-Inform. Hardy Kremer
  Dipl.-Inform. Emmanuel Müller
  Dipl.-Inform. Marc Wichterich
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, bio-molecular and other multimedia data to name only a few of many application areas which need special data exploration algorithms.

Teaching

Summer term 2007:

- Lecture on “Data Mining Algorithms” (V4)
- Seminar on “Complex Objects in Databases”
- Lab course on “Data Structures”
- Contribution to the seminar “Medical Image Processing”

Winter term 2007:
• Lecture on “Index structures for databases” (V4)
• Seminar on “Methods and Tools”
• Seminar on “Recent developments in data mining”
• Lab course on “Data mining algorithms”
• Contribution to the lecture on “Bionics”
• Contribution to the lecture on “Medical Image Processing”
• Contribution to the lecture on “Data Intensive Computing”

Summer term 2008:

• Lecture on “Advanced Data Mining Algorithms” (V3)
• Lecture on “Algorithms and Data Structures” (V2)
• Seminar on “Complex Objects in Databases”
• Seminar on “Methods and Tools”
• Contribution to the seminar on “Medical Image Processing”
Research Projects
Core Data Base Technologies & Indexing

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.

Intervals represent a fundamental data type for temporal, scientific, and spatial databases where time stamps and point data are extended to time spans and range data, respectively. For database applications on large amounts of data, not only intersection queries have to be processed efficiently but also general interval relationships including before, meets, overlaps, starts, finishes, contains, equals, during, startedBy, finishedBy, overlappedBy, metBy and after. Our new algorithms use the Relational Interval Tree, a purely SQL-based and object-relationally wrapped index structure for managing interval data. This technique therefore preserves the industrial strength of the underlying RDBMS including stability, transactions, and performance. The efficiency of our approach has been demonstrated by experimental evaluations on large sets of generated as well as real-life data. In order to support broader ranges of data with our approach, we will extend our algorithms to support intervals with floating-point valued endpoints. Furthermore, we plan to adopt the newly developed methods to similarity search as well as to various application domains.

The increasing use of temporal and spatial data in present-day relational systems necessitates an efficient support of joins on interval-valued attributes. Standard join algorithms do not support those data types adequately, whereas special approaches for interval joins usually require an augmentation of the internal access methods which is not supported by existing relational systems. To overcome these problems we introduced new join algorithms for interval data.

Based on the Relational Interval Tree, these algorithms can easily be implemented on top of any relational database system while providing excellent performance on joining intervals. As experimental results on an Oracle9i server have shown, the new techniques outperform existing relational methods for joining intervals significantly. Furthermore, we enhanced our algorithms to support additional selection predicates on scalar and temporal attributes as well as additional join predicates on scalar attributes. We also investigated the applicability of our join algorithms to scenarios where one of the joining relations is provided by a stream. In order to integrate the RI-tree in present-day object-relational database systems, we use their extensible indexing frameworks that enable developers to extend the set of built-in index structures by custom access methods. Although these frameworks permit a seam-less integration of user-defined indexing techniques into
query processing they do not facilitate the actual implementation of the access method itself. In order to leverage the applicability of indexing frameworks, relational access methods such as the Relational Interval Tree (RI-tree), an efficient index structure to process interval intersection queries, mainly rely on the functionality, robustness and performance of built-in indexes, thus simplifying the index implementation significantly. To investigate the behavior and performance of the recently released IBM DB2 indexing framework we use this interface to integrate the RI-tree into the DB2 server. The standard implementation of the RI-tree, however, does not fit to the narrow corset of the DB2 framework which is restricted to the use of a single index only. We therefore adapt the originally two-tree technique to the single index constraint. As experimental results with interval intersection queries show, the plugged-in access method delivers excellent performance compared to other techniques.

Index support for CFD data post-processing
Christoph Brochhaus, in cooperation with the Virtual Reality group at CCC Aachen University

Methods numerically simulating the interaction of gases or fluids with complex surfaces (computational fluid dynamics, CFD) are able to perform calculations with increasing levels of detail due to the ongoing development of more powerful computers. CFD simulations are utilized during the design of e.g. combustion engines or airplanes, amongst many others. An increasing level of detail on the one hand allows for more accurate and meaningful simulation results proving very useful in industrial development and research. On the other hand, huge amounts of raw CFD data are generated and need to be repeatedly accessed during the subsequent interactive post-processing (e.g. isosurface extraction) by experts in the application domain. The efficiency of post-processing is significantly increased by the use of virtual reality (VR) technology, letting users immerse into the visualized data sets and extracted features. Interactive post-processing is efficiently performed on data sets stored in main memory, which outperforms secondary storage by magnitudes regarding access times. Large CFD data sets not fitting into main memory thus require efficient secondary storage methods.

We propose methods which appropriately arrange CFD data on secondary storage and allow for an efficient access during post-processing. The efficiency of post-processing is improved by novel view-dependent query methods. The continuous extraction and visualization of partial results in the proximity and direct line of sight of the user allow for a “quick first impression” of the result set. The approaches are enhanced by dynamic aspects, reacting to a user freely roaming the VR environment with immediate alignment of query execution and of the result data stream.

We developed the index supported graphics data server IndeGS, which offers the developed indexing and access methods and can be integrated into arbitrary virtual reality frameworks. IndeGS executes post-processing queries according to a multitude of user parameters and streams the result data to the visualizing component of the VR framework. Relational database management systems (RDBMS) offer comfortable means to integrate user-defined indexes. An improvement of the relational interval tree (RI-tree) is proposed and utilized to
enable indexing and efficient view-dependent querying of CFD data in the context of interactive post-processing.

Data Mining

Subspace Clustering & Classification
Ira Assent, Ralph Krieger, Emmanuel Müller, Stephan Günnemann

Increasingly large data resources in life sciences, mobile information and communication, e-commerce, and other application domains require automatic techniques for gaining knowledge. One of the major knowledge discovery tasks is clustering which aims at grouping data such that objects within groups are similar while objects in different groups are dissimilar. In scenarios with many attributes or with noise, clusters are often hidden in subspaces of the data and do not show up in the full dimensional space. For these applications, subspace clustering methods aim at detecting clusters in any subspace.

We propose new subspace clustering models which remove redundant information and ensure the comparability of different clusters to enhance the quality and interpretability of the clustering results. At the same time the efficiency of the clustering process is guaranteed by the development of new algorithms.

Additionally we focus our research on the evaluation and visualization of patterns to benefit from human cognitive abilities for the knowledge generation.

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.

Anytime Stream Mining
Philipp Kranen, Ira Assent, Ralph Krieger

Management of data streams plays an important role, especially data mining tasks such as classification, aggregation, prediction and identification of relevant data. Due to the increasing volume of the data, it is no longer possible to buffer a stream and to process the data by using multiple passes. Thus the underlying algorithms for mining data streams have to
be designed in such a way that each data item is accessed at most once. There can be the requirement to provide results very fast, e.g. for peak load situations. For other tasks this requirement is not given but the luxury of additional time, with which a quality up to the best possible result can be achieved. Under greatly varying time constraints of a priori unknown stream inter-arrival rates, anytime algorithms provide the best result up to a point of interruption dictated through the arrival of the next stream element. For many mining tasks traditional algorithms are known that provide good results, yet cannot be interrupted in a meaningful manner. We therefore focus on such adaptive techniques for stream mining that enable interruptions at any time and that improve the quality of their results with more execution time available.

Data streams have naturally a temporal component and usually change over time. Mining algorithms have to be optimized for this case so that they are aware of the evolution of the data during the stream. The evolution of the underlying data distribution model is referred to as concept drift and novelty. Algorithms that try to find a model for the distribution of a given data set often need a considerable amount of time. To be able to deal with concept drift and novelty of very fast data streams, we therefore examine algorithms for modeling stream data distributions that support incremental learning. Other mining tasks like ranking and top-k queries search for the most interesting data or most relevant dimensions based on characteristic measures. However, as the data stream proceeds, previous results may become invalid with respect to recently arrived data items. Thus, maintaining correct result in a data stream environment, e.g. to a top-k query, makes efficient continuous query processing and incremental algorithms necessary.

Anytime algorithms are capable of dealing with the varying time constraints and high data volumes as described above. The advantages of anytime classifiers can be summarized as flexibility (exploit all available time), interruptibility (provide a decision at any time of interruption) and incremental improvement (continue improvement from current position without restart).

### Similarity Search

**Fast EMD Search**

Ira Assent, Marc Wichterich, funded by DFG grant SE 1039/1-2

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.
Continuous growth in sensor data and other temporal data increases the importance of retrieval and similarity search in time series data. Analysis of this data typically requires searching for similar time series in the data base. For interactive applications the efficiency of the search process is essential.

Existing multidimensional indexes like the R-tree provide efficient querying only for relatively few dimensions. Time series are typically long which corresponds to extremely high dimensional data in multidimensional indexes. Due to massive overlap of index descriptors, multidimensional indexes degenerate for high dimensions and access the entire data by random I/O. Consequently, the efficiency benefits of indexing are lost. Therefore we develop new index structures for efficient time series retrieval and similarity search. For example, by exploiting inherent properties of time series, it is possible to index the time series in an overlap-free manner. For query processing, powerful pruning mechanisms are being developed which rely on additional information, e.g. metadata, to greatly reduce the number of pages which have to be accessed, resulting in substantial speed-up.

Dynamic Time Warping (DTW) is a widely used high quality similarity measure for time series. As DTW is computationally expensive, efficient algorithms for fast DTW computation are crucial. Scalability to long time series, wide DTW bands, and a high number of attributes are still challenging issues. We develop new techniques that exploit properties of DTW to substantially reduce the number of calculations required to compare a query time series with the time series in a data base in multistep retrieval. The techniques address high flexibility and combinability with existing indexing structures and DTW filters.
Relevance Feedback
Christian Beecks, Marc Wichterich

Large multimedia databases are common in scientific, commercial and entertainment applications. As the amount of data grows, the effort to get insight into the data grows. Relevance Feedback is a promising approach to explore comprehensive multimedia databases. Based on adaptable distance functions, our research focuses on capturing user preferences. We therefore develop several new techniques for the Earth Mover’s Distance (EMD) and for the Quadratic Form Distance (QF) that reflect the users’ perception in the search process. In addition to an effective and efficient search process, we develop new interactive visualization techniques to make the exploration process more accessible and more intuitive. The interaction allows exploration of large amount of data with modest effort for the user.

UMIC

Energy Awareness of Applications
(Part of UMIC Research Area D)
Emmanuel Müller, Philipp Kranen, funded by DFG grant EXC 89

While bandwidth of mobile networks and processing power of mobile devices are enhanced continuously, the energy capacity of mobile clients stays the bottleneck of mobile applications. Due to this energy efficiency has to be considered through all layers of mobile communication. We focus our research on the energy awareness of applications. In a first subproject we develop Air Indexing techniques for transmitting large volumes of data through error prone broadcast channels. In a second subproject we focus on mobile sensor networks and energy efficient data provisioning out of such sensor networks.
Data dissemination: Air Indexing
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.

Figure 3: Possible grouping in a sensor network

Data provisioning in mobile sensor networks
We develop techniques to achieve energy efficient communication also for peer-to-peer communication. An interesting application in this domain are mobile sensor networks, where mobile clients are equipped with multiple sensors and can be seen as a huge distributed data source. The task is to collect the measured sensor data by querying the mobile clients. The problem in this scenario is the lifetime of the sensor network, which is highly dependable on the energetic cost for querying the mobile clients.

In this subproject we focus our research on the detection of possible groups of sensors and aggregation techniques for the measured sensor data. Finding a grouping of the sensors by analyzing their measurements can be used to query only one representative client of a group at a time. Thus we can prolong the overall lifetime of a sensor network by reducing the number of queries on the network.

Mobile Stream Mining
(Part of UMIC Research Area B)
Philipp Kränen, Emmanuel Müller, funded by DFG grant EXC 89
Data streams are ubiquitous in mobile environments ranging from broadcast scenarios to sensor networks. For mining data streams in a mobile context we focus our research on scalable solutions that take the limited resources of mobile devices such as mobile phones or sensor nodes into account. Furthermore we examine distributed mining processes, e.g. for sensor networks or multi-user environments, that solve parts of the task on the single devices before sending intermediate results to a central server or another device in a hierarchy. Particular attention is paid to techniques that reduce the amount of communication and still meet guaranteed quality criteria for the overall result.

Mobile stream mining becomes inherently complex on multidimensional data and high frequent streams. Algorithms have to be designed in a way that allows processing all data as precise as possible regarding the available resources. Therefore we also investigate stream aggregation techniques that allow situation dependent processing of incoming data. Again, particular attention is paid to approximation techniques that meet guaranteed quality criteria.

For example, with the UMIC Device in the HealthNet project (UMIC B.2) we get the ability to collect data continuously from patients and mobile medical staff resulting in large data volumes. By analyzing multidimensional sensor data from possibly correlated sensors, the device can classify the health status of a patient. The device uses a preclassifier that we derive from the full-classifier on the server and that is tailored for the limited resources. Based on the classification result on the mobile device, the data can either be aggregated or transmitted for further mining purposes.
Other Activities

Dissertations

Industrial and Academic Collaboration
- AT&T Labs Research, USA
- Chair of Information Processing, Universität Konstanz
- CIM GmbH, Aachen
- DaimlerChrysler AG, Böblingen
- Forschungsinstitut für Rationalisierung (FIR), Aachen
- Institut für Kunststoffverarbeitung (IKV) in Industrie und Handwerk, RWTH Aachen
- National Instruments, Aachen
- UMIC Research Cluster, RWTH Aachen

Conference and Workshop Organization
- Datenbanksysteme in Business, Technologie und Web (BTW 2007) (in coop. with i5)
- Workshop on Nature Inspired Methods for Local Pattern Detection (NiLoP 2007)

Reviewing Activities
- IEEE Transactions on Computers (TC)
- Elsevier Information Systems (IS)
- Elsevier Data & Knowledge Engineering (DKE)
- The International Journal on Very Large Data Bases (VLDBJ)
- ACM SIGMOD Int. Conf. on Management of Data (SIGMOD 2007)
- IEEE Int. Conf. on Data Engineering (ICDE 2008)
- IEEE Int. Conf. on Data Engineering (ICDE 2009)
- IEEE Int. Conf. on Data Mining (ICDM 2007)
- Int. Conf. on Database and Expert Systems Application (DEXA 2007)
- Int. Conf. on Database and Expert Systems Application (DEXA 2008)
- Int. Conf. on Extending Database Technology (EDBT 2008)
• Int. Conf. on Extending Data Base Technology (EDBT 2009)
• Int. Conf. on Extending Data Base Technology (EDBT 2009 Demo)
Publications


Brochhaus C., Seidl T.: IndeGS^RI : Efﬁcient View-dependent Ranking in CFD Post-processing Queries with RDBMS. Proc. of the 20th International Conference on Scientiﬁc and Statistical Database Management (SSDBM), Hong Kong, China (2008)


Wichterich M., Beecks C., Seidl T.: History and Foresight for Distance-Based Relevance Feedback in Multimedia Databases, Workshop on Future Directions. Multimedia Knowledge Management (MMKM 2008), Milton Keynes, United Kingdom (2008) (Poster presentation)

Kim S., Leonhardt S., Zimmermann N., Kranen P., Kensche D., Müller E., Quix C.: Influence of contact pressure and moisture on the signal quality of a newly developed textile ECG sensor shirt. 5th International Workshop on Wearable and Implantable Body Sensor Networks (BSN 2008), Hong Kong, China (Jun 2008)


Staff

- **Head:**
  Prof. Dr.-Ing. Ulrik Schroeder
  schroeder@informatik.rwth-aachen.de
  http://eLearn.rwth-aachen.de/

- **Secretary:**
  Katrin Römer
  roemer@informatik.rwth-aachen.de
  Phone: +49-241-80-21931
  Fax: +49-241-80-22930

- **Research Assistants:**
  Dipl.-Inform. Eva Altenbernd-Giani
  Dipl.-Inform. Mostafa Akbari (partly funded by Gender research grant, excellence program of RWTH since October 2008)
  Dipl.-Inform. André Calero Valdez (partly funded by RWTH research grant since March 2008)
  Dipl.-Gyml. Thiemo Leonhardt (partly funded by MINT research grant, excellence program of RWTH since October 2008)
  Anne-Christien Pielka, M.A. (partly funded by Gender research grant, excellence program of RWTH since October 2008)
  Dipl.-Gyml. Nils van den Boom (Jan.07 funded by regio iT)

- **Technical Staff**
  Detlef Wetzeler
• Diploma-, Master-, and Secondary Teacher Thesis Students
  Susanne Aghassi, Mostafa Akbari, Jan Balter, Philipp Brauner, Samer Catalan, Daniela Deutz, Anna Lea Dyckhoff, Barbara Friemann, Nina Gholidazeh, Nils Gräf, Stefan Hamacher, Michaela Hauck, Bodo von der Heiden, Daniel Herding, Dirk Hesse, Anke Honskamp, Andreas Horstmann, Bernd Kaleß, Andrea Klinkenberg, Thiemo Leonhardt, Juliane Mattes, Anne-Christien Pielka, Patrick Stalljohann, Norbert Töpker, David van de Water

• Student Researchers and Teaching Assistants
  Mostafa Akbari, Sebastian Bitzen, Susanna Bölling, Andreas Hackelöer, Tim Hemig, Philipp Kucirek, Thiemo Leonhardt, Mario Lukas, Carsten Mai, Andreas Molitor, Claire Prouve, Tobias Reimes, Jascha Ulrich, Yan Zhang
Overview

The group’s focus in research and teaching covers various topics in computer-supported learning, web technologies, user-centered design methodologies and the didactics of computer science, among them:

- instructional design of content and eLearning functions:
  - utilization of innovative software engineering methods and tools for the analysis, specification, design and implementation of eLearning scenarios, and contents;
  - innovative instructional theories and their realization with modern web technology (Web 2.0);

- user-centered 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;
  - feedback focusing on the learning process;

- tools for user-centered design of interactive systems:
  - seamless integration of different level prototypes;
  - automatic evaluation of user interaction with prototypes;

- 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
  - gender- and diversity in computer science education

This year’s activities focused on establishing the CiL–center for integrative teaching and learning concepts – as the central eLearning center of RWTH Aachen University and widening the group’s research in eLearning, usability engineering and computer science education as well as gender and diversity issues.

The CiL team, being responsible for the sustainable introduction of eLearning elements into the university’s study programs, designs the technological, instructional and administrative framework for blended learning at RWTH Aachen University. The main focus of 2007 activities were the design, development, and deployment of the central eTeaching & eLearning portal L²P in cooperation with the computer and communication center and supportive measures such as courses and first level support for all questions concerning eLearning. The portal had a very successful start in the summer term 2007 with more than 300 regular courses using the system. The following winter term exceeded even our best hopes with already more than 800 courses utilizing L²P and more than 60.000 students booked in these courses. Within the one and a half years since its launch L²P has been established as a stable and well-adopted eLearning platform. These numbers put RWTH Aachen University into the top universities in Germany concerning its adoption of a blended learning approach.

Within the last year we were very successful with research proposals. All of our four applications for research scholarships as well as our research proposal within the BMBF program of empirical educational research have been approved. The first scholarship has been granted to André Calero-Valdez for his research in the design of eHealth systems in cooperation with Prof. Ziefle from the psychology department. The other pre-doctorial fellowships for research on gender and diversity and for research in didactic approaches in
MINT subjects have been granted to Anne-Christien Pielka, Mostafa Akbari, and Thiemo Leonhardt within the program of excellence of RWTH Aachen University. Ms. Pielka will investigate gender differences in interaction with eLearning systems and focus on the design of help- and support systems from a standpoint of communication science. Mr. Akbari will be concerned with a user-centered design of widgets for mobile learning, specifically utilizing Web 2.0 applications, social networks and integration of learning into spare time. He will also investigate gender and diversity issues in his approach. Mr. Leonhardt will research new ways of raising interest in MINT topics in schools especially for girls.

In the BMBF-funded three-year project “SAiL-M – semi-automatic analysis of individual learning processes in mathematics” we will investigate new ways in formative evaluation and feedback based on observation and classification of learning processes in mathematics in similar disciplines.

During the 6th eLearning conference in computer science - DeLFI 2008, where our group presented four papers and organized a workshop on “eLearning 2.0 – social software in the field of technology enhanced learning”, our paper on “GUI adaptation in learning contexts” was awarded the best paper of the conference.

**Teaching**

Lectures:
- eLearning (summer term 07 & summer term 08)
- Introduction to Web Technologies (winter term 06/07 & winter term 07/08)
- Einführung in die Fachdidaktik Informatik – FdI 1 (summer term 08)
- Unterrichtsmethoden der Informatik – FdI 2 (winter term 06/07)
- Introduction to Computer Science: Programming (winter term 07/08)

Lab Courses:
- eLearning Engineering project lab (winter term 06/07 & summer term 07)
- eLearning Content Design Projektpraktikum (winter term 06/07 & winter term 07/08)
- Fachdidaktisches Schulpraktikum (winter term 06/07, summer term 07, winter term 07/08)

Seminars:
- Fachdidaktisches Seminar zu den Praxisphasen (winter term 06/07, summer term 07)
- Fachdidaktisches Seminar "Projektmanagement in Softwareprojekten des Informatikunterrichts in der Schule" (summer term 07)
- Weiterbildungsseminar „Fachdidaktik“ für Informatiklehrkräfte (winter term 07/08)
- Research seminar eLearning (winter terms 06/07 & 07/08, summer terms 07 & 08)
- Research seminar Computer Science Education (winter terms 06/07 & 07/08, summer terms 07 & 08)
In order to support more than 30,000 students and 2,500 academic employees of RWTH Aachen University with web-based eLearning and eTeaching facilities and to step up to the challenge of fast-growing administrative complexity to handle thousands of courses, enrollments, and exams, RWTH Aachen University has founded the Center for integrative eLearning & eTeaching (CiL) in 2005. In cooperation with the Center for Computing and Communication (CCC) of RWTH and sponsored by Microsoft Germany, the CiL has developed and introduced the university-wide eLearning portal L²P.

Studies show that a close integration to existing processes and IT-infrastructure is necessary to establish a sustainable usage of eLearning at universities. Thus, L²P is seamlessly integrated with the campus management system (CAMPUS) and the identity management (TIM) of RWTH. Using L²P was designed to be simple: Lecturers enter their courses in the electronic course catalog and book rooms and lecture halls within the CAMPUS system. They are then able to create virtual course rooms just by one click. L²P-course rooms are made available through the central, university-wide eLearning portal. All virtual course rooms are structured alike and provide the same functions (e.g., announcement functions, discussion forums, and wiki-pages). Course rooms are customizable but adaptability is limited in favor of a clear homogeneous structure of all course rooms. Since L²P is password protected and students can only access a course room, if they have been enrolled to the course within CAMPUS, lecturers are able to address exactly the students of their courses.

While working with virtual course rooms, lecturers upload course materials including slides, scripts, video recordings and compile catalogs of literature. They can set up lists of hyperlinks to relevant websites, write announcements, or create surveys and electronic tests to check the learning progress of their students. Supported by integrated workflows, they can request digitalization of literature that will be examined on the basis of German copyright law and in case of approval be carried out directly to the course room by staff of the universities library. Course rooms also support several ways for communication and collaboration between students, tutors, and teachers. Similarly, students can access all relevant information and materials of their courses at one website via the web.

The platform has been well-adopted among lecturers and students of RWTH Aachen University since it was introduced university-wide in summer term 2007. During the three successive semesters since the start of L²P, over 2,000 virtual course rooms have been created and over 120,000 students have been booked to courses.
SAiL-M: semi-automatic analysis of individual learning processes

Daniel Herding (funded by BMBF) and Ulrik Schroeder in collaboration with Ch. Bescherer, Ch. Spannagel (PH Ludwigsburg), U. Kortenkamp (PH Schwäbisch Gmünd), W. Müller (PH Weingarten)

The Federal Ministry of Education and Research funds this 3-year project within its program of empirical educational research.

In university courses with hundreds of participants, it is impossible for the tutors to take extensive care of each student. On the other hand, completely automated learning environments often do not offer the feedback that weaker students require in order to catch up. Therefore, the goal of the project is to develop concepts and tools that allow for a semi-automated analysis of individual learning processes in mathematics and other disciplines.

The learning environments of the SAiL-M project will be based on existing educational applications developed by our project partners on the one hand, and on the Jacareto tool on the other hand. In the course of the project, these tools will be augmented to allow for the evaluation of learning processes. The project findings will be applied to computer science courses in Aachen, such as the "Introduction to Programming" lecture.

Jacareto

Ulrik Schroeder, Daniel Herding together with 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 has been successfully 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 focusing 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.
Learning process oriented eAssessment and intelligent feedback
Eva Altenbernd-Giani, Patrick Stalljohann, and Ulrik Schroeder

Presenting information does not suffice to ensure successful learning. Rather, the learner must deal with the material actively. For this purpose, exercises are offered among other things. To increase the number and frequency of the exercises offered to the learner, computers have been used for automatically correcting objective tests for a long time. These are such that the correct solution must be known in advance, and that the answers given by the learner are evaluable by a simple test procedure (e.g. single/multiple choice). These simple procedures allow using such objective tests in a variety of fields. To really benefit from such tests, the learner should receive evaluated feedback concerning both his solution and his approach to reach the solution. However, the type and scope of feedback to objective and automatically evaluable tests often do not exceed a justification of either correctness or faultiness, and they mostly report only success or failure (correct/false). Determining the reason of failure is seldom possible and depends on the design of the test.

Special skills, such as programming, drawing a diagram or writing an essay, cannot be evaluated by such tests. Therefore, there were soon first approaches of eAssessment systems, with a focus on specific domains, which tried to at least semi-automatically correct exercises specific to these domains. In these systems, specialized correction procedures where implemented to identify typical errors and thus to give better feedback.

In addition to correcting a learner’s solution and giving feedback, it is also reasonable to support him in the process of reaching the solution. To achieve this, the learner may solve exercises in teams, with the additional help of tools supporting collaborative work. Moreover, one can use tools that allow to monitor the learner’s progress while solving an exercise, and that allow to give hints when the learner gets stuck or is heading in the wrong direction.

In this project, we aim for a workflow-based framework that will allow to create arbitrary, domain independent exercises together with their respective correction procedures. The framework should also allow manual correction phases at specific points in the correction procedure, which are referred to as “tutor-in-the-loop” steps. Furthermore, we develop specific tools that give feedback and hints to a learner solving an exercise.

Gender- and diversity-sensitive, user-centered design for help and support systems in eLearning environments
Anne-Christien Pielka (funded by a gender research grant within the excellence program of RWTH Aachen University) and Ulrik Schroeder

The intent of the dissertation is to develop a method of a gender- and diversity-sensitive, user-centered design for the construction of help and support systems implemented in eLearning-
portals or software. Such an adapted help and support system ought to enhance the usability of the complete system. In combination with integrated measures of qualification it also communicates gender- and diversity-sensitive competences. Concrete object of research is the learning and teaching portal L²P of RWTH Aachen University. This system is suitable for empirical surveys of gender and diversity studies because of its functionality and its heterogeneous user groups. In consideration of interdisciplinary approaches, methods and consolidated findings, particularly of communication science, it should constitute deduced criteria to specify different user groups by means of gender- and diversity-sensitive aspects. Furthermore the coherence between this criteria and the choice of existing communication structures of the different user groups will be analyzed. Of particularly interest are Web 2.0 communication structures.

Gender- and diversity-sensitive design of mobile learning widgets
Mostafa Akbari (funded by a gender research grant within the excellence program of RWTH Aachen University) and Ulrik Schroeder

In this project, we investigate gender and diversity issues in the design of mobile Web 2.0 access via small-screen devices to integrate continuous learning in all-day lives. The goal is the development and evaluation of a novel, Internet-based social network in the educational context. As a prerequisite a Web 2.0 network specifically for the interaction on mobile devices is to be designed in a user-centered manner. The research will involve students, faculty and future students of RWTH Aachen University, who traditionally come from diverse social and cultural backgrounds. In order to test the learning network we will investigate and evaluate the impact on the audience’s organization and motivation and learning outcomes. This evaluation includes the measurement of success and study skills enhancement through the use of the learning network. We especially take gender and diversity issues and different learner’s profiles into account. Since the scientific disciplines education, psychology, sociology and computer science play a role in the context of web-based social learning, the existing evaluation methods of the different disciplines must be integrated and extended in terms of a comprehensive Web science.
To awaken interest in MINT-subject and especially in Computer Science, we conduct specific, didactical separated free workshops in schools. Content of the workshop is the internationally proven didactic approach on robots. The workshops will be offered for girls of the 6th until 8th grade. Additionally a Computer Science community for young professionals by Social Software as accompanying measure will be established to stabilizing the interest of the students in school at a high stage and making the decision for a technical study easier. Here is the networking with other MINT-initiatives an important goal. To create sustainable solutions all MINT- and gender activities are anchored in teacher training at RWTH Aachen University.

In the wake of the MINT-scholarship this project will be supported by scientific research in teaching computer science in context of gender issues. Based on the robotic approach variables that are relevant for success in motivating students will be identified and empirically verified. From these results further approaches will be developed and implemented. Objects of investigation are virtual fantasy worlds, games and simulations. For these approaches teaching and learning materials will be created, which are also tested in school (workshops), and scientifically evaluated.

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 Zurich, 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.

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eLearning 52.0+: Teaching older adults the usage of small screen eHealth devices
Filippos Efstathiou and Ulrik Schroeder

The purpose of this dissertation is the utilization of eLearning to specifically define and overcome acceptance barriers on the usage of small screen eHealth devices by older adults.

It is a well know fact that statistically the population grows older. This will lead to increasing need of Medicare, manpower and funding. Fortunately, eHealth technology can prevent it. By means of small screen eHealth devices we can not only minimize the costs of Medicare but also allow the elderly to continue living independently in their home. On the other hand, recent research shows that older people are not accepting those devices for various reasons. The hypothesis of this research is that eLearning technologies can be used in helping the elderly to familiarize with the devices, while we discover further diversity aspects hidden behind those acceptance barriers.
Other Activities

Ulrik Schroeder
- Scientific director of CiL – center for integrative eLearning & eTeaching concept at RWTH Aachen University
- Reviews for the journal "it – Information Technology -- Methods and Applications of Informatics and Information Technology"; Oldenbourg Wissenschaftsverlag Munich, Germany
- Programm Committee member of 6th eLearning conference of computer science DeLFI 2008 in Lübeck
- Program Chair Workshop eLearning 2.0 auf der DeLFI 08 in Lübeck
- International program committee member of CATE 2008 (Computers and Advanced Technology in Education) - Creete
- International program committee member of the 8th IEEE International Conference on Advanced Learning Technologies, ICALT 2008, Spain
- Program committee meber for Expertenworkshop "Social Tagging in der Wissensorganisation – Perspektiven und Potenziale", IWM Tübingen
- International program committee member of Multimedia Education - ACM Workshop EMME 2007 auf der ACM Multimedia 2007 (Augsburg)
- International program committee member of WoLLIC'07 (The 14th Workshop on Logic, Language, Information and Computation)
- Member of the expert commission of BMBF "eLearning 2.0"
- Programm Committee for the 5th eLearning conference of computer science Delfi, Siegen 2007
- Program Chair for the Workshop on eLearning 2.0 at Delfi, Siegen 2007
- 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
- Member of external PhD committees

Mostafa Akbari
- Preparations and support for 1st workshop on eLearning 2.0, 5th German eLearning conference in computer science, DeLFI 2007
- Development of twittopia tool, used as Web 2.0 application in the 2nd workshop on eLearning 2.0, 6th German eLearning conference, DeLFI 2008

Eva Altenbernd-Giani
- Co-organization of the “Girls Day” for Computer Science.

Thiemo Leonhardt
- Co-organization of the “Girls Day” for Computer Science.
- Project go4IT! / MINT and Roberta training for schools
Anna Dyckhoff

- Co-organization of the “Girls Day” for Computer Science.
- Preparations for the project go4IT / Roberta training for schools
- E-mentoring program Cybermentor

Philipp Rohde

Talks and Publications

Talks


U. Schroeder, Ph. Rohde: *eLearning strategies of NRW Universities on tehir way to eUniversities*, Workshop, Meidenzentrum Duisburg, Jul. 2008

U. Schroeder: The integrated eLearning infrastructure L²P and sophisticated eCampus software, Workshop CiL/CCC and Microsoft Germany, Aug 2008


**Publications**


**Press Releases**

Insert of Spektrum der Wissenschaft, issue 01/2007.


Interview with Ph. Rohde in Financial Times Deutschland, May 2007.

start.07, Jun 2007.


Check.point eLearning, Aug 2007.

Case Study at eTeaching.org, Jan 2008.
Interview with U. Schroeder, podcast eTeaching.org, Jan 2008
Media Computing

Staff

• Faculty
  Prof. Dr. rer. nat. Jan Borchers
  borchers@cs.rwth-aachen.de
  http://hci.rwth-aachen.de/

• Secretary
  Clarissa de Gavarelli
  Tel.: +49-241-80-21051
  Fax: +49-241-80-22050

• Visiting Researchers
  Elaine M. Huang, Ph.D. (Humboldt Stipend, Jan-Dec 2007)
  Omid Farivar (UROP Student, May–July 2008)

• Research Assistants
  Dipl.-Inform. Daniel Spelmezan
  Dipl.-Inform. Thorsten Karrer
  Dipl.-Inform. Jonathan Diehl
  Dipl.-Inform. Malte Weiß
  Dipl.-Inform. Gero Herkenrath
  Dipl.-Inform Dipl.-Wirt.Inform. Max Möllers
  Rafael Ballagas, M. Sc.
  Eric Lee, M. Sc.
  David Holman, M. Sc.

• Student Researchers:
  Julie Wagner, Yvonne Jansen,
Anna Koster, Henning Kiel,
Sarah Mennicken, Christian Mattar,
Florian Heller, Moritz Wittenhagen,
Jan-Peter Krämer, Christoph Kurtz,
Tim Hemig, Sören Busch, Florian Heller,
Johannes Fundalewicz, Christopher Gretzki,
Roksaneh Krooß, Moritz Wittenhagen

- Technical Staff:
  Jonathan Diehl, 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, Jonathan Diehl, Thorsten Karrer, Daniel Spelmezan, Malte Weiß, Gero Herkenrath, Max Möllers, Florian Heller, Moritz Wittenhagen

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. A room-wide audio server handles the array 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.

**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 Work- shop 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.
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 three sub-projects so far, which will be continued to expand our concept of Organic Interfaces:

Fly (see picture below) 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. First test results support this claim and show the potential of the system.

DRAGON (see below) is a novel technique for video interaction. Based on the concept of ‘direct manipulation’ which embodies several traits of Organic Interfaces, Dragon allows users to navigate in video scenes more easily and precisely than previous approaches like the timeline slider.

TWEND (see below) is a malleable input device that serves as a first prototype for bendable mobile devices. Controlling a device like, e.g., an eBook reader via bending gestures is not only natural and intuitive but also saves valuable space on the devices surface that otherwise would have been occupied by physical controls.
DRAGON is a direct-manipulation interaction technique for frame-accurate navigation in video scenes. This technique benefits tasks such as professional and amateur video editing, review of sports footage, and forensic analysis of video scenes.

By directly dragging objects in the scene along their movement trajectory, DRAGON enables users to quickly and precisely navigate to a specific point in the video timeline where an object of interest is in a desired location. Examples include the specific frame where a sprinter crosses the finish line, or where a car passes a traffic light.

Through a user study, we have shown that DRAGON significantly reduces task completion time for in-scene navigation tasks by an average of 19–42% compared to a standard timeline slider. Qualitative feedback from users is also positive, with multiple users indicating that the DRAGON interaction felt more natural than the traditional slider for in-scene navigation.

The DRAGON interaction technique is illustrated in the figure shown below: The user has clicked on the car at the diamond marker, and is now free to drag the car along its trajectory in the video. As she moves the car, the video scrolls through time accordingly. Notice how evenly spaced positions on the car’s trajectory correspond to a non-linear temporal spacing on the timeline slider.
TWEND: Twisting and Bending as new Interaction Gesture in Mobile Devices
Gero Herkenrath, Thorsten Karrer, Jan Borchers

The goal of the project is to find new interaction methods for mobile devices. Traditional input methods suffer from certain problems in this context. First, there is a real estate problem between space used for input and space used for output. Screen sizes and number of input buttons are limited to keep the device small. Touch screens counter this, but can lead to occlusion problems. Tilting introduces a new interaction style by facilitating not just the fingers, but sometimes it can be hard to correctly interpret the users intention with this (just try to read something on the iPhone while lying in your bed...).

TWEND consists of a hardware prototype that enables users to perform bending gestures and a Mac OS X software framework that maps these gestures to system events. These events can be configured to mimic scrolling, keystrokes or Apple Script events. This enables a quick way to set up experiments to research the value of different bending gestures as input method for interactive tasks involving a computer system. In case standard system events are not sufficient for an experimental setup, the framework also allows custom applications to directly get the measured bending state of the prototype device via a port. An example application following this approach is an e-book reader. It shows how the continuous bending input can be used to easily manipulate a virtual book. When turning pages, their movement is directly mapped to the bending state of the prototype device, creating a natural and easy to understand mapping.

A bendable device also makes use of the users wrists, i.e., just like tilting it makes use of an additional part of the dexterous system. Because the hands are already "in position" holding the device, no further space for input areas is needed.

The Associative PDA
Jonathan Diehl, Eileen Falke, Jan Borchers

Personal information management (PIM) is an umbrella term for all activities involving the information you use throughout your every-day life, like mail, notes, or a shopping list.
Common systems for PIM fail because of poor support for mobile use, separation of information, and increasingly complex hierarchical structures, which are hard to search. The system we imagine makes use of an associative network to store all of your information in one place. Associations are simple connections between individual items. If, for instance, you receive an email from a colleague, the text of the email will be associated with the colleague, the time it was sent, and yourself as the recipient. To find information in this network of associations you can traverse it, by moving along the associations, or search in it, by showing only related items for a small selection (this technique will be demonstrated in one of the storyboards later on).

With the Associative PDA we proposed an associative system that overcomes the shortcomings of previous systems. We have shown that the use of associations for personal information management is well understood and perceived as useful by the users. Further, the use of associations for note taking has led to very efficient search behavior.

In this project we want to investigate how wearable computing can help trainees learn new sports techniques and keep them motivated. For example in snowboarding, instructors cannot be with students while going down the slope. Due to this spatial separation, a trainer typically provides feedback after exercises. 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.
Our wearable system is intended to automatically supervise posture during the ride and to alert users to incorrect body movements. Tiny sensors on the rider's body detect common snowboarding mistakes. Actuators provide immediate tactile feedback across the body that subtly communicates hints for corrections. Results from this project can be applied to other sports techniques and to healthcare in unsupervised situations.

Rapid Prototyping for Wearable Computing
Daniel Spelmezan, Jan Borchers

To advance the field of wearable computing, end-users need support in creating wearable computing applications. Our toolkit was designed to lower the threshold for experimenting, to reduce the time required for creating initial prototypes, and to increase the number of prototyping cycles.

A Java-enabled mobile phone acts as host device for custom-built sensor/actuator boxes (SensAct). Sensors and actuators can be exchanged at run-time. Software libraries offer signal processing and classification algorithms for building systems that measure and react to human motion. These algorithms can be distributed between the host and the SensAct boxes to take full advantage of the specific capabilities each device offers. SensAct boxes preprocess raw sensor data and stream results to the host. The host implements higher application logic required for interactive systems and links classification results to real-time feedback.

MultiTouch.Framework
Stefan Hafeneger, Malte Weiß, Gero Herkenrath, Jan Borchers

MultiTouch.framework is a native Cocoa multi-touch framework for Mac OS X. It uses the default event handling system and the responder chain of the operating system, providing a familiar application-programming interface to Mac OS X developers. It is built upon a
modular low-level architecture that unifies all touch events, with input units for different multi-touch input devices including FTIR, DI, iPhone/iPod touch, as well as any TUIO-based devices. Thus, as a developer, you do not need to care about the actual input device being used.

One of the great advantages of this toolkit is that you can develop and test your multi-touch application on your standard desktop Mac, using your iPhone as multi-touch input device, without having to work at an FTIR table all the time.

Physical user interface components such as buttons, sliders, knobs and keyboards have many advantages: thanks to their haptic nature, they are easy to operate without looking, and their shape guides the user's input gestures. However, they are often expensive, and it is hard to change their labeling on the fly.

Computer interfaces have largely replaced these devices with virtual on-screen controls, such as push buttons, scrollbars, rotary knobs and soft keyboards. Virtual controls are very flexible, easily changed dynamically - but they lack the physical, haptic texture and feedback of their real-world counterparts.

Our Silicone Illuminated Active Peripherals, or SLAP widgets, are physical widgets made from silicone rubber and acrylic that combine the advantages of physical and virtual devices on multi-touch tables: Our SLAP buttons, sliders, knobs and keyboards have the physical shape of real devices to provide the right haptic feedback, but are still easily relabeled using a
tabletop rear projection. At the same time, they are particularly low-cost, and easy to put to use.

SLAP widgets are transparent. This means we can always show the current labeling using the table's rear projection underneath the widget. For example, we can change the labels on our keyboard from normal characters to shortcut commands when the modifier key is held down. This makes it easier to use command shortcuts and other special keyboard mappings. But SLAP widgets are still physical, simplifying their eyes-free use.

Route Charlemagne
Malte Weiß, Max Möllers, Jan Borchers

Route Charlemagne is an Aachen-wide touristic concept where a multitude of exhibits, cultural events, and presentations of Aachen’s architecture are integrated. We currently work on several exhibits for the Route Charlemagne: Our audioguide (AIXplorer) guides tourists through Aachen and tells them the secrets only good tourist guides or locals know. The city hall will include an interactive exhibit of the Karlspreis and its famous laureates, and last but not least visitors will be able to experience historical events in the coronation hall by immersing into a virtual three-dimensional audio space.
Other activities

We hosted the second World Usability Day at RWTH Aachen University in November 2007. 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. We will host the third World Usability Day at RWTH Aachen University in November 2008. The topic of this year’s event will focus on usability in transportation.

Our infrastructure consists of 4 XServe servers with a 5TB XServe RAID, around 25 desktop machines (15 G5, 10 Intel) with 23” and 30” 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 five 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 2007 and 2008, we worked as reviewers for CHI, UIST, Ubicomp, TOCHI, and various other conferences and journals in Media Computing and HCI. We also host the hcipatterns.org home page as heads of the IFIP task group on this topic.
Talks and Publications

Talks


*Connectivity & Tools in Hardware Sketching.* Sketching In Hardware 3, Providence, Rhode Island, July 26, 2008.


*Physical User Interface Prototyping Toolkits,* Ubiquitous Computing / Campus Of The Future Research Group, UCSD, California, Jan 23, 2008

*The Media Computing Group at RWTH Aachen University: A Research Overview,* CogSci 120 Class on Human-Computer Interaction, UCSD, California, Nov 29, 2007


*The Media Computing Group at RWTH Aachen University: A Research Overview,* Dept. of Computer Science, UCSD, California, Oct 9, 2007

Publications


Jonathan Diehl, Jan-Peter Krämer, and Jan Borchers. *A Framework for using the iPhone as a Wireless Input Device for Interactive Systems.* In Extended Abstracts of UIST '08, October 2008.

Stefan Hafeneger, Malte Weiss, Gero Herkenrath, and Jan Borchers. *PocketTable: Mobile Devices as Multi-Touch Controllers for Tabletop Application Development.* In Extended Abstracts of Tabletop '08, 2008.

Malte Weiss, Roger Jennings, Julie Wagner, James D. Hollan, Ramsin Khoshabeh, and Jan Borchers. *SLAP: Silicone Illuminated Active Peripherals.* In Extended Abstracts of Tabletop '08, 2008.


Jan Borchers. *Interacting with ubiquitous media - A research matrix.* Interfaces, 76:6-9, Sep 2008.


Eric Lee, Thorsten Karrer, and Jan Borchers. *Improving Interfaces for Navigating Continuous Audio Timelines.* In CHI 2007 Workshop on Supporting Non-Professional Users in the New Media Landscape, San Jose, USA, April 2007.


Embedded Software Laboratory

Staff

- Faculty:
  Prof. Dr.-Ing. Stefan Kowalewski

- Secretaries:
  Marina Herkenrath
  Karin Vonderstein
  Telefon +49 241 80-21151 / -21152
  Email sekretariat@embedded.rwth-aachen.de
  Internet http://embedded.rwth-aachen.de

- Technician:
  Herwig Linß

- Senior Researchers:
  Dr. rer. nat. Bastian Schlich
  Dr. rer. nat. Carsten Weise

- Researchers:
  Ashraf Armoush, M.Sc.
  Dipl.-Inform. Eva Beckschulze
  Dipl.-Inform. Ibtissem Ben Makhlouf
  Dipl.-Inform. Jörg Brauer
  Hilal Diab , M.Sc.
  Dipl.-Inform. Dominique Gückel
  Dipl.-Ing. Gerlind Herberich (until 06/2008)
  Dipl.-Ing. Daniel Klünder
  Dipl.-Inform. Jianmin Li
Dipl.-Inform. Daniel Merschen
Dipl.-Inform. Ralf Mitschting
Dipl.-Inform. Jacob Palczynski
Dipl.-Inform. Andreas Polzer
Dipl.-Ing. Falk Salewski
Dipl.-Inform. John Schommer
Dipl.-Ing. Andre Stollenwerk
Dipl.-Inform. Dirk Wilking
Overview

Informatik 11 represents the field of embedded systems and software at RWTH Aachen University. 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.

Research Projects

Model Checking Assembly Code for Microcontrollers
Bastian Schlich, Jörg Brauer, Dominique Gückel (Algosyn)

We developed the model checker [mc]square for model checking microcontroller assembly code. Currently, [mc]square checks assembly code of the following microcontrollers: ATMEAL ATmega16 and ATmega128, Infineon XS167 and Intel C51. We are currently extending [mc]square to support the Renesas R8C\23 microcontroller. Beside model checking microcontroller assembly code, [mc]square is also able to model check Instruction List programs for Programmable Logic Controllers and Abstract State Machines.

In our approach a tailored simulator is used to build the state space of a program for model checking. The simulator creates an over-approximation of the behavior shown by the real microcontrollers. Using a tailored simulator enables users of the tool to make propositions about all features of the supported microcontrollers.

To tackle the state-explosion problem, we employ different techniques. The focus of our work is the application of abstraction techniques such as delayed nondeterminism within this simulator. In this simulator, also hardware-dependent information is utilized to limit the state-explosion problem. To support these abstraction techniques, we use static analysis and abstract interpretation to annotate the program. The simulator uses these annotations to limit state-space sizes and to support implemented abstraction techniques. In a project funded by the graduate school Algosyn, we investigate how such simulators can be synthesized algorithmically.

We conducted several case studies to show the applicability of the approach for certain microcontroller programs taken, for example, from lab courses, diploma theses, or student exercises.
Adaptive Protocol Stacks and Model Checking (UMIC)
Carsten Weise

Due to many-sided communication (wired vs. wireless, USB, Bluetooth, WiFi, Ethernet, GSM, GPRS, UMTS, WiMax, LTE, etc.) and a huge number of different terminal profiles (cpu speed, main memory, IO capabilities, user interaction, etc.), we are faced with versatile scenarios in mobile networks. On the network layer, multi-mode protocol architectures and functional unit networks have been proposed as a solution. These solutions lead to the problem of a high number of configurations, for which correctness cannot be easily checked.

The project investigates the feasibility of applying model checking techniques to the problem. Possible solutions are off-line and on-line model checking of configuration, where the on-line method is limited by the resource constraints of the device and the efficiency of model checking algorithms.

For the off-line case, we have investigated the application of several model checking tools to a simple case of a router protocol. A major obstacle is the use of dynamic data structures in protocol implementations. We are currently investigating how to tune existing tools to deal with the dynamic case, while at the same time also looking into implementations which use static data structures only.

Scalable Software Architectures for Massively Distributed Systems (UMIC)
Jianmin Li

The aim of the project is to develop new concepts for software architectures (SWA) of future generations of mobile systems, realizing not only the envisioned functional requirements but also supporting critical non-functional requirements, like e.g. scalability, maintainability, availability, adaptability etc. In the first phase, we conducted a workshop with the UMIC Groups of Prof. Wehrle and Prof. Spaniol, applying the Architecture Trade-Off Analysis Method (ATAM). The result is a catalog of non-functional attributes of Massively Distributed Mobile Systems (MDMS)-software architectures (SWAs).

Starting from this analysis, current research concentrates on two application scenarios: the tourist navigator, and the shopping assistant. Both applications will be formally specified and implemented within a test environment. For the formal specification, approaches from the fields of rich component specifications and of rich interfaces are used. Especially the suitability of the rich component/rich interface approach for the formalization of the identified main non-functional attributes of MDMS-SWAs will be in the focus of the investigation, and possibly needed extensions will be proposed. The investigation concentrates on the end-user application parts, and thus on the higher levels of the ISO-OSI-model. The implementation of the two scenarios will be done within widespread frameworks for mobile applications: Android (Google), Java for Mobile Applications (J2ME, Sun) together with the Open
Services Gateway Initiative (OSGi) platform, Trolltech’s Qtopia, and Openmoko. For the implementation of the applications, a testbed has been set up that comprises of a number of mobile devices with open architectures that allow the loading of different mobile application platforms. Thus a comparison of the different applications within several usage scenarios is possible, and allows for several measurements in order to be able to evaluate different approaches for different traffic models. The testbed currently uses existing mobile networks that are accessible within UMIC.

**Simulator for a Rail Testing Environment**

Carsten Weise, Ralf Mitsching

We investigate the challenges of testing reactive embedded systems. Model-based testing is a formal approach to test reactive embedded systems. The idea is to produce a test suite on the basis of a specification. The existence of a formal specification or model provides the possibility of automated test generation. In particular, we are not interested in only functional, but also timed testing. Rather than testing whether an implementation behaves functionally correct according to the specification, timed testing also takes into account the timelines of events. Within an industrial collaboration, we discover the challenges during the application of this approach in real-life.

**Timing Issues in an Automotive Testing Environment**

Carsten Weise, John Schommer

Together with an industrial partner we investigate different timing issues within the implementation of a measurement tool for an automotive testbed. Demanding real time requirements lead to sophisticated challenges in the set up and the tuning of the system.

**Safety and Reliability of Embedded Systems**

Eva Beckschulze, Ashraf Armoush, Falk Salewski

An increasing number of embedded systems are used in safety-critical applications. Therefore, specific safety requirements have to be considered during the development of these systems. Moreover, strong interactions between hardware and software components are an
important factor in embedded systems, especially as several different hardware platforms are available (e.g. different types of single and dual core microcontroller, reconfigurable hardware as CPLDs and FPGAs).

In our work, we investigated these interactions in experiments conducted in lab courses at our chair. In this context, we observed differences between microcontrollers and FPGAs, especially with respect to real-time properties. According to their parallel nature, FPGAs allowed a good encapsulation of different real-time functions. Further work in this area was part of a project funded by the Research Association of Automotive Technology (Forschungsvereinigung Automobiltechnik, FAT). This project deals with the effects of current trends in technology and reliability of automotive electronics. Specifically, aspects of hardware and software as well as interactions between hardware and software are regarded. Our analyses showed the increasing importance of safety-critical functions in the automotive domain associated with safety requirements given by the arising automotive standard ISO 26262. Safety requirements especially include extensive measures (e.g. hardware redundancy) for detecting and handling safety-related hardware faults. In this context the use of two promising novel hardware platforms has been evaluated by means of an application example. It could be shown that both hardware platforms, namely on the one hand a dual-core microcontroller and on the other hand a MCU-FPGA architecture, are able to fulfill the safety requirements. While the chosen application-specific safety concept did not reveal significant differences when implemented on diverse hardware platforms, a number of differences could be made out comparing the application-specific function monitoring with a generic device monitoring. Beside safety these differences address reliability, modifiability and costs.

Moreover, the design of safety-critical embedded applications requires an integration of the commonly used software and hardware design methods. It is considered as one of the applications that could benefit from the use of design patterns. Therefore, we investigated the application of design pattern for the design of safety-critical systems. We proposed a pattern representation for safety critical embedded application design methods by including fields for the implications and side effects of the represented design pattern on the nonfunctional requirements of the safety-critical applications. These requirements include safety, reliability, modifiability, cost, and execution time. In our research, which is supported by DAAD, we are going to construct a catalog of patterns with application guidelines to facilitate the automatic recommendation of a suitable design method for the required application. Therefore, the commonly used hardware and software design methods were collected, classified, and represented using the new proposed design pattern template. Moreover, we proposed a new software fault tolerance pattern, which is called Recovery Block with Backup Voting pattern. This pattern can be used to improve the software reliability of the classical recovery block pattern in applications in which the construction of an effective acceptance test can not be guaranteed.
and software into everyday life boosts the need for engineering methods and tools for the development of high quality embedded systems. As complexity is steadily increasing, software engineering is recognized as a means to reaching crucial quality requirements of these systems. However embedded systems differ fundamentally from desktop or enterprise software. They are engineering artifacts involving computation that is subject to physical constraints which arise through interactions with the physical world. This includes reactions to the physical environment (reaction constraints) and execution on a physical platform (execution constraints). Additionally they are used for safety critical tasks, making formal verification desirable. Hence, we work on enriching classical software engineering approaches with reaction and execution constraints. Therefore, we added expressions for these constraints to the pre- and postconditions of the Business Object Notation’s static diagrams thus enabling their modeling at early stages of the design process.

The functional modeling is done with abstract state machines which enable early verification. We presented a novel approach to verifying dynamic properties for given ASMs directly and automatically that takes advantage of the fact that ASMs are not logical formulae, but machines coming with a notion of run. We utilize the simulation capabilities of the tool CoreASM, adapting it to branch into all possible successor states instead of choosing a random successor when faced with scheduling of distributed ASMs or nondeterministic choose. The so-built state space can be model checked with the lab’s tool [mc]square by querying the boolean values of the verification formula’s atomic propositions from CoreASM.

Agile Methods for Embedded Systems
Dirk Wilking

The agile techniques of refactoring, test driven development and the main aspects of short iterations have been analyzed within experiments. Results show some advantages for embedded system software engineering like reduced memory consumption for refactoring or a reduction of function oriented programming spikes at projects deadlines for short iterations. While differences can be found, the effect strength of these agile techniques seems questionable. Consequently a variable oriented approach has been taken leading to some new ideas borrowed from human sciences. Overall a measure for human abilities like C knowledge has been created as well as a measure for the abstract concept of source code viscosity allowing to both assess experiment participants as well as source code quality.

Integration of Model-based Software Engineering with Model-based Controller Design (ZAMOMO)
Jacob Palczynski, Andreas Polzer
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 exemplary 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. We evaluated this approach by implementing an hardware independent automotiv parking assistant on an experimental vehicle.

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 partners are 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.

Smart Extracorporeal Lung Assistance (SmartECLA)

Andre Stollenwerk

In modern intensive medical care ARDS (acute respiratory distress syndrome) became one of the most problematic disease patterns. Mortality rate for ARDS is still between 40 and 60 percent.

A newer treatment option for this illness is the extracorporeal oxygenation. Here the patient is connected to an oxygenator. This device realizes a high percentage of the needed gas exchange with the blood outside the human body. The lung is disencumbered during this procedure in order to have a chance to regenerate faster.

The overall aim of the project SmartECLA is to optimize the used devices for the extracorporeal oxygenation according to the medical requirements and to develop a safety driven closed-loop control for this system. SmartECLA is part of a research network of 6 chairs out of 4 different faculties founded by the DFG.

It is our goal to increase the safety of the whole system this shall be archived on different layers. On the one hand the hardware-layer is taken care of by implementing additional redundancy and supervising hardware; on the other hand we will create a model of the whole system in order to predict malfunctions or errors and avoid them. The overall result will be a higher surveillance rate. This project started in September 2007.
The infrastructure of highways in most major countries are congested because of the rapid increase of the traffic flow in the last years. Many considerations such as the rising construction costs, the lack of suitable land, environment pollution make it unfeasible to add new highways. The most suggested solution to this problem is to increase the capacity of these highways by forming platoons and automatically control the vehicles in order to maintain short but at the same time safe distances between different vehicles within the platoon.

Within our project funded by the German Research Council (DFG) and in collaboration with the Control Engineering Institute (IRT) in Aachen, a Lagrange energy based controller will be designed for a platoon of 4 vehicles, in which each vehicle sends its position, its velocity and its acceleration to the next following one via a communication network.

Communication networks generally introduce delays and drop packets. However, these communication faults are typically not taken into account while designing the controller. The objective of our project work is to analyze the effects of the communication faults on the safety of the vehicles within the platoon. The Platoon, controller and network are modeled using the framework of hybrid automata. The discrete events are introduced by the communication network. The continuous part of the hybrid automaton consists of the dynamics of the platoon and its controller. The problem of safety verification is then reduced to a reachability analysis of a hybrid system.

A student team supported by Informatik 11 won the competition Carolo-Cup 2008 for autonomously driving model cars in 1:10 scale. The team consists of five students: Yves Duhr, Philipp Fischer, Stefan Kockelkoren, Julian Krenge and Hugues Tchouankem.

The Carolo Cup took place for the first time and was organised by the Technical University of Braunschweig. The competition consisted of several disciplines. The main tasks for the model cars were automatic parking, autonomous driving around a circuit and autonomous circumvention of obstacles. The car developed by the GalaXIs-Team won all driving disciplines and the whole competition.

The aim of the competition is to provide insights into interdisciplinary problems to the students while developing automotive applications.
Publications


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Institute for Scientific Computing

Staff

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

- Secretary
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  Dipl.-Inform. Michael Lülfesmann
  Dipl.-Ing. Monika Petera
  Dr. Arno Rasch
  Dipl.-Inform. Andre Vehreschild
  Dipl.-Inform. Johannes Willkomm
  Dipl.-Inform. Andreas Wolf
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
  - *Parallele Algorithmen zur Vorkonditionierung linearer Systeme* (Parallel Preconditioning Techniques for Linear Systems),
  - *Parallele Algorithmen und Software für iterative Methoden* (Parallel Algorithms and Software for Iterative Methods),
  - Computational Differentiation,
  - Automatic Differentiation in MATLAB,
• *Virtuelle Realität* (Virtual Reality) offered in cooperation with the Computing and Communication Center,
• Algorithms for Simulation and Optimization of Physical Processes,
• Software Tools for Computational Science,
• Combinatorial Scientific Computing.

In addition, seminars and practical courses are offered, giving a deeper understanding of HPC-related issues. More information on our teaching activities is available at

http://www.sc.rwth-aachen.de.
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’.

Computational Differentiation in Numerical Flow Analysis

A. Rasch, A. Vehreschild, C. Bischof, M. Bücker

This project 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. Bücker

This project is part of the Collaborative Research Centre (SFB) 540, "Model-based experimental analysis of kinetic phenomena in fluid multi-phase reactive systems". Several projects in the SFB 540 aim at developing a better understanding of complicated processes through the use of already existing simulation packages or newly developed software in the context of an inverse problem formulation. In order to support this process, we are developing an environment for parameter identification, which allows the coupling of simulation codes with algorithms for the solution of inverse problems with little effort. Tools for the automatic differentiation of programs are an important ingredient, as they allow the exact and efficient computation of derivatives of existing programs and thus increase both the robustness and speed of solvers for inverse problems. Another contribution is the automatic generation of marshalling code which effects the interfacing of the world of simulation with that of numerical solvers for inverse problems. In particular, we plan to develop such an environment around the models for dripping processes on films that are employing the commercial FLUENT CFD solver, and the SEPRAN solver, developed at Delft University of Technology, that is used in the modelling of boundary processes. The development of numerical methods that are specifically tailored to these problems is infeasible due to the complexity of the codes employed.

ADiMat—Automatic Differentiation of MATLAB Programs
A. Vehreschild, C. Bischof, M. Bücker

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 SHEMAT (Simulator for HEat and MAss Transport). SHEMAT is an easy-to-use, general-purpose reactive transport simulation code for a wide variety of thermal and hydrogeological problems in two or three dimensions. The goal of this project is to develop a parallelization of SHEMAT based on the OpenMP standard for shared memory computers as well as to establish a methodology to reliably estimate model parameters using automatic differentiation. This project is funded by GEOPHYSICA Beratungsgesellschaft mbH and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

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. Lülfesmann, 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.

Novel methods for exploration, development, and exploitation of geothermal reservoirs - a toolbox for prognosis and risk assessment
A. Rasch, C. Bischof, M. Bucker

The goal is to develop a new, integrated procedure for the exploration of geothermal deposits with reduced risk in exploitation and operation. It is crucial to improve the methodology for reservoir characterization, stochastic uncertainty analysis, and seismic investigation. In particular, our aim is to improve the solution of the resulting nonlinear systems of equations by a novel automatic differentiation-based preconditioning approach. The project is funded by the Federal Ministry of Education and Research with partners at RWTH Aachen, University of Kiel, Free University of Berlin, and GEOPHYSICA Beratungsgesellschaft mbH.
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:

- Ursula van Rienen, Uni Rostock, January 8, 2007
- Ulrich Rüde, University Erlangen-Nuremberg, February 1, 2007
- Rob Bisseling, Utrecht University, February 28 - March 2, 2007
- Peter Eberhard, University Stuttgart, May 14, 2007
- Rolf Hempel, German Aerospace Center, July 3, 2007
- Boyana Norris, Argonne National Laboratory, USA, July 9-13, 2007
- Robert A. van de Geijn, The University of Texas at Austin, USA, July 24-25, 2007
- Bill Gropp, Argonne National Laboratory, USA, August 29-31, 2007
- Alan Edelman, Massachusetts Institute of Technology, USA, Oktober 8-9, 2007
- Brian Gunter, Delft University of Technology, The Netherlands, December 3, 2007
- Emil Slusanschi, University Politehnica of Bucharest, Romania, April 7-12, 2008
- Francois Irigoin, École des Mines de Paris, France, April 10, 2008
- Frank Dehne, Carleton University, Ottawa, Canada, June 9, 2008
- Terence Parr, University of San Francisco, USA, June 16, 2008

Christian Bischof is speaker of the Working Group "Parallelism" within the Forum Informatik and organizes – jointly with Th. Lippert (Forschungszentrum Jülich GmbH), U. Lang (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:

- 5th International Conference on Automatic Differentiation (AD08) held at Bonn, Germany, August 11-15, 2008. (Co-organized by Christian Bischof, Martin Bücker and Oliver Fortmeier)
- 6th European Workshop on Automatic Differentiation held at Sophia-Antipolis, France, November 15-16, 2007. (Co-organized by Martin Bücker)
- Parallel Computing (Parco2007) held at Jülich and Aachen, Germany, September 4-7, 2007. (Co-organized by Christian Bischof)
- 5th European Workshop on Automatic Differentiation, Hatfield, UK, May 21-22, 2007. (Co-organized by Martin Bücker)
- Minisyposium High-Performance Computing in the Geosciences at DGG 2007 held at Aachen, Germany, March 26-29, 2007. (Co-organized by Christian Bischof, Martin Bücker)
- 4th ASIM Workshop held at Aachen, Germany, February 28 - March 2, 2007. (Co-organized by Christian Bischof, Martin Bücker)

In addition, Christian Bischof served on the program committee for:

- Parallel Computing (Parco2007) held at Jülich and Aachen, Germany, September 4-7, 2007.

Martin Bücker served on the program committee for:

- Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC-07) held in conjunction with the 21th IEEE International Parallel & Distributed Processing Symposium (IPDPS-07), Long Beach, USA, March 26-30, 2007.
- Workshop on High Performance Computing for Engineering Applications held in conjunction with the 7th International Conference on Parallel Processing and Applied Mathematics (PPAM 2007) held at Gdansk, Poland, September 9-12, 2007.
- Parallel Computing (Parco2007) held at Jülich and Aachen, Germany, September 4-7, 2007.
- Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC-08) held in conjunction with the 22th IEEE International Parallel & Distributed Processing Symposium (IPDPS-08), Miami, USA, April 14-18, 2008. (Martin Bücker)

Christian Bischof and Martin Bücker are also co-editors of the following books:

Talks and Publications

Talks


A. Vehreschild, Coping with a Variable Number of Arguments when Transforming MATLAB Programms, The 5th International Conference on Automatic Differentiation, Bonn, 13. Aug 2008

O. Fortmeier, ParDROPS, SFB540 Seminar, Aachen, Germany, 6. Aug 2008

A. Vehreschild, Recent developments of AD for MATLAB, SIAM Annual Meeting 08, San Diego, USA, 7. July 2008

H. M. Bücker, What Automatic Differentiation Can Do for Quantum Chemistry Programs, Heinrich-Heine University, Duesseldorf, Germany, 3. July 2008

O. Fortmeier, Parallel matrix computations arising in two-phase flow problems, 5th International Workshop on Parallel Matrix Algorithms and Applications (PMAA'08), Neuchatel, Switzerland, June 22, 2008


A. Rasch, Automatisches Differenzieren und optimale Versuchsplanung, Institut für angewandte Geophysik der RWTH Aachen, April 29, 2008

A. Rasch, Rechnergestützte Gradientenbildung in der numerischen Strömungsanalyse, Kolloquium des SFB 401, RWTH Aachen, April 11, 2008


O. Fortmeier, Lastverteilung von hierarchischen Tetraedergittern mittels Graphen, Tag der Informatik, RWTH Aachen, Germany, December 7, 2007


Integrative Production Technology for High-Wage Countries at RWTH and the Aachen Institute for Advanced Study in Computational Engineering Science at RWTH, Aachen, Germany, November 8, 2007

C. H. Bischof, Research activities in automatic differentiation and parallel computing, Joint Workshop of the Computational Design Optimization program at MIT and the Aachen Institute for Advanced Study in Computational Engineering Science at RWTH, Aachen, Germany, October 8, 2007

M. Lülfesmann, Robust Shape Optimization for Artificial Blood Pumps: Hematological Design, Large-scale Transient Simulations, and Influence of Constitutive Models, Sensitivity Analysis, Annual meeting of the SPP1253, Bad Honnef, Germany, October 5, 2007


C. H. Bischof, Automatic Differentiation, Advisory Board Meeting 2007 of the Aachen Institute for Advanced Study in Computational Engineering Science, Aachen, Germany, August 30, 2007

M. Petera, ADiCape: AD for portable process systems models, Minisymposium "Automatic differentiation: applications and tools", 6th International Congress on Industrial and Applied Mathematics, Zürich, Switzerland, July 17, 2007


M. Lülfesmann, Shape Optimization for Artificial Blood Pumps, Fifth European Workshop on Automatic Differentiation, Hatfield, UK, May 21, 2007

M. Petera, Optimizing a chemical engineering application, Fifth European Workshop on Automatic Differentiation, Hatfield, UK, May 21, 2007

C. H. Bischof, Automatic Differentiation of Computer Programs, Köln, May 9, 2007


H. M. Bücker, Informatik-Aspekte in Computational Science and Engineering, Institut für
Publications


H. M. Bücker, M. Petera, and A. Vehreschild. Code Optimization Techniques in Source


Software and Tools for Computational Engineering

Staff

- Faculty
  Uwe Naumann

- Secretary
  Gabriele Meessen

- Research Assistant
  Ebadollah Varni
  Hakima Lakhdar
  Markus Beckers
  Viktor Mosenkiss

- Teaching Assistant
  Hakima Lakhdar

- Visitors
  Jan Riehme, Dmitrij Gendler (U. of Hertfordshire, UK)

- Student Researcher
  Michael Maier
Overview

The focus of our research and development efforts is on derivative code compiler technology and on combinatorial problems in derivative accumulation.

Derivative code compilers transform numerical code that implements multivariate vector functions $y = F(x)$, $F : \mathbb{R}^n \rightarrow \mathbb{R}^m$ into code for computing various derivatives including products of the transposed Jacobian matrix $F' = F'(x)$ with a vector $\bar{y} \in \mathbb{R}^m$. 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.

Derivative code 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 (AICES, http://www.aices.rwth-aachen.de) that has been established within the framework of the Excellence Initiative of the German federal and state governments in November 2006.
Research Projects

Derivative Code Compilers for Fortran.
Maier, Riehme, Naumann

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 project has recently been extended for another two years (Jan 2009 -- Dec 2010).

The multi-language AD platform OpenAD and its Fortran incarnation OpenAD/F has been developed as part of a collaboration with Argonne National Laboratory, Colorado State University, MIT, and Rice University, USA. See http://www.mcs.anl.gov/openad for details.

Derivative Code Compiler for Assembler.
Gendler, Riehme, Naumann

A tangent-linear code compiler for Intel 80386 assembly code has been developed as part of the CompAD project. The tool is used as a back-end to the differentiation-enabled NAGWare Fortran compiler to generate second-order adjoint code for the efficient evaluation of accurate (projected) Hessians.

See http://wiki.stce.rwth-aachen.de/bin/view/Projects/CompAD/WebHome.

Derivative Code Compilers for C/C++ and MatLab.
Naumann

We have been developing derivative code compilers for subsets of C/C++ and MatLab. These tools are mostly used in the context of teaching activities and external tutorials.

See http://wiki.stce.rwth-aachen.de/bin/view/Projects/DCC/WebHome.
Adjoint Error Analysis in ICON.
Riehme, Naumann

In collaboration with colleagues at the Max-Planck Institute for Meteorology we have been working on adjoint methods for error analysis in a newly developed ocean model based on ICON. The differentiation-enabled NAGWare Fortran compiler is used to generate the required adjoint code.

Sensitivity Analysis in Telemac/Sisyphe.
Riehme, Naumann

The aim of this collaboration with the German Federal Waterways Engineering and Research Institute, Karlsruhe, is to apply the differentiation-enabled NAGWare Fortran compiler to Telemac, a numerical modeling system for free surface hydrodynamics, sedimentology, water quality, waves and underground flows.

Subgradient Propagation for McCormick Relaxations.
Maier, Naumann

McCormick relaxations of factorisable functions are applied by colleagues at AICES and at MIT's Process Systems Engineering Laboratory to a range of global optimization problems. The ability to propagate subgradients for the generally not differentiable underestimators has been added to the NAGWare Fortran compiler.
We are interested in various combinatorial and graph problems arising in Scientific Computing including elimination methods on linearized computational graphs and coloring methods for the compression of derivative tensors. See http://www.cscapes.org.

We are working with colleagues at Max-Planck Institut für Eisenforschung GmbH and at the Institute of Chemistry and Dynamics of the Geosphere, Forschungszentrum Jülich on the application of AD to two numerical simulation codes.
Talks and Publications

Talks

Several talks were given at different conferences / workshops by various members of the group.

Publications


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
  Dipl.-Inform. David Böhme
  Dipl.-Inform. Zoltán Szebenyi

- Student Assistants/Researchers
  David Krings
  Divya Sankaranarayanan

- Former staff members and guests who worked in our group during the reporting period
  Prof. Dr. Erika Ábrahám
  Ralph Altenfeld
  Björn Kuhlmann
  John Linford
  Ventislav Petkov
  Matthias Pfeifer
  Felix Voigtländer
  Dr. Liang Yang
Overview

Located at the Jülich Supercomputing Centre of Forschungszentrum Jülich, the objective of this group 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. To satisfy their growing demand for computing power, numerical simulations are therefore being required to harness higher degrees of parallelism available on systems such as the IBM BlueGene/P called JUGENE at the Jülich Supercomputing Centre. 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.

Acknowledgement. We would like to thank the following staff members of the Jülich Supercomputing Centre for their contributions to the work of our group: Wolfgang Frings, Marc-André Hermanns, Dr. Bernd Mohr, Morris Riedel.

University Courses

- Grid Computing (SS 2008)
- Seminar Multithreading (SS 2008)
- Multithreading (WS 2007)
- Behandlung großer Datenmengen (WS 2007) together with Prof. Bischof, Prof. Kobbelt, and Prof. Seidl
- Rechnerstrukturen (SS 2007)
Research Activities

Scalable Performance Analysis of Large-Scale Parallel Applications (Scalasca)

_Funded by the Helmholtz Association and carried out in cooperation with the University of Tennessee._

At the center of our activities lies the development of Scalasca, a performance-analysis toolset for massively-parallel simulation programs used in science and engineering. Developed in cooperation with the University of Tennessee, Scalasca is an open-source software package that has been specifically designed for use on large-scale systems such as IBM BlueGene or Cray XT, but is also well-suited for small- and medium-scale HPC platforms. Scalasca supports an incremental performance-analysis procedure that integrates runtime summaries with in-depth studies of concurrent behavior via event tracing, adopting a strategy of successively refined measurement configurations. A distinctive feature is the ability to identify wait states that occur, for example, as a result of unevenly distributed workloads. Especially when trying to scale communication-intensive applications to large processor counts, such wait states can present severe challenges to achieving good performance. Compared to its predecessor, Scalasca can detect such wait states even in very large configurations of processes using a novel parallel trace-analysis scheme. Performance analysis results are presented to the user in an interactive analysis report explorer that allows the investigation of the performance behavior on different levels of granularity along the dimensions performance problem, call path, and process.

During the reporting period, a runtime-summarization module was added to Scalasca, forming the basis for more targeted as well as more accurate performance measurements by avoiding the collection of irrelevant performance data along with the associated runtime overhead. Moreover, the scalability of the overall system was further improved and performance analyses were demonstrated for configurations with up to 65,536 cores. In addition, Scalasca was effectively used to identify performance bottlenecks in a number of applications from various disciplines including engineering, weather forecast, and plasma physics. As a major milestone, the problem of insufficiently synchronized node-local clocks in clusters that prevents the accurate measurement of inter-process timings in event traces was addressed by extending and parallelizing the controlled logical clock, an algorithm for the retroactive correction of event timestamps taken from message-passing applications. To better understand the root causes of wait-state formation, a method for verifying hypotheses on causal connections between temporally or spatially distant performance phenomena without altering the application itself was developed. The method is based on simulating hypothetical behavior based on previously modified event traces, offering advantages in terms of...
scalability, prediction accuracy, and platform independence. Furthermore, to simplify usage of Scalasca in Grids, its relatively complex analysis workflow was mapped onto the workflow management capabilities of the UNICORE Grid middleware. Finally, components of Scalasca were used in the BMBF-funded ParMa project. Besides purely technical advancements, Scalasca was also presented to supercomputer users during local and external hands-on workshops/tutorials.

Scalable I/O Library for Native Parallel File Access (SIONLIB)

*Funded by the Helmholtz Association.*

When parallel applications or performance measurement tools operate at very large processor configurations, they confront the problem of how to efficiently write process-local data in parallel to files. Unfortunately, the traditional approach of having each process write a separate file does often not scale (e.g., due to metadata conflicts when creating thousands of files simultaneously). In this context, not only the aggregate data size but also the number of files can influence the I/O performance. For this reason, we started developing an I/O library that addresses this problem by mapping larger numbers of logical process-local files onto a smaller number of physical files, which include metadata to locate the data belonging to individual processes. The library is designed in a platform-independent way, requiring only standard UNIX file system calls.

Aachen Institute for Advanced Study in Computational Engineering Science (AICES)

*Funded by Deutsche Forschungsgemeinschaft (DFG).*

AICES is a doctoral program established under the auspices of the Excellence Initiative of the German state and federal governments to meet the future research challenges in computational engineering science. Currently, two members of our group conduct their thesis projects funded through AICES Ph.D. fellowships. One thesis project characterizes the time-dependent behavior of parallel applications and tries to find ways of exploiting this knowledge to make the performance analysis more scalable with respect to the length of execution, whereas the other project is aimed at characterizing load and communication imbalances in parallel codes to better understand the formation of performance-degrading wait states.
Virtual Institute – High Productivity Supercomputing (VI-HPS)

*Funded by the Helmholtz Association and carried out in cooperation with RWTH Aachen University (Institute for Scientific Computing), TU Dresden, University of Tennessee, and University of Stuttgart (associated partner).*

The mission of this virtual institute is to improve the quality and accelerate the development process of complex simulation programs in science and engineering that are being designed for the most advanced parallel computer systems. For this purpose, we develop and integrate state-of-the-art programming tools for high-performance computing that assist domain scientists in diagnosing programming errors and optimizing the performance of their applications. In these efforts, we place special emphasis on scalability and ease of use. Besides the purely technical development of such tools, the virtual institute also offers training workshops with practical exercises to make more users aware of the benefits they can achieve by using the tools. In 2008, two tuning workshops with hands-on sessions were organized in Aachen and Dresden, respectively. Tool integration efforts concentrated on improved interoperability between Scalasca and the Vampir time-line browser with the objective of simplifying the exchange of performance data and using the time-line view of Vampir for in-depth analyses of performance problems previously identified by Scalasca. The latter activity was carried out with support from the RWTH Undergraduate Funds.

Compilation and Optimization with Performance Feedback

*Funded by the US National Science Foundation (NSF) and carried out in cooperation with NCSA, University of Houston, University of Tennessee, and Virginia Tech.*

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. During the reporting period, we optimized the profiling interface between the OpenUH compiler and the KOJAK trace analyzer and implemented a mechanism to return feedback from KOJAK on application performance back to the compiler.
Other Activities

We organized the Minisymposium on Scalability and Usability of HPC Programming Tools at the Parallel Computing Conference (ParCo 2007) in Aachen/Jülich and co-organized the Workshop on Productivity and Performance (PROPER 2008) at the Euro-Par conference in Las Palmas de Gran Canaria.

Members of this group served on the program committees of the European PVM/MPI Users’ Group Meeting (EuroPVM/MPI 2007 and 2008), the IEEE International Parallel and Distributed Processing Symposium (IPDPS 2008), and the International Conference on High-Performance Computing (HPCC 2007 and 2008).

Conference Tutorials

Talks and Publications

Publications


Virtual Reality Group

Staff

- Faculty
  Prof. Dr. rer. nat. Torsten Kuhlen
  kuhlen@vr.rwth-aachen.de
  http://www.vr.rwth-aachen.de/

- Research Assistants
  Dipl.-Inform. Ingo Assenmacher (funded by DFG within CoE “Integrative Production Technology”)
  Dipl.-Inform. Thomas Beer (funded by DFG within CoE “Integrative Production Technology”)
  Dipl.-Inform. Philippe Cerfontaine (funded by DFG)
  Dipl.-Inform. Bernd Hentschel (funded by GRS and DFG)
  Dr. rer. nat. Lenka Jerabkova (until November 2007)
  Dipl.-Inform. Tobias Rick (since January 2008, funded by BMBF)
  Dr. rer. nat. Marc Schirski (funded by DFG)
  Dipl.-Inform. Irene Tedjo-Palczynki (since January 2008)
  Dipl.-Inform. Sebastian Ullrich (funded by DFG)
  Dipl.-Inform. Marc Wolter (funded by IZKF)

- Technical Staff
  Dipl.-Math. (FH) Daniel Bündgens
  Robin Ziehe, B. Sc. (since September 2007, funded by JARA-Sim)

- Trainees
  Andrea Bönsch (since September 2007), Patric Schmitz, Sebastian Weißborn, Robin Ziehe (until August 2007)

- Student Researchers:
  Tongliang Bao, Oleg Fiksels, Eduard Fried, Thorsten Frommen, Alexander Gnech, Daniel Haupt, Daniel Holz, Jan Hückelheim, Christian Krawczyk, Sebastian Pick, Christoph Röttgen, Aymen Sfar, Stoyan Stoyanov
Overview

The Virtual Reality Group was founded in 1998 and is a member of the Center for Computing & Communication as well as an associate member of the Computer Science Department. Our research goal is to develop new Virtual Reality techniques and methods and to push this technology forward towards applicability in complex scientific applications. As such, our work is characterized by basic as well as application-oriented research in collaboration with other RWTH institutes from multiple faculties, industrial companies, and other research groups from around the world in mostly third-party funded joint projects. As a part of the Center for Computing & Communication, we are in particular involved with providing methodical support and complete solutions. Thus, producing journal papers is not the one and only – although undoubtedly important – goal of our scientific work. Instead, we also aim at making our research work available to our partners, allowing them to explore even complex technical and physical phenomena in an intuitive way. Therefore, a lot of effort goes into the development of comprehensive software frameworks in order to make Virtual Reality technology a valuable tool in the scientists’ daily work.

In principle, Virtual Reality (VR) is a computer-generated scenario (the virtual world) a user can interact with in real time and in all three dimensions. The interface should be as intuitive as possible, and multiple senses like vision, haptics, and audio should be included into the interaction. By special display technology an immersion effect can be achieved, i.e., users have the impression of being a part of the virtual environment, fully surrounded by it instead of just looking from outside.

VR has proven its potential to provide an innovative human-computer interface, from which multiple application areas can profit. The VR applications fields we are working on comprise architecture, mechanical engineering, medicine, life science, psychology, and more. In the field of mechanical engineering, for instance, we provide immersive visualizations from very big things like complete plants, over mid-size things like machine tools and robots, down to microscopic scenarios arising in material science.

In recent years, Simulation Science has more and more attracted our attention. At RWTH Aachen, numerical simulation of technical and physical phenomena has traditionally been an important pillar in engineering research. With the excellence initiative, Simulation Science has definitely become a main focus at the University. In Aachen and elsewhere, simulation is an indispensable and essential tool in production technology and the development of, e.g., airplanes, cars, combustion engines, turbines etc. Even in medical projects at RWTH, numerical simulation is going to play an important role, e.g., in the analysis of flow within artificial blood pumps, or in order to understand the air flow within the human respiratory organs. Researchers are going to simulate phenomena of such a high complexity that traditional methods of post-processing, like producing static images or at best animations, are no longer neither an effective nor an efficient approach to understand the simulation results. Instead, engineers demand interactive exploration of their data in 3-D space, what eventually leads in the use of VR technology. As such, the VR Group actively supports RWTH institutes and research groups in CCES, AICES, GRS, JARA-Sim, and the CoE “Integrative Production Technology” in analyzing their data by means of Virtual Reality. From the computer science point of view, the grand challenge is that on the one hand we are facing huge datasets, and on the other hand we have to handle these data in real time. Thus, new concepts for hybrid visualization environments have to be developed, including advanced data management, parallel approaches, novel methods for feature rendering, and, above all, interaction techniques which allow for an intuitive exploration of complex, transient phenomena in 3-D
Since recently, our research is also focusing on VR-based simulators in medicine. In contrast to other research groups mainly working on simulators for minimal invasive surgery, we are concentrating more on open surgery procedures. The challenge here is to simulate not only deformable objects in real time, but to – among others – also provide methods which allow for an interactive and at the same time stable cutting through simulated tissue. Other interesting research activities are related to an already long-standing collaboration with (neuro- ) psychologists, who are using VR-based experimental setups for brain research. Lust but not least, thanks to an excellent collaboration with the Institute of Technical Acoustics, Professor Vorländer, we claim to have one of the most sophisticated VR audio rendering systems ever developed.

Our teaching curriculum comprises a Virtual Reality lecture always held in winter term, as well as a seminar on advanced VR topics and a practical course on VR in summer term. We are also engaged in the organization of the Virtual Reality Center Aachen (VRCA), which is an interdisciplinary non-profit network founded by Christian Bischof and Torsten Kuhlen in 2000 in order to further bundle and expand the VR activities at RWTH and the region of Aachen. Today, more than 40 RWTH Professors and 15 companies as well as external research institutions are organized in the VRCA, carrying out more than 50 research projects. On the national level, Torsten Kuhlen is the speaker of the “Fachgruppe Virtual & Augmented Reality” as a sub-organization of the “Gesellschaft für Informatik”. The goal of this section is to bundle the expertise of the various German-speaking research groups in academia as well as industry.
Within the Jülich Aachen Research Alliance (JARA), we have developed an interactive visualization for simulated ventricular assist devices in cooperation with Prof. Marek Behr, Chair for Computational Analysis of Technical Systems (CATS).

A ventricular assist device (VAD) is a mechanical blood pump to support a patient’s weakening heart, which can help a patient to survive the waiting time until a suitable heart transplant is available. The long-term goal is to enable a permanent use of VADs, and thus obviate the need for a heart transplant. One of the main concerns in the advancement of the current VAD generation is blood damage (hemolysis), in which the blood cells’ content leaks into the surrounding blood fluid.

To analyze the cause of blood damage and facilitate the optimization of the VAD design, CATS developed computational methods to simulate human blood flow. The computation considers not only standard flow features, but also the impact of the flow on the blood cells which enables a prediction of the rate of hemolysis.

As the computation quantifies the impact of the flow on the blood cells by their deformation, the visualization depicts this feature by morphing, semi-transparent ellipsoids. The main axes of the ellipsoid are not only shown to illustrate the deformation, but also to enable the observation of the so-called tank-treading of the blood cell. This is a natural protection mechanism of red blood cells in a shearing flow. To give an overview of the whole deformation process, the visualization application provides a static view, which is inspired by the multiple exposure technique in photography. This static overview can be used as a means for navigating through the time dimension. By picking one of the ellipsoids along the pathline, which is also a time line, the user jumps directly to the time step corresponding to that position of the blood cell.

Figure 1: Particle traces moving throughout the VAD. Rate of hemolysis is used as basis for colour coding. Particle traces darken with time to indicate the temporal context.
The Virtual Reality Group participates in an interdisciplinary research project kindly funded by the DFG, investigating the airflow inside the human nasal cavity. The human nose has to satisfy a variety of different functions. Besides respiration it is responsible for moistening, tempering, and cleaning the air. These functions are expected to strongly depend on the complex internal geometry of the nasal cavity. Impaired nasal respiration especially under normal breathing conditions, i.e., in everyday life situations, is a common and widespread disease, which makes nose surgery one of the most frequent operations in the western world. Unfortunately, the success rate, i.e., the number of people having no problems after surgery, is by no means satisfactory. To enhance this situation, researchers from the fields of fluid mechanics, medicine and computer science cooperate in an interdisciplinary research team. The main goal of this effort is to devise objective criteria which on the one hand quantify the quality of a given nasal cavity’s flow field and on the other hand help to predict the outcome of a surgical intervention. In this project, the Virtual Reality Group is designing new, interactive visualization methods which are custom tailored to the investigation of the nasal cavity. Work is split up into four main strands:

In a first step the complex nasal geometry had to be visualized. Unlike in most other simulation output analysis settings where the shape of the simulated domain is some form of artificially created geometry, the highly complex, natural shape of the cavity poses major problems inhibiting an efficient navigation. A combination of CT-data displays used as a “map” of the nasal cavity and direct 3D interaction techniques has been used to solve this task.

A second field of work arises from the fact, that in order to understand the influence of the nose’s main anatomical components, flow simulations have been performed for different nasal geometries. A manual, purely image-based comparison of the results would have been very tedious and time consuming. Therefore, a set of visualization techniques has been devised that are used to assess the differences of the various data sets more efficiently. These techniques facilitate a direct comparison on the raw data level, either using a set of similarity metrics to show a global image of the data set similarities or by providing the user with 3D point probes which allow to locally assess any two data fields at the same time.

Third, in order to integrate the expertise from different research fields, the development of the virtual annotation system IDEA (Interactive Data Analysis and Annotation) has been started. This system combines an underlying model which links meta-information – the annotations – to respective parts in the scene. The annotation data is saved to a data base along with the annotated scene data for later restoration and follow-up analysis.

Finally, the fourth part of the project deals with the integration of quantitative data into the analysis process and the interaction therewith. Here, concepts from information visualization are transferred to a 3D immersive setup. Ultimately, this will lead to a comprehensive set of methods which allow the interactive specification, extraction, quantification, and follow-up assessment of arbitrary data characteristics. Based on these, aerodynamics engineers will be able to easily identify areas where certain combinations of values are present in the data and to cross-link this data to medical statistics on the nasal respiration. Ultimately, this cross-
referencing should lead to the establishment of the aforementioned objective criteria, which facilitate an evaluation of any given nasal geometry.

Figure 1: An annotated view of a real patient’s main nasal cavity including its main anatomical components.

Figure 2: A user marks an interesting data region by *brushing* it via direct interaction in an immersive virtual environment.

**Explorative Analysis of Multiple, Heterogeneous Simulation Data**  
P. Cerfontaine, T. Beer, T. Kuhlen, C. Bischof

In the “Cluster of Excellence: Integrated Production Technology for High-Wage Countries” we are developing a flexible framework to enable linked, distributed simulations of entire manufacturing processes. Our goal is to provide the technological means and methods required to:
1. Facilitate data exchange and easy transfer of results from one simulation to another through a common language that is powerful enough to convey all the necessary information.

2. Take advantage of distributed soft- and hardware resources with an appropriate middleware that has a sufficient layer of abstraction to encapsulate system specific details behind a standardized interface.

3. Establish a unified mechanism to describe single simulation jobs as well as complex workflows consisting of several simulations working hand in hand to model a certain production process.

4. Further insight and understanding of the process as a whole using leading edge Virtual Reality technology to visualize and adequately post process the computed results of all simulations involved in the same process.

To overcome syntactic and semantic differences between data formats employed in the simulation programs, we introduce a common language capable of handling all sorts of data types and field attributes that occur. Aside from asserting the reusability of tools operating on this common data language, this strategy will supposedly minimize the workload overhead required to integrate new simulations. Our approach reflects industrial reality as closely as possible. For an easy integration we take advantage of already available infrastructure, processing power and tools to keep additional investments in terms of hardware and licenses as low as possible. Through establishing methods to formalize simulation runs into a common framework we gain sufficient abstraction from system and software specificities to enable dynamic workflow construction encompassing several simulations. In contrast to traditional scientific visualization, which focuses on a single dataset, it is of the outmost importance to be able to find and identify interdependencies and causalities between several simulation datasets. This forces us to integrate all simulation results from a processing chain into a single visualization context running at interactive frame rates. Being able to understand the whole process for the various simulation experts makes it mandatory for our framework to preserve and reconstruct the time and space coherency between datasets thus reflecting the real process as closely as possible.

Interactive Visualization for Prognosis and Risk Assessment of Geothermal Reservoirs
I. Tedjo-Palczynski, T. Kuhlen

This visualization project is part of the BMBF funded joint research project MeProRisk (novel MEthods for exploration, development, and exploitation of geothermal reservoirs – a toolbox for PROgnosis and RISK assessment). The goal of the visualization is to help detecting geothermal deposits, improving the underlying geological model, and finding coherencies between the geological properties, e.g. between permeable zones and temperatures.

Due to scattered and limited source of geological measurements the generation of reliable geothermal datasets is a current topic in the geothermal research. Thus, it is crucial to investigate the possibilities to include and emphasize the estimated uncertainty of the data in
the visualization.

Displaying the visualization in an immersive environment should not only provide a better visual depiction of the volume dataset than the currently widely-used desktop visualization applications, but also enable the use of 3D user interfaces to support the analysis of the complex geological structures. In the further development phase of this project the interaction is going to be extended to enable the parameter editing of the underlying geological model.

![Visualization of a drill hole dataset showing the flow structure of ground water, porosity field (displayed by volume rendering), and an isosurface where the temperature is 100 degree celsius.](image)

Figure 1: Visualization of a drill hole dataset showing the flow structure of ground water, porosity field (displayed by volume rendering), and an isosurface where the temperature is 100 degree celsius.

![RASim - Regional Anaesthesia Simulation
S. Ullrich, T. Kuhlen](image)

This DFG-funded research project is focusing on the simulation of regional anaesthesia in virtual environments. It is an interdisciplinary collaboration with anaesthesists (Prof. R. Rossaint), anatomists (Prof. A. Prescher) and computer scientists (Prof. Thomas Deserno) from the RWTH Aachen University and the University Hospital Aachen. The goal is to provide a VR-based simulator for regional anaesthesia in order to improve the training of medical residents and thus minimize risks for patients. With our cooperation partners, medical imaging acquisition techniques have been used to create multiple MRI data sets of individual subjects. Experts from the department of Medical Informatics developed customized segmentation algorithms to extract geometrical representations of different soft tissue types. With a novel VR-based modeling tool virtual nerve cords are inserted into these anatomical
data sets. Functional anatomical systems are used to manage these data sets and provide an interface for simulation algorithms. The most essential part of the simulation is the electric impulse transmission through inhomogeneous soft tissue, which results in nerve stimulation and motor response (i.e., muscle activation). In order to achieve this, path finding algorithms have been adapted and rules of electrophysiology are employed.

Figure 1: The simulator is combined by visualization techniques with stereoscopic output and interaction metaphors that utilize intuitive input devices like commercial haptic devices.

Interactive Cutting of Deformable Objects in a VR-based Surgical Simulator

L. Jerabkova, T. Kuhlen

In this research activity, methods for an interactive simulation of finite elements based deformable objects including topological changes have been developed. The key to this method, which allows for an interactive cutting of deformable objects in virtual environments, is the usage of the extended finite elements method (XFEM). The XFEM can effectively model discontinuities within an FEM mesh without creating new mesh elements and thus minimizing the impact on the performance of the simulation.

The method has been integrated into a software framework suitable for the creation of complex VR applications as, e.g., a surgical simulator. It uses thread level task parallelization for the concurrent execution of visualization, collision detection, haptics and deformation. Moreover, we propose a parallelization approach for the deformation algorithm, which is the most computationally intensive part. The solution is based on OpenMP and requires only minimal changes to the source code while achieving a speedup comparable to the results of more sophisticated approaches. The framework benefits from the current developments in the computing industry and allows an optimal utilization of multicore CPUs.

On the basis of the framework, we developed a prototype of a trainer for open surgery. The
main differences between minimal invasive and open surgery are the size of the working area and the way the surgeon interacts with the tissue. Generally speaking, the minimal invasive surgery is suitable for smaller interventions, the manipulations with the tissue are simpler, and the variability of operating tools is rather limited. In order to create a realistic VR simulation of open surgery, large deformable objects have to be simulated at a reasonable accuracy. The current implementation only allows certain cut shapes, and an implementation of arbitrary cuts including the extension of an existing cut is desirable. In principle, the XFEM is suitable for modeling arbitrary discontinuities, the main challenge here is a consistent remeshing of the geometry surface.

Figures 1 and 2: In the surgical simulator, interactive cutting is enhanced by force feedback.

Spatial Processing in Virtual Reality – Fundamentals and Clinical Applications

M. Wolter, T. Kuhlen

This joint research project is a cooperation with B. Fimm, W. Sturm, and K. Willmes (University Hospital Aachen) and is kindly supported by a grant from the Interdisciplinary Center for Clinical Research 'BIOMAT.' within the faculty of Medicine at RWTH Aachen University.

Since the 1990s, VR has found its way into psychological research and neurosciences. Virtual environments enable new experimental possibilities concerning human spatial processing. Advantages of the use of VR applications in psychological research are, amongst others, high ecological validity, experimental control, experimental realism, the use of “impossible” manipulations, and the ease of implementation and conduction of experiments.

The overall project consists of four sub-projects:
(A) The functional fields of three-dimensional visual space – a VR- and fMRI-study,
(B) Threedimensional uni- and crossmodal cueing in spatial shift of attention: a VR study,
(C) Interaction of task irrelevant object features with perception in virtual reality 3D space – an fMRI-guided TMS study, and
(D) Standardization and evaluation of a VR-based system for the assessment and therapy of disorders of spatial representation.

In these four sub-projects, different aspects of cognitive processing of 3D spatial perception are investigated using VR methods.

To provide a common basis for all psychology related projects, the ReactorMan software is developed. ReactorMan provides an interface customized for the medical or psychological researcher to define a virtual world and the experimental sequence. The software provides special functionalities such as reaction-time measurements and performance monitoring, as well as interfaces for employed medical devices (e.g., fMRI scanner).

Project (A) tries to find attentional asymmetries in 3D-space, such as a known pseudoneglect, i.e., a facilitated processing of left-sided stimuli, for healthy subjects in 2D space.

Project (B) tackles the question, if cueing effects (i.e., one reacts faster to a signal if one gets a cue, which turns the attention to the signal’s location) occur analog to 2D space. In addition, cueing effects are not only studied in the visual modality, but also crossmodal, that is between visual and acoustic modality.

Project (C) analyzes the interaction of task irrelevant object features such as numerical size and physical size. It is known that numerical size of a number influences the spatial perception of this displayed number. In this project, an fMRI-guided transcranial magnetic stimulation (TMS) in a 3D VR context is employed for the first time.

The main aim of project (D) is the standardization and evaluation of a VR-based assessment and therapy system for patients with impairments of spatial representation. A previously developed system, the virtual city Eurade, is evaluated in a study involving 150 normal subjects in order to provide normative data for the assessment of the patients. Based on these normative data, the performance of patients during a baseline phase, before and after the training and long term stability effects of the training can be evaluated.

Figure 1: The virtual city Eurade for orientation therapy
Localization of Moving Stimuli in the 3D Virtual Space

M. Wolter, T. Kuhlen

This project is a cooperation with J. Müßeler (Institute for Psychology) and B. Fimm (University Hospital Aachen) and is kindly funded as a Pathfinder Project within the Exploratory Research Space @ RWTH Aachen University.

In this project, human spatial perception and motion control are analyzed with the aid of a known mislocalization from 2D space: for a fast moving stimulus, the location of occurrence is systematically mislocalized in the direction of movement. The analysis of this and similar mislocalization allows to draw conclusions for principles of perception-action-interactions.

Two approaches of explanation are proposed for this phenomenon: an attentional capture approach and the so-called “bow-wave activation” approach. The latter theory does not explain the mislocalization in 3D, while the former does. Virtual Reality offers the possibility to accurately control spatial and temporal presentation of stimuli in the 3D space. Again, the ReactorMan software is applied to design and implement the experimental paradigm.

Real-time Room-Acoustics for interactive and dynamic Virtual Environments

I. Assenmacher, D. Rausch, T. Kuhlen

This project is a joint-research project with the Institute of Technical Acoustics (Prof. M. Vorländer, and D. Schröder). It is funded by the German Research Foundation (DFG). The focus of the project is the implementation of an immersive virtual environment with a dynamic and real-time capable acoustic reproduction. The main features are the capability to change the room-acoustic simulation parameters inside of a virtual environment. Thereby the acoustic simulation accounts for advanced effects such as diffraction, transmission and scattering in dynamic environments. The overall system is to enable novel applications, for example interior architecture or training of emergency situations.

Subtasks of the project are the evaluation of the degree of immersion into a virtual scene by the help of highly plausible auralizations in conjunction to the visual environment. The
system is based on developments of a preceding project also supported by the DFG where the acoustic reproduction of dynamic spatialized sound sources with few loudspeakers was in focus. Main work packages research on the ability for advanced manoeuvring in the virtual environment with the help of acoustic stimuli, the real-time visualization of the acoustic simulation inside of a virtual sound laboratory as well as the parallelization of the simulation algorithms in order to enable real-time processing of the room acoustics simulation. Other aspects cover the development of novel interaction technology for the modification of the dynamic room setup.
Other Activities

As part of the Center for Computing & Communication, the VR Group is hosting and continuously upgrading a high end Virtual Reality and visualization infrastructure, consisting of immersive displays and 3D interaction devices. In the last 18 months, we have given more than 100 presentations in our VR lab for visitors from within RWTH as well as for delegations from industry and research institutions from all over the world.

With the excellence initiative, VR systems are going to be installed not only in the Center for Computing & Communication, but also at multiple RWTH facilities. For instance, the VR Group is supporting the Graduate School AICES with the installation of a large high-resolution wall, providing a stereo projection of about 4096x2048 pixels. Together with JSC Jülich, we have recently established ivNet (immersive visualization network) as a structural and methodical measure under JARA with the goal to integrate advanced visualization and exploration methods into the scientists’ daily work. To achieve this goal, high end 3D workplaces which fit into an office environment, are connected via Grid technology to each other and also to remote, parallel file servers and post-processing servers. Such an infrastructure will allow for an intuitive and collaborative exploration of even very complex phenomena between researchers in Aachen and Jülich.

In a lot of smaller cooperations with RWTH institutes and industry, we provided methodical support, helping our partners to visualize their data by means of state-of-the-art methods and beyond. For this purpose, we have been developing the software framework ViSTA (Virtual Reality for Scientific and Technical Applications) for more than ten years now. ViSTA is based on Open Source standards and is freely available to our research partners.

Torsten Kuhlen is the CEO of the Virtual Reality Center Aachen (see www.vrca.rwth-aachen.de) and in addition the speaker of the “Fachgruppe Virtual & Augmented Reality” within the “Gesellschaft für Informatik”. In 2008, he co-organized the yearly workshop of this GI section and was a member in the program committees of several national and international conferences like the IEEE VR.
Talks and Publications

Talks

Ingo Assenmacher, VR Toolkit ViSTA, TU Dresden, April 10, 2007
Ingo Assenmacher: Near to head acoustics using few loudspeakers for immersive virtual Environments, University of Lousiana at Lite3D, March 6, 2008
Ingo Assenmacher: ViSTA Device Driver Intergration, SOFA Workshop, INRIA Grenoble, September 10, 2008
Thorsten Frommen: Virtual Reality-based Simulation for Regional Anaesthesia Block of the Lower Limbs, 5. GI-VR/AR Workshop, Magdeburg, September 25, 2008
Lenka Jerabkova: Surgical Cutting on a Multimodal Object Representation, Bildverarbeitung für die Medizin, München, March 26, 2007
Torsten Kuhlen: Computational Engineering Science and Virtual Reality at RWTH Aachen University, TU Dresden, April 10, 2007
Torsten Kuhlen: Virtual Reality at RWTH aachen University, TU Freiberg, September 18, 2007
Torsten Kuhlen: Immersive Visualization at RWTH Aachen University, ZKI AK Supercomputing, TU Ilmenau, September 18, 2008


Marc Schirski: Interactive Exploration of Large Data in Hybrid Visualization Environments, EGVE 2007, Weimar, July 18, 2007

Sebastian Ullrich: Subject-Based Regional Anaesthesia Simulator Combining Image Processing and Virtual Reality, Bildverarbeitung für die Medizin, München, March 26, 2007


Sebastian Ullrich: Extending MPML3D to Second Life, 8th International Conference on Intelligent Virtual Agents, Tokyo, September 2, 2008


**Publications**


Tobias Walter (i3) won the Microsoft Partner Program ‘Student of the Year 2007’ award for his Diploma Thesis entitled ‘Analyse und Redesign von Softwarearchitekturen in Telekommunikationssystemen.

Tobias Heer (GK 643, LuFG i4) will receive GI/ITG-KuVS award for the best Diploma Thesis in 2007, entitled ‘HIP: Lightweight Authentication for the Host Identity Protocol’

Georg Kunz (UMIC, LuFG i4) received ‘Friedrich-Wilhelm Preis’ 2008 for his diploma thesis ‘Design and Implementation of a Platform Abstraction Layer for Modular Communication Protocols’

Daniel Neider’s (i7)diploma thesis, entitled ‘Lernverfahren für Automaten über linearisierten XML-Dokumenten’, was selected as best theoretical thesis at the “GI-Informatiktag” in Bonn (June 2008).

Dr. Dietmar Berwanger (Mathematical Foundations of Computer Science Group) received the Ackermann Outstanding Dissertation Award for Logic in Computer Science for his PhD-Thesis ‘Games and Logical Expressiveness’.

Others

The competition ‘Experience Math’ (funded by the BMBF) aims to rise kids’ interest in Mathematics. Helen Bolke-Hermanns (i4) won a prize for her contribution ‘How tall was Charlemagne – the Aachen Tour of Mathemtics’.

Walter Oberschelp (i7) won an award in the Competition ‘Kopf und Zahl’ in the ‘Year of Mathematiks’ 2008.

The ‘GalaXIs’ student team (i11) won the ‘Carolo-Cup’ for autonomous model cars.

In the Robocup league ‘Robocup@Home’ the team of the Knowledge-Based Systems Group
• won the 2007 German Championship and the World Championship in the Robocup league ‘Robocup@Home’
• won the 2008 German Championship and were runner-up at the World Championship

Renate Eschenbach-Thomas, Head of the Computer Science Library, won the award “Prädikat Familienfreundlich” of the City of Aachen for her project ”KiWi” (children's corner in the library), and received the prize in Sept. 07 from the Lord Mayor of Aachen.

The tool AproVE (LuFGi2) won the International Competition of Termination Tools 2007 in the categories functional programming, logic programming, and term rewriting.
Dissertations
Robust Real-Time Localization and Mapping in Single and Multi-Robot Systems

Vazha Amiranashvili

This thesis addresses several aspects of mobile autonomous navigation in the single and multi-robot systems. Novel solutions to the single robot localization and simultaneous localization and mapping (SLAM) problems are presented for both the single and multi-robot cases. The global localization algorithm is an instance of the known Monte-Carlo localization technique. Optimizations of the so-called perception model led to an order of magnitude reduction in the overall localization time of a robot in comparison to the existing techniques known from the literature. Based on the mentioned perception sensor model, a heuristics is developed for solving one of the most challenging problems in mobile robotics -- the "kidnapped" robot problem. Also, the thesis presents a new approach to the solution of the robotic SLAM problem. The approach is based on the so-called Rao-Blackwellized particle filters, which is a new technique in the context of the robotic SLAM problem. The implementation of this algorithm is capable of mapping an environment several times faster than the existing approaches. It extends our single robot localization and mapping algorithms to the multi-robot case. The main idea is to determine the relative poses of robots by localizing them in sup-maps of each other. The multi-robot localization and mapping approaches have also shown good experimental results.

Examiners: Prof. Gerhard Lakemeyer, Ph.D., Prof. Dr. Rudolf Mathar
Day of Examination: 14.02.2007
Bringing Iterative Design To Ubiquitous Computing: Interaction Techniques, Toolkits, and Evaluation Methods

Tico Ballagas

An iterative human-centered design process is required to create interfaces that are useful, intuitive, efficient, and enjoyable for users in the ubiquitous computing domain. Currently, only experts can design, prototype, and deploy ubiquitous computing applications; others lack the tools and conceptual frameworks. This work starts to fill the gap by providing contributions that support each phase of the iterative human-centered design process and address the complexity of ubiquitous computing application scenarios.

- To support the design phase, the range of ubiquitous mobile input techniques are organized into a design space, which helps identify the relationships between input techniques, and select the most appropriate input technique for an interaction scenario.

- To support the prototyping phase, the iStuff Toolkit architecture simplifies construction of functional prototypes for ubiquitous computing application scenarios. The architecture has been used to create two separate toolkits: iStuff to simplify prototyping physical user interfaces for ubiquitous computing, and iStuff Mobile to simplify prototyping new sensor-based interactions for mobile phones in ubiquitous computing.

- To support the evaluation phase, a new conceptual framework based on expressiveness is used to demonstrate how to evaluate input devices in prototype form (suffering from reduced resolution or sampling rates) and still make conclusions about future performance if further time and money were invested in improvements.

To illustrate how this iterative design process can be used from drawing board to deployment, experiences developing REXplorer are shared. REXplorer is one of the first permanently installed pervasive games and helps tourists explore the historical UNESCO World Heritage city of Regensburg, Germany. Players use a special “paranormal activity detector” (a device composed of a mobile phone and a GPS receiver) to interact with location-based and site-specific spirits. “Casting a spell” by waving the wand-like detector lets players awaken and communicate with the spirits to receive and solve quests. The game is designed to make learning history fun and influence tourists’ path through the city.

Evaluator: Prof. Dr. Jan Borchers

External Evaluator: Prof. Dr. Hans Werner Gellersen

Examination date: 23. August 2007
Automatic Presentations of Infinite Structures

Vince Bárány

The work at hand studies the possibilities and limitations of the use of finite automata in the description of infinite structures. An automatic presentation of a countable structure consists of a labelling of the elements of the structure by finite words over a finite alphabet in a consistent way so as to allow each of the relations of the structure to be recognised, given the labelling, by a synchronous multi-tape automaton. The collection of automata involved constitutes a finite presentation of the structure up to isomorphism. More generally, one can consider presentations over finite trees or over infinite words or trees, based on the appropriate model of automata. In the latter models, uncountable structures are also representable.

Automatic presentations allow for effective evaluation of first-order formulas over the represented structure in line with the strong correspondence between automata and logics. Accordingly, automatic presentations can be recast in logical terms using various notions of interpretations. The simplicity and robustness of the model coupled with the diversity of automatic structures makes automatic presentations interesting subject of investigation within the scope of algorithmic model theory.

Although automata have been in use in representations of infinite structures in computational group theory, in the analysis of numeration systems and finitely generated infinite sequences as well as in the theory of term rewriting systems, a systematic investigation of automatic structures using model theoretic methods has only just begun in the last twelve years.

There are two main lines of research in this field. One would like to have a classification of automatic models of certain first-order theories of common interest, such as linear orderings, trees, boolean algebras, groups, etc. Though efforts aimed at obtaining structure theorems have produced considerable advancement in recent years, this programme is still in an early stage. Even further lacking is our understanding of the richness of automatic presentations of key individual structures. A prominent result in this area is the deep theorem of Cobham and Semenov concerning numeration systems. In this style, one would like to know the degree of freedom in choosing automatic presentations of a particular structure.

In this thesis we present contributions to both of these problem areas. We also study restricted notions of presentations and clarify the relationship of automatic presentations over finite and infinite words. The peculiarities of using automata to represent structures up to isomorphism introduce problems out of the range of classical automata theory. We present some new techniques developed to tackle these difficulties.

Evaluator: Prof. Dr. Erich Grädel
External Evaluator: Prof. Dr. Jean-Éric Pin
Date of oral exam: September 5, 2007
In development processes, a multitude of inter-dependent documents is created. They are elaborated by different developers using heterogeneous tools. As the documents are describing the same product from different perspectives, there are numerous fine-grained relationships between their contents. Thus, the documents have to be kept consistent to each other to ensure the quality of the developed product. In current development processes, this is done manually most of the time, which is error-prone and time consuming. Available tool support only covers simple batch-wise generation of one document out of another, neglecting the incremental nature of development processes and the need for user interaction.

This thesis presents a more advanced approach for supporting consistency management using so called integrators. The basis of the approach are graphs, graph transformation and triple graph grammars (TGG). As area of application, development processes in chemical engineering are considered.

Integrators allow bi-directional transformation between documents as well as checking their mutual consistency. The fine-grained relationships are persistently stored in an integration document. Integrators work incremental, only propagating the changes between documents during each transformation. Integration is controlled by a set of integration rules. As the dependencies between documents are ambiguous, user interaction is supported. New rules can be derived at runtime from user interactions. As there are a lot of different types of documents to be integrated in different domains of applications, it is needed to be able to implement integrators with low efforts and to quickly adapt them to new types of documents.

Integration rules are defined with a mostly declarative multi-layered formalism realized as an extension of the Unified Modeling Language (UML). There is a type layer defining types of documents and types of entities they contain as well as constraining the inter-document relationships by specifying link types. On an instance layer, link templates specify pattern for possible relationships using instances of entity types and link types. From link templates, which are purely declarative, operational rules can be derived using the TGG approach. They allow forward and backward transformation as well as consistency checking.

The execution of integration rules is done using graph transformations. In contrast to the original triple graph grammar approach, each rule is applied by multiple transformation steps following and overall integration algorithm. This mode of execution allows for separating the detection of possible rule applications and their application which is the basis to resolve ambiguous situation by user interaction. The interleaved execution of forward, backward, and consistency checking rules is supported.

Different prototypes have been implemented as proof of concept: A rule editor, extending a commercial UML tool, allows modeling integration rules supporting checks of their syntax and semantics. There are two approaches for realizing integrators. One aims at the evaluation of the approach. It is based on directly deriving a graph transformation system from a set of integration rules. It is not connected to external applications. For the a-posteriori integration of real-world tools, an integrator framework has been developed consisting of an architecture as well as of pre-defined components that comprise most of the functionality needed in integrators. Its central component is an interpreter for integration rules that implements the integration algorithm.
The results of this thesis are being transferred to industry in cooperation with a partner company as part of the subproject T5 “Tools for Consistency Management between Design Products” of the Transfer Center 61 “New Concepts and Tools for Chemical Engineering Practice”.

**Supervisor:** Prof. Dr.-Ing. Manfred Nagl  
**External Supervisor:** Prof. Dr. Gregor Engels  
**Day of Exam:** June 26, 2007
Robot Controllers for Highly Dynamic Environments With Real-time Constraints

Alexander Ferrein

The fields of mobile autonomous robotics and cognitive robotics are active research fields. While in recent years several successful applications showed that mobile robots can interact with their environment and fulfill meaningful and useful tasks, many questions on how to design autonomous mobile robots still remain open and are subject to active research in this field. For problems like navigation, collision avoidance, and localization, robust approaches have been proposed, which are widely used. On the other hand, the question how such robots can act intelligently, has wide-spread ideas and various approaches.

This thesis proposes an approach to the problem of decision making (deliberation) for robots or agents which moreover have to decide under real-time constraints in adversarial domains, i.e. multi-agent domains where opponents have contrary goals and try to foil the goals of the opposing team. More precisely, it proposes the language Readylog as an account to intelligent decision making in dynamic real-time domains. Readylog is a Golog family language and combines features known from other dialects in one framework. It is based on the Situation Calculus and offers probabilistically projecting a given world situation into the future or dealing with a continuously changing world. It comes with an efficient implementation and a mechanism to progress the internal database. Further, Readylog makes use of decision-theoretic planning. Several alternatives in the robot program are left open and Readylog chooses the most promising one against a background optimization theory. As decision-theoretic planning is computationally costly, the thesis looks for ways to reduce the complexity of planning. One possibility that is proposed is to make use of options, which are macro actions in the decision-theoretic context. The detailed applications of Readylog in the robotic soccer domain is shown.

Evaluator: Prof. Gerhard Lakemeyer, Ph.D.
External Evaluator: Prof. Michael Beetz, Ph.D.
Date of oral exam: 20.12.2007
Decentralized and View-based Management of Distributed Design Processes

Markus Heller

Competition on the global market with globally acting companies or contractors/subcontractors is a big issue. Products and services have to be developed in highest quality, faster and even cheaper within product life cycles. Companies and organizations have to react quickly and flexibly on the changing constraints of the market. Therefore, an efficient management of development processes is of central importance.

Development processes in engineering disciplines, as e.g. chemical engineering or software development, are characterized by uncertainty and dynamics. They can hardly be planned in advance, as changes of product requirements, unexpected backtracking steps, and the dependency of the process on already developed intermediate results have to be regarded. Especially, in bigger development projects, the support of the process manager and the developers by a process management system is necessary, to allow a better planning, execution, and control of these processes.

On one hand, in large development processes crossing different organizations, the coordination of development activities is difficult, as teams are spread over different organizations and sites. Additional problems have to do with the cooperation partners, looking for autonomy and saving their knowhow. On the other hand, the cooperation of organizations and their process managers is necessary.

Difficult tasks are the support of a decentralized management approach, the autonomous management of the visibility of private and public process information, the management of different and individual cooperation situations between the partners, and the integration of heterogeneous process management systems. According to these requirements, the currently available tool support has a lot of severe drawbacks, which basically are the result of the insufficient flexibility of the used and current management systems.

To solve these deficits and resulting problems, in this dissertation a new cooperation model is introduced. Accordingly, we address the corresponding tool support for the management of distributed development processes in development networks. The graph-based process management system AHEAD, developed at the Department of Informatics 3 of RWTH Aachen University, is taken as basic platform. It was comprehensively extended. AHEAD was developed in the interdisciplinary Collaborative Research Center IMPROVE, which deals with models and tools for development processes in chemical engineering.

The conceptual framework of the cooperation model has different modeling layers for distributed development processes and their management: On the level of process instances, activities, products, and resources of the development processes are modeled. One layer up, common process interfaces of different process instances are dealt with. On the topmost layer individual cooperation scenarios are modeled, in order to configure the collaboration of different partners of process interfaces.

The given approach is characterized by the following properties:

- Support of dynamic processes: Process managers are able to plan their development process in their organizations autonomously and exclusively and are able to control and monitor their processes.
• Dynamic process views: In order to publish activities, products, and resources of a subprocess in another organization, process managers can define and publish autonomous process views of certain parts of their process. The connection of the processes of different organizations is made via mutual exchange of process views.

• Cooperation of different partners: Corresponding rights and duties of the cooperation partners, can be modeled individually. Process managers can agree on cooperation contracts for individual process interfaces, in which the process views and the rights of the contract partners are determined in relation to cooperative process modeling and process execution.

• Consistency control for the decentralized management: A comprehensive approach for consistency control was realized which – for different process managers – allows the cooperation of process instances, process views, and cooperation contracts. Inconsistent situations during planning and execution are detected and can be repaired by process managers.

The cooperation model was specified by a graph rewriting system. From this specification management tools for an extended process support was generated.

Summing up, we now have a view-based process management system, which by a decentralized approach supports process management and developers of cooperating organizations, when cooperatively modeling local processes, common process interfaces, and the execution of distributed processes.

Supervisor: Prof. Dr.-Ing. M. Nagl, RWTH Aachen University
External Supervisor: Prof. Dr. W. Schäfer, University of Paderborn
Day of Exam: February 2, 2008
Logic and Games on Automatic Structures
Łukasz Kaiser

The evaluation of a logical formula can be viewed as a game played by two opponents, one trying to show that the formula is true and the other trying to prove it false. This correspondence is exploited algorithmically to evaluate formulas of first and second-order logic on finite structures. We extend the game-based algorithmic approach to first-order logic on infinite structures that arise in computer science. Such structures are stored and manipulated by a computer, thus elements and relations must be represented in a finite way. We study a prominent class of finitely presentable structures, namely automatic structures.

Automatic structures consist of elements represented by words over a finite alphabet. Relations within these structures are represented by synchronous automata that perform step-by-step transitions on tuples of symbols from the alphabet. A prominent example of an automatic structure is Presburger arithmetic, for which the natural way of writing numbers as sequences of digits and the standard column addition method constitute an automatic presentation.

An important property of automatic structures is that first-order logic is decidable on these structures. To develop the correspondence between games and logic on automatic structures, we first look for suitable extensions of first-order logic that remain decidable. We study the notion of game quantification and extend the notions of open and closed game quantifiers, introduced in the model theory of infinitary logics, to a regular game quantifier. We show that this game quantifier preserves regularity on automatic presentations and investigate its expressive power. We identify the classes of structures on which first-order logic extended with this quantifier collapses to pure first-order logic. For better understanding of the classes where this is not the case, we introduce the notion of inductive automorphisms and show that they preserve relations defined using the game quantifier.

Model-checking games for the above extension of first-order logic can be defined in a more natural way than for pure first-order logic. Towards this, we extend the classical two-player parity games to a multiplayer setting where two coalitions play against each other with a particular kind of hierarchical imperfect information about actions of the players. In contrast to the classical case, in hierarchical games it is essential that players alternate. We show that otherwise the problem which coalition wins a hierarchical game is undecidable. Nevertheless, there is an important aspect in which they are similar to classical games: hierarchical games are robust with respect to changes of the representation of winning condition.

One reason for this robustness of hierarchical games is that only a finite memory is needed to reduce games with complex winning conditions to games with simpler ones. While this technique has been well-known for games with finitely many priorities, our approach is the first to extend it to games with infinitely many priorities on infinite arenas. We generalize the classical notion of latest appearance record to a new memory structure, which we show to be sufficient for winning Muller games with a finite or co-finite number of sets in the Muller condition, and additionally for a few other classes of games with infinitely many priorities. Certain classes of winning conditions on infinitely many priorities admit descriptions in terms of generalized Zielonka trees. We investigate such conditions and show that the correspondence between the number of branches of a Zielonka tree and the memory needed for strategies generalizes to the case of infinitely many priorities.
A basic way of extending first-order logic is by adding generalized Lindström quantifiers. We address the following question: which generalized unary quantifiers can be added to first-order logic without introducing non-regular relations on automatic structures. We answer this question by giving a complete characterization of such quantifiers in terms of definability using cardinality and modulo counting quantifiers. We show that these quantifiers indeed preserve regularity on all automatic structures, including the non-injective omega-automatic ones. As a corollary we answer a question of Blumensath and prove that all countable omega-automatic structures are in fact finite-word automatic. Further, we study cardinality quantifiers on a large class of generalized-automatic structures. We use the composition method for monadic second-order logic to show that on such structures cardinality quantifiers collapse to first-order logic.

Evaluator: Prof. Dr. Erich Grädel

External Evaluators: Prof. Dr. Joost-Pieter Katoen, Prof. Dr. Damian Niwinski

Date of oral exam: June 26, 2008
In recent years, significant improvements have been achieved in statistical machine translation (MT), but still even the best machine translation technology is far from replacing or even competing with human translators. However, an MT system helps to increase the productivity of human translators. Usually, human translators edit the MT system output to correct the errors, or they may edit the source text to limit vocabulary.

A way of increasing the productivity of the whole translation process (MT plus human work) is to incorporate the human correction activities in the translation process, thereby shifting the MT paradigm to that of computer-assisted translation (CAT). In a CAT system, the human translator begins to type the translation of a given source text; by typing each character the MT system interactively offers and enhances the completion of the translation. Human translator may continue typing or accept the whole completion or part of it. Here, we will use a fully fledged translation system, phrase-based MT, to develop computer-assisted translation systems.

An important factor in a CAT system is the response time of the MT system. We will describe an efficient search space representation using word hypotheses graphs, so as to guarantee a fast response time. The experiments will be done on a small and a large standard task. Skilled human translators are faster in dictating than typing the translations, therefore a desired feature of a CAT system is the integration of human speech into the CAT system. In a CAT system with integrated speech, two sources of information are available to recognize the speech input: the target language speech and the given source language text. The target language speech is a human-produced translation of the source language text. The main challenge in the integration of the automatic speech recognition (ASR) and the MT models in a CAT system, is the search.

The search in the MT and in the ASR systems are already very complex, therefore a full single search to combine the ASR and the MT models will considerably increase the complexity. In addition, a full single search becomes more complex since there is not any specific model nor any appropriate training data. In this work, we study different methods to integrate the ASR and the MT models. We propose several new integration methods based on N-best list and word graph rescoring strategies. We study the integration of both single-word based MT and phrase-based MT with ASR models. The experiments are performed on a standard large task, namely the European parliament plenary sessions.

A CAT system might be equipped with a memory-based module that does not actually translate, but find the translation from a large database of exact or similar matches from sentences or phrases that are already known. Such a database, known as bilingual corpora are also essential in training the statistical machine translation models. Therefore, having a larger database means a more accurate and faster translation system.

In this thesis, we will also investigate the efficient ways to compile bilingual sentence-aligned corpora from the Internet. We propose two new methods for sentence alignment. The first one is a typical extension of the existing methods in the field of sentence alignment for parallel texts. We will show how we can employ sentence-length based models, word-to-word translation models, cognates, bilingual lexica, and any other features in an efficient way. In the second method, we propose a new method for aligning sentences based on bipartite graph matching. We show that this new algorithm has a competitive performance with other
methods for parallel corpora, and at the same time it is very useful in handling different order of sentences in a source text and its corresponding translation text. Further, we propose an efficient way to recognize and filter out wrong sentence pairs from the bilingual corpora.

Referent: Professor Dr.-Ing. Hermann Ney
Coreferent: Professor Dr. Enrique Vidal
Oral exam: 10.07.2008
Semantical Support for Conceptual Design of Buildings
Bodo Kraft

The first phase of an architectural design is called conceptual design. It is not adequately supported by existing software tools. In this early design phase the understanding of the organization and the functions of a building are more important than exact dimensions and definitions of materials. Most important are the functional units of a building, as areas and rooms, and their complex mutual relations. This abstract view on a building design allows to regard a semantical level of design problems.

The architect has to know and to obey all regulations and constraints of a conceptual design. These are laws, regulations, norms, but also requirements and predeterminations of all stakeholders of a design process. Erroneous conceptual designs imply additional costs or even the failure of the whole process. As no suitable support for architects is available, conceptual designs use simple CAD-programs or the classical paper sketch. When these sketches are later transformed in a CAD-system, the implicit and conceptual information cannot be mapped and gets lost.

This dissertation identifies two topics for supporting the architect within conceptual design. Firstly, architects get a better tool support for the development of conceptual designs. The corresponding tools regard the high abstraction level and the creative and evaluative activities of architects. Secondly, a domain expert – an experienced architect or a civil engineer – gets the possibility, to formalize relevant conceptual design knowledge. The formalization is given specifically for a class of buildings. The combination of both above aspects allows the use of formalized knowledge to analyze conceptual designs. Error messages and hints for inconsistent parts of the design are given to the architects.

This dissertation follows two approaches: On one hand, the formal modeling and specification of concepts for later realizing suitable tools can be done using corresponding tools. They are based on the graph rewriting system PROGRES and corresponding generation mechanisms. On the other hand, a practical approach is taken. Looking how an architect is working and analyzing current CAD-tools, new functionalities are identified. A corresponding industrial CAD-tool was extended in order to incorporate this new functionality.

The dissertation gives an extended motivation, validates concepts, and approves realizations to support the conceptual design by software tools. Problem adequate concepts are offered for the design phase, a possibility to formalize and use conceptual knowledge, and the realization of corresponding tools are given. They support the architect and decrease manual, organizational, and cognitive workloads. The saved capacity the architect can use to improve design plans.

Supervisor: Prof. Dr.-Ing. M. Nagl, RWTH Aachen University
External Supervisor: Prof. Dr. A. Borkowski, Polish Academy of Sciences, Warsaw
Day of Exam: January 26, 2007
A Semantic Time Framework for Interactive Media Systems

Eric Lee

Despite continuing advancements in computer technology, interaction with time-based media such as audio and video remain predominantly limited to the 1960s tape recorder metaphors of “play”, “pause”, “fast-forward” and “rewind”. These metaphors restrict users’ control over the timebase of the media, making it difficult to, for example, freely manipulate the tempo of an audio recording. This control is often taken for granted, for example when playing a musical instrument, or reading a book. While the technologies to build “malleable time” applications are already available, incorporating and integrating these technologies into a single interactive system remains non-trivial, and existing design tools and frameworks do not provide adequate support, especially with designing and implementing time-based interactions for digital media.

This research addresses these shortcomings in a number of ways. A time-design space is proposed that classifies existing research and technology for constructing interactive media systems into three domains: user, medium, and domain. This time-design space is a refinement of a traditional classification scheme used in human-computer interaction, and is inspired by existing work on conceptual frameworks for interaction design, as well as existing work studying time in computer music and the media arts. Some challenges of mapping time across these three domains are then presented; two such challenges include an analysis of how users time their beats relative to the music when conducting (user to medium time mapping), and an analysis of how processing latency in phase vocoder-based time-stretching algorithms affects requested audio play rate changes (medium to technology time mapping). The concept of semantic time is proposed as a common means of referring to time throughout the system. Semantic time includes mechanisms to represent time, including stymes (a polymorphic media time interval) and time maps (the expression of styme over real time); it also includes mechanisms to represent synchronization as constraints, and an algebra to manipulate beat microtiming for music. These ideas were realized in the Semantic Time Framework, a software library for constructing interactive media systems: the framework allows designers to more easily develop malleable time applications by allowing them to work with time as it is defined by the application (e.g., musical beats), instead of by the underlying technology (e.g., audio samples). The Semantic Time Framework is a hybrid architecture, using a data flow model based on the pipes and filters model for media processing, and declarative constructs for representing and manipulating time. To demonstrate its benefits, a number of interactive media systems built on the framework were constructed; these systems include Personal Orchestra, a family of interactive conducting systems; DiMaß, an audio timeline navigation system using direct manipulation; and iRhyMe, a visual programming environment for manipulating beat microtiming. These systems illustrate how designers can easily adopt the Semantic Time Framework for their applications (low threshold), but at the same time use it to build systems with a high ceiling of functionality.

Examiner: Prof. Dr. Jan Borchers
External Examiner: Prof. Dr. Sidney Fels
Examination date: 7. September 2007
Integrated Experience-Based Support of Cooperative Engineering Design Processes

Michail Miatidis

The main concern of a (engineering) design process is the investigation and application of novel, state of the art methodologies on the design of an (engineered) product, in order to increase its anticipated quality in a profitable way. Undoubtedly, design process excellence is vital for a company to stay in business, since it predetermines to a large degree the competitiveness of its products. The employment of well-established approaches aiming at the computer-based improvement of processes seems promising for making strides towards the faster and cheaper development of better products. The support provided by most of the existing approaches is based on prescribed assumptions concerning the evolution of the process. Yet, design processes exhibit an inherent dynamic nature that is less clear in other domains (e.g., routine business processes). As a consequence, many available process support systems fail to provide them with adequate support. The goal of this thesis is to present an approach for the fine-grained support of design processes, taking their inherent dynamic nature into consideration. The developed concepts build on the idea of the process integration of tools that which was contributed by preceding researchers, and extends it towards three directions. First, the original models for process integration are integrated with selected cooperative extensions in order to achieve a better synergy with the administrative level and provide support across several technical workplaces. The second direction has to do with the extension of the idea of process integration itself. More specifically, the existing mechanism is reworked in order to facilitate the flexible integration of a broader variety of tools according to their assessed capabilities. Last, a reuse mechanism is introduced for the direct and situated reuse of product, media and process traces captured in previous design processes. The overall approach has been validated through implementation in the frame of an interdisciplinary project dealing with the support of the early design phases in chemical engineering.

Advisors: Prof. Dr. Matthias Jarke, Prof. Dr.-Ing. Manfred Nagl

Date of exam: 18. April 2007
Exact Algorithms Based on Specific Complexity Measures for Hard Problems

Daniel Moelle

At present, most of the important computational problems – be they decision, search, or optimization problems – are known to satisfy one of the following two criteria:

1. The problem can be solved in polynomial time with respect to the input size n, where the degree of the polynomial is small enough to guarantee that the problem can be tackled efficiently in practice. In particular, the decision version of the problem is in $P$. Typical time complexities are $O(n \log n)$ and $O(n^k)$, $k < 4$.

2. The problem is NP-hard, and its decision version is NP-complete. We do not know whether the problem can be solved in polynomial time, but it is complex enough to express every other NP-complete problem via polynomial-time transformations. A typical time complexity for this case is $O(c^n)$ with $c > 1.1$.

Under the widely accepted assumption that $P$ does not equal $NP$, exact algorithms for problems of the second variety inevitably take superpolynomial time (not necessarily for every input, but in the worst case). In terms of worst-case behavior, it is easy to see that the respective algorithms can be infeasible even for instances of moderate size. The thesis at hand addresses this intricacy by combining two concepts, one of which is a well-known paradigm and the other one of which is an analytical tool that has only been used less explicitly in earlier scholarship. Firstly, we consider the parameterized complexity of hard graph problems. In particular, we design and analyze parameterized algorithms, i.e., algorithms whose running times are typically exponential in some parameter of the input (such as the desired size of the solution), but only polynomial in the size of the input. Secondly, we employ problem-specific complexity measures: we identify quantities whose smallness can be exploited in order to solve the problem more efficiently, then prove that they are small in any case, or that they can be made small using bounded additional effort. Such complexity measures are not to be confused with parameters for several reasons. Most importantly, we derive runtime bounds that are functions in the parameter $k$ and the input size $n$, not in the complexity measure. The term smallness is also used in varied interpretations – for most of the aforementioned problems, we even investigate complexity measures that can be exponentially large in $k$ and thus greater than $n.n$ Although the focus of this thesis clearly lies on the theoretical part, we complement the mathematical analysis of the algorithms with case studies and practical experiments. In one case, we exemplify how a theoretical algorithm (i.e., an algorithm tailored to the mathematical analysis) can be implemented and optimized for use in real-world applications.
Traceability and accountability of financial flows are among the main issues faced by credit institutes and long-term aid measures in crisis regions of the so-called Third World, especially in the context of credit rating and credit evaluation. Databases, data warehouses and business intelligence naturally play a key role in such situations, but equally important are the cultural adequacy and acceptance of solutions in the regional population, business, and administration. The thesis therefore pursues the key research question how concepts of data warehousing and datamining – originally created in the US and Europe – can be adapted to the needs of banks and other credit organizations in the Third World, more specifically, in the West-African Franc Zone. Based on a case study in Togo, the problems of credit handling in this region as well as the situation concerning data management and data quality are explored. Subsequently, the thesis evaluates solution concepts from the area of data warehousing, specifically metadata management, semantic modeling, and data quality management, with respect to the given context. Finally, an example data set gained from the case study is used to compare a number of data mining method variants and combinations from the Neural Network area with respect to the question which of them might be best suitable for the situation, where under a given risk acceptance of non-repayment (error of type alpha), you want to reduce the number of credit requests which are rejected wrongly (error of type beta) in order to avoid stifling the economy. Among the investigated variants of basic backpropagation networks, cascade correlation, resilient propagation, pre-optimization with genetic algorithms, and fuzzy classification, the best results were achieved backpropagation networks that have a relatively high number of hidden neurons. The results from problem analysis, literature analysis, and selected experiments with experimental data indicate some conclusions for promising strategies in data warehousing and data mining that could form a foundation for future large-scale field studies in the region.

Advisors: Prof. Dr. Matthias Jarke, Prof. Dr. Michael Bastian

Date of exam: 10. January 2008
An intelligent home, what could that be? More and more electronic appliances enter our private homes. Their presence seems to become ubiquitous. But we usually do not associate intelligence when we install new electronic appliances in our home environment. When will we start to call a setup of such appliances intelligent? Probably if this setup simplifies tasks at hand in our daily lives or increases security or comfort of living. Setups of such intelligent home environments in different places all over this world have given us a clue of some useful setups and some useful services which could be provided by these. Such homes are usually called smart homes or eHomes.

This work introduces a software engineering approach to support the installation of such setups for regular home owners. Its key contribution is the dissolution of the software development process in favor of a partly automated configuration process. There are various fields where the services provided in such eHome environments could support our daily life: One would be the enhancement of your comfort. This could be a central remote control, personal information management, or even an advanced wakeup service. Another need, which could be satisfied by such a service is security. In this field video surveillance or interactive alarm systems are possible. In the field of communication email, voice-over-ip, or instant messaging services are already widely used. There is a great potential for services in the health sector. Telemedicine or instant medical advise based on up-to-date sensor data are just some examples. Furthermore, infotainment services, like video on demand, teaching, or advanced multimedia experiences are of great interest. Via the monitoring facilities of energy consuming devices, automatic optimizations or exact billing is possible. Of course these areas are not very clearly separated from each other. A security service can also integrate services from other fields, especially using communication or even infotainment abilities. Services integrating different fields will be the most interesting services for potential customers of eHome systems. As the prices of lots of appliances used in the previously discussed services have decreased to affordable amounts. The appliances are affordable for regular home-owners. Hence, from this point of view the hardware for the realization of smart home environments is already available at reasonable costs.

The question arising is: Why are eHomes not more conventional? If you have a closer look at all these setups you will discover that these implementations are either research or hobby projects. One of the main barriers blocking a broader spreading of eHomes systems is the price of such systems. Even if appliances are affordable, the software driving an eHome is rather expensive as it is mostly developed or adapted for every single eHome. A complete software development process per case is not affordable for everyone. As software engineers, we are particularly interested in simplifying the software development process, arising when implementing a service for a specific home environment. The vision is: If the software for eHomes could be reused, and its adaptation and configuration be automated, one of the price barriers on home automation mass-market would be broken. The key point of this work is the dissolution of the software development process for eHome systems.

**Supervisor:** Prof. Dr.-Ing. Manfred Nagl

**External Supervisor:** Prof. Dr. Albert Zündorf

**Day of Exam:** June 27, 2007
Planung und Umsetzung von Geschäftsmodellen für eGovernmentdienste in Public Privat Partnerships

Gertraud Peinel


Advisors: Prof. Dr. Matthias Jarke, Prof. Dr. Helmut Krcmar

Date of exam: 2. September 2008
The graph rewriting systems PROGRES and Fujaba allow the model-driven development of software applications. For this purpose, the structure and the behavior of an application are modeled with PROGRES or Fujaba. Based on the specification, PROGRES and Fujaba enable the generation of corresponding source code which may be executed as visual prototype.

Although PROGRES and Fujaba offer an extensive mechanism, they are restricted to the development of monolithic, unstructured software applications. Thus, their usage is not advantageous when developing complex and large software applications. Instead of having a monolithic architecture, a complex application should be realized as a modularized or even as a distributed system. Therefore, this thesis extends PROGRES and Fujaba by concepts for the model-driven development of distributed systems.

The concepts introduced in this thesis enable the development of distributed systems with a general architecture: Every distributed system may consist of heterogeneous applications which may be executed independently from each other at runtime. A coordination system is responsible for coupling these applications to a cooperating system.

To model the coupling of the applications, the coordination system has to define the static structure of the distributed system in means of a graph schema. For this purpose, it uses interfaces provided by the different applications which consist of node types, edge types, and graph transformations. The graph schema of the coordination system comprises all types imported from the application interfaces. The coordination system may define additional edge types between imported node types, which model the relations between the different applications.

Based on the constructed graph schema, the coordination system defines the behavior of the distributed system by distributed graph transformations. This thesis offers three different techniques for modeling distributed graph transformations: The technique of remote transformation calls resembles the concept of remote procedure calls and allows calling graph transformations in remote applications. Messages can be used within graph transformations for propagating events to other applications. As a third technique, the behavior of the distributed system may be defined declarative by so called distributed declarative graph transformations (DDGT).

The main challenge of this thesis is the development and realization of DDGTs, as these transformations constitute a completely novel way for modeling the behavior of a distributed system. The idea of this thesis is to internally map every DDGT onto several regular graph transformations (partial transformations). Each partial transformation comprises those aspects of the DDGT, which concern the same application. Thus, partial transformations can be executed as regular graph transformations in the applications. When using DDGT several problems have to be addressed, e.g. the preservation of consistency within the distributed system. This thesis presents adequate concepts for solving these problems.

This thesis also adapts the code generation facility and the runtime environments of PROGRES and Fujaba. In that way, the new concepts are seamlessly integrated into the existing graph rewriting systems and their model-driven development of software
applications. To evaluate the practical usage of the new concepts, we have modeled a
distributed process management system.

**Supervisor:** Prof. Dr.-Ing. Manfred Nagl

**External Supervisor:** Prof. Dr.-Ing. Mark Minas

**Day of Exam:** June 16, 2008
Model Checking of Software for Microcontrollers
Bastian Schlich

Software of microcontrollers is getting more and more complex. It is mandatory to extensively analyze their software as errors can lead to severe failures or cause high costs. Model checking is a formal method used to verify whether a system satisfies certain properties. This thesis describes a new approach for model checking software for microcontrollers. In this approach, assembly code is used for model checking instead of an intermediate representation such as C code.

The development of [mc]square, which is a microcontroller assembly code model checker implementing this approach, is detailed. [mc]square has a modular architecture to cope with the hardware dependency of this approach. The single steps of the model checking process are divided into separate packages. The creation of the states is conducted by a specific simulator, which is the only hardware-dependent package. Within the simulator, the different microcontrollers are modeled accurately.

This work describes the modeling of the ATMEL ATmega16 microcontroller and details implemented abstraction techniques, which are used to tackle the state-explosion problem. These abstraction techniques include lazy interrupt evaluation, lazy stack evaluation, delayed nondeterminism, dead variable reduction, and path reduction. Delayed nondeterminism introduces symbolic states, which represent a set of states, into [mc]square while still explicit model checking techniques are used. Thus, we successfully combined explicit and symbolic model checking techniques. A formal model of the simulator, which we developed to prove the correctness of abstraction techniques, is described. In this work, the formal model is used to show the correctness of delayed nondeterminism.

To show the applicability of the approach, two case studies are described. In these case studies, we used programs of different sizes. All these programs were created by students in lab courses, during diploma theses, or in exercises without the intention to use them for model checking.

**Supervisor:** Prof. Dr. Stefan Kowalewski  
**External Supervisor:** Prof. Dr. Jan Peleska,  
**Oral exam:** 04.06.2008.
During patient care physicians have to make important decisions, often based upon uncertain and incomplete data, about diagnostic and therapeutic actions. Various kinds of decision support exist in form of paper-based recommendations and guidelines, yet only a few proactive systems support the physician in selecting and executing these guidelines.

This thesis contributes to the research on computerized clinical guidelines by assessing, combining and extending existing methods and technologies used for automating clinical guidelines:

A meta-model is developed to capture process knowledge which exists e.g. in form of guidelines. The model is based upon the main common elements of computerized guideline languages and is for the first time extended by a strategic level by means of specific goal modelling.

An execution engine is implemented which is based on flexible workflow techniques and connected by an HL7 interface to communicate with a patient data management system. User interaction is through the electronic patient record in the patient data management system only. Thus, the execution engine integrates into the working environment of a physician seamlessly.

Thus, for the first time computerized guidelines are combined with explicit means of goal modelling and automation accompanied by an iterative modelling method.

A tool chain for formalizing and automating clinical guidelines was implemented and evaluated with physicians of an intensive care unit in the context of a research project part-financed by the German Research Council (DFG). This paves the way towards the assessment of the effects of automated guidelines based on clinical data.

Advisors: Prof. Dr. Matthias Jarke, Prof. Dr. Thomas Rose, Prof. Dr. Gunter Hempelmann

Date of exam: 5. September 2008
MultiView systems for explorative analysis of unstructured information

Christian Seeling

Information research tasks often require condensed information from different information sources. Patent analysis, for instance, requires the combination of structured data like patent classes or company names with unstructured text documents like patent abstracts or claims. Due to missing IT support, the combined analysis of structured and unstructured information often remains a manual and intellectual task. This work motivates, develops and evaluates an approach for interactive text and data analytics. The goal of this approach is to offer concise exploration of the task-relevant information and relationships in a single system. Information from text documents, categories and relational data is presented in graphical views which are interactively coupled so that information relationships might be used for navigation among views. The system SWAPit implements the system concept. One conceptional-technical challenge has been the adaptability of the reference technology for different application domains, business processes, and tasks. Therefore, the methods for tailoring the system and for measuring usefulness are considered important contributions by themselves. SWAPit has been evaluated and optimized in a broad spectrum of industrial case studies from the fields of Business Intelligence (BI), Customer Relationship Management (CRM), and Cooperative Work (CSCW).

Advisors: Prof. Dr. Matthias Jarke, Prof. Dr. Thomas Seidl

Date of exam: 28. November 2007
The success of community information systems depends on a careful design of the digital media, and on the related tools for communication and collaboration. Particularly for the cultural sciences the community engine should be capable of supporting the discursive processes of hypermedia knowledge management and sharing. Information systems therefore need to reflect the underlying community processes through well adapted media sets of drawings, animations, pictures, digital video, text etc. The information system architecture ATLAS (Architecture for Transcription, Localization, and Addressing Systems) is based on a formalization of an operational media-theory and knowledge management theory for information systems. My work introduces the Lightweight Application Server (LAS), which is an infrastructure to support this formalization. LAS offers dedicated multimedia services for media centric work in communities on the basis of the multimedia content description interface MPEG-7. Besides its advanced multimedia support LAS offers extending and reloading of services at runtime, as well a role-based security concept. The introduced theory and the LAS have been evaluated in different information systems for cultural science communities in research and education.

Advisors: Prof. Dr. Matthias Jarke, Prof. Dr. Ludwig Jäger

Date of exam: 6. August 2007
Mobile Hosts in Enterprise Service Integration
Satish Srirama

It is now feasible to access basic web services from smart phones due to the advances in wireless devices and mobile communication technologies. While mobile web services (MWS) clients are common, the thesis addressed the scope of providing web services from smart phones, thus integrating personalized mobile services into cellular enterprises and Internet. A 'Mobile Host' capable of providing basic web services from smart phones was developed, with acceptable performance penalties. The thesis extensively studied the applications of Mobile Host in m-learning domain and developed the MobileHost CoLearn system, as a tool helping in collaborative learning process. The study also tried to provide proper quality of service (QoS) for the Mobile Host. In the security realm the study analyzed the adaptability of WS-Security specification to the mobile web service provisioning (MWSP) domain and the scalability analysis tried to reduce the size of the MWS messages being transmitted with different compression technologies.

Apart from this, the huge number of web services possible, with each Mobile Host providing some services in the wireless network, makes the discovery of these services quite complex. The traditional centralized UDDI (Universal Description, Discovery and Integration) based registries are not adaptable, as they can have bottlenecks and can make single points of failure. A dynamic MWS discovery mechanism is proposed by the study that uses the peer to peer network and its features for publishing and discovery of mobile web services. The study also identified the deployment scenario for the Mobile Hosts in cellular networks. A 'Mobile Web Services Mediation Framework (MWSMF)' is established as an intermediary between the web service clients and the Mobile Hosts, based on the enterprise service bus (ESB) technology.

Advisors: Prof. Dr. Matthias Jarke, Prof. Dr. Ludwig Jäger

Date of exam: 19. September 2008
Termination is the fundamental property of a program that for each input, the evaluation will eventually stop and return some output. Although the question whether a given program terminates is undecidable, many techniques have been developed which can be used to answer the question of termination for many programs automatically. Especially, termination of term rewriting is an interesting and widely studied area: Since the basic evaluation mechanism of many programming languages is term rewriting, one can successfully apply the termination techniques for term rewriting to analyze termination of programs automatically. Nevertheless, there still remain many programs that cannot be handled by any current technique that is amenable to automation.

In this thesis, we extend existing techniques and develop new methods for mechanized termination analysis of term rewrite systems. Currently, one of the most powerful techniques is the dependency pair approach. Up to now, it was regarded as one of several possible methods to prove termination. We show that dependency pairs can instead be used as a general concept to integrate arbitrary techniques for termination analysis. In this way, the benefits of different techniques can be combined and their modularity and power are increased significantly. We refer to this new concept as the "dependency pair framework" to distinguish it from the old "dependency pair approach".

Moreover, this framework facilitates the development of new methods for termination analysis. To demonstrate this, we design several novel techniques within the dependency pair framework. They can successfully be applied to prove termination of previously challenging programs. For example, our work describes new ways how to handle programs using accumulators, programs written in higher-order languages, and programs which only terminate w.r.t. a given evaluation strategy. We additionally show how to disprove termination, even under strategies.

All presented techniques are formulated in a uniform setting and are implemented in our fully automated termination prover AProVE. The significance of our results is demonstrated at the annual international Termination Competition, where the leading automated tools try to analyze termination of programs from different areas of computer science: Without the contributions of this thesis, AProVE would not have reached the highest scores both for proving and disproving termination in the years 2004-2007.

Evaluators: Prof. Dr. Jürgen Giesl, Prof. Dr. Aart Middeldorp
Examination date: 24. October 2007
Strategies in Infinite Games with Liveness Winning Condition: Synthesis, Optimization and Implementation
NicoWallmeier

In this thesis we develop methods for the solution of infinite games and present implementations of corresponding algorithms in the framework of a platform for the experimental study of automata theoretic algorithms. Our focus is on games with winning conditions that express certain liveness properties. A central type of liveness requirement in applications (e.g., in controller synthesis) is the “request-response condition”. It has the form of a conjunction of conditions “Whenever a ‘request’-state is visited, sometime later a corresponding ‘response’-state is visited”. A closely related winning condition is the “Streett condition” in which for repeated visits of certain states the repeated visits of other states is required. We present methods for the solution of request-response games and Streett games, the latter with an application in the analysis of live-sequence-charts. The main contribution is a quantitative analysis of request-response games. We pursue a natural approach for the quantitative evaluation of winning strategies by taking into account the waiting times that elapse between visits of “request”-states and subsequent visits of “response”-states in an infinite play. We introduce and discuss several related measures of plays in request-response games (over finite game arenas). For measures that induce a “penalty” which grows more than linearly in the waiting times, we present an algorithm to compute optimal winning strategies. The core of the argument is a reduction to mean-payoff games over finite arenas; it also shows that optimal strategies are implementable by finite-state machines. The experimental platform GaSt (“Games, Automata & Strategies”) offers numerous algorithms of the theory of omega-automata and for the solution of infinite games.

Evaluator: Prof. Dr. W. Thomas
Evaluator: Prof. G. Lakemeyer, Ph.D.
Date of oral exam: September 06, 2007
Robust Appearance-based Sign Language Recognition
Morteza Zahedi

In this work, we introduce a robust appearance-based sign language recognition system which is derived from a large vocabulary speech recognition system. The system employs a large variety of methods known from automatic speech recognition research for the modeling of temporal and language specific issues. The feature extraction part of the system is based on recent developments in image processing which model different aspects of the signs and accounts for visual variabilities in appearance. Different issues of appearance-based sign language recognition such as datasets, appearance-based features, geometric features, training, and recognition parts are investigated and analyzed.

We discuss the state of the art in sign language and gesture recognition. In contrast to the proposed system, most of the existing approaches use special data acquisition tools to collect the data of the signings. The systems which use this kind of data capturing tools are not useful in practical environments. Furthermore, the datasets created within their own group are not publicly available which makes it difficult to compare the results. To overcome these shortcomings and the problems of the existing approaches, our system is built to use video data only and evaluated on publicly available data. First, to overcome the scarceness of publicly available data and to remove the dependency on impractical data capturing devices, we use normal video files publicly available and create appropriate transcriptions of these files. Then, appearance-based features are extracted directly from the videos. To cope with the visual variability of the signs occurring in the image frames, pronunciation clustering, invariant distances, and different reduction methods are investigated.

Furthermore, geometric features capturing the configuration of the signers' hand are investigated improving the accuracy of the recognition system. The geometric features represent the position, the orientation and the configuration of the signers' dominant hand which plays a major role to convey the meaning of the signs.

Finally, it is described how to employ the introduced methods and how to combine the features to construct a robust sign language recognition system.

Referent: Professor Dr.-Ing. Hermann Ney
Coreferent: Professor Dr.-Ing. habil. Gerhard Rigoll
Phrase-based Statistical Machine Translation: Models, Search, Training
Richard Zens

Machine translation is the task of automatically translating a text from one natural language into another. In this work, we describe and analyze the phrase-based approach to statistical machine translation. In any statistical approach to machine translation, we have to address three problems: the modeling problem, i.e. how to structure the dependencies of source and target language sentences; the search problem, i.e. how to find the best translation candidate among all possible target language sentences; the training problem, i.e. how to estimate the free parameters of the model from the training data.

We will present improved alignment and translation models. We will present alignment models which improve the alignment quality significantly. We describe several phrase translation models and analyze their contribution to the overall translation quality. We formulate the search problem for phrase-based statistical machine translation and present different search algorithm in detail. We analyze the search and show that it is important to focus on alternative reorderings, whereas on the other hand, already a small number of lexical alternatives are sufficient to achieve good translation quality.

The reordering problem in machine translation is difficult for two reasons: first, it is computationally expensive to explore all possible permutations; second, it is hard to select a good permutation. We compare different reordering constraints to solve this problem efficiently and introduce a lexicalized reordering model to find better reorderings. We investigate alternative training criteria for phrase-based statistical machine translation. In this context, we generalize the known word posterior probabilities to n-gram posterior probabilities. The resulting machine translation system achieves state-of-the-art performance on the large scale Chinese-English NIST task. Furthermore, the system was ranked first in the official TC-Star evaluations in 2005, 2006 and 2007 for the Chinese-English broadcast news translation task.

Referent: Professor Dr. Ing. Hermann Ney
Coreferent: Professor Dr. Francisco Casacuberta
Oral exam: 29.02.2008
Rapidly changing requirements and dynamic environments drive the development of context-aware applications. Research into context-aware computing focuses on programming frameworks and toolkits that support the development of context-aware applications (Chen, 2004; Dey et al., 2001; Efstratiou, 2004; Henricksen and Indulska, 2006). However, current approaches emphasise developers as the main actor in the software development process and lack properties making context-aware computing transparent and applicable for other actors. Developers cannot anticipate all potential situations and all possible ways of application behaviour during the development phase. During runtime, a change in the configuration, structure or content of the developed prototype is difficult. This work claims that the extension of the spectrum of actors participating in the design, implementation, authoring and configuration of context-aware applications beyond developers substantially tackles the reduction of usability problems introduced by context-aware computing. Addressing these issues requires this work to accomplish both a conceptual and a software framework. The conceptual framework bases on a comprehensive understanding of the processes involved with context-aware computing in general that can be communicated to the entire spectrum of actors comprising developers, domain experts, authors and end-users. The software framework implements the conceptual framework and supports the actors on diverse implementation skill levels in their roles within the software development cycle for context-aware applications. The core contribution of this work comprises a design view of context-aware applications, which permits the control over the internals of the application during design- and runtime, and a Context Management System, which provides different tools and abstraction levels according to the actors’ roles within the software development process. Two case studies document and evaluate the application of the system for the construction, authoring, maintenance and tailoring of context-aware applications and their behaviour. As operational and adaptable context-aware applications, these case studies prove the validity and general applicability of the tool suite, the software architecture and the concepts behind.

Advisors: Prof. Dr. Matthias Jarke, Prof. Dr. Reinhard Oppermann

Date of exam: 23. October 2007
Central Services
System Administration Group

Staff

- Faculty
  Prof. Dr.-Ing. Hermann Ney

- Research Assistants
  Dipl.-Inform. Willi Geffers

- Technical Staff
  Marion Brandt-Röhrig, M.A.
  Viktor Keil
  Stefanie Scholten
  Karl-Heinz Thevis

- Trainees
  Alexandra Espe
  Janina Jansen
  Christian Königs

- Student Workers
  Damian Lukowski
  Enisa Musovic
  Antonia Navarro Perez
  Wolfgang Refisch
  Ilhan Ucar
Overview

Since 1985 the System Administration Group (Rechnerbetrieb Informatik, RBI) operates several computer labs and provides technical support for the Department of Computer Science at RWTH Aachen University. 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 based on Intel and AMD CPUs and running the Debian GNU/Linux operating system. 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 and desktop publisher OpenOffice are available. Programming languages are particularly important and C, C++, Fortran, Pascal, and JAVA including extension libraries, source code management systems like CVS and subversion as well as source level debuggers are available. Coding is done with popular editors like vi and XEmacs. Especially for students in the first stage of the study course interpreters and compilers for Clisp, Scheme, and Prolog are installed.

In addition the computers in the labs are configured for cluster grid computing. The N1 Grid Engine software is used to schedule jobs on the cluster.

Server Equipment

- Currently the RBI operates 2 file servers, a Sun Fire 280R and a Sun Enterprise 250 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 helpdesk@informatik.rwth-aachen.de, or by phone (0241) 80-21038.

Usually the computer labs are open as follows:

during terms:  
mon: 9 am - 7 pm

tue - thu: 9 am - 9 pm

fri: 9 am - 6 pm

between terms:  
mon - thu: 9 am - 7 pm

fri: 9 am - 5 pm

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.
Staff

- **Head:**
  Dipl.-Bibl. Renate Eschenbach-Thomas

- **Assistants:**
  Jonas Becker (since 02.05.2008)
  Nadine Behnke
  Florentine Gruhn (since 01.07.2008)
  Rainer Hallmann (volunteer gardener since 19.02.2008)
  Ingo Hengstebeck
  Dieter Schwache (until 30.06.2007)
  Richard Hoffmann (since 02.05.2008)
  Alexander Mertens (since 02.07.2007)
  Michael Rose (until 30.06.2007)
  Nina Scharenberg (since 07.07.2008)
  Nora Smets (until 15.07.2008)
  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 staff 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
1. What you can find in our library

- More than 34700 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; henceforward only selected titles. Additionally we have complete digital access to all LNCS-Volumes since 1997
- More than 300 journals
- Always up to date: Magazines like C’ť, PC Magazin, free X, Der Spiegel, Die ZEIT, . . .
- Annual reports from domestic and foreign universities
- Service for department staff: Books and articles not available on site are procured from the central university library or from international library supplies

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 his/her topic
- Website containing plenty of information on our stock and interesting computer science links
- 3 internet workstations and 60 comfortable work places; separate student group work spaces
- MoPS-zone for laptop users
- Large Open-Air-Reading-Room with another 50 work places
- 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. Highlights

- In 2007 we started our program of library tours (including a tutorial on search of literature) for the first-year-undergraduates.
- Our popular children's corner is a room where children can play in the presence of parents who do their studies. This project was allocated in September 2007 with the award "Prädikat Familienfreundlich" of Aachen. In the following months we could improve the equipment, for example by a chair for breast feeding mothers, playpen, travel bed etc. with the support of student fees. In June 2008 we opened the complete children's corner with a lunch party.
Kiwi „Kinder und Wissenschaft“
Bei uns ist das möglich!

Angebot der Informatik-Bibliothek

Studierende mit Kindern können unbeschwert die Bibliothek nutzen.

Für sie steht in einem Lernraum eine Spielecke mit Wickelplatz sowie für Mütter eine Möglichkeit zum Stillen zur Verfügung!

Wo?
Ahornstr. 55, Erweiterungsgebäude 1, Raum 4002, in der Informatik-Bibliothek

Ausgezeichnet mit dem „Prädikat Familienfreundlich“ der Stadt Aachen im September 2007
• Fitting to the opening of the children's corner, one of our student assistants gave birth to a child. So the baby called Emma was one of the first customers.

• Again from student fees we were able to extend our stock of text books for the standard courses of computer science, called "Handapparate".
• As a continuous trend over the past years, we observe that the number of students, visiting the library for reading and studying, increases. Often all 60 seats are occupied. Very popular is also the possibility to stay until 10 p.m. in one special room.

• In Summer 2008 we took over the administration of the library of the Center for Computing and Communication, which is situated around 800 m away in another building and has a stock of 4840 books. A large part of the administration is done in our library. Two student assistants care for the transport between the two buildings and furthermore they provide service for the staff of the Center for Computing and Communication.

• With the gardening of our popular Open-Air Reading Room (“Lesegarten”) we fortunately are supported by a volunteer gardener.

• We were able to provide 36 additional lockers for visitors, also from student fees.
Staff
People who volunteered at the Fachschaft during the last year:

- Adam Stephanides
- André Goliath
- Andrea Hutter
- Andreas Ganser
- Angélina-Géraldine Bieler
- Anna Nelles
- Beatrix Blank
- Bettina Schmiedt
- Brigitte Boden
- Christian Fuchs
- Christoph Rackwitz
- Daniel Schmitz
- David Altmann
- Dominic Jabs
- Dominik Masur
- Felix Reidl
- Fernando Sanchez Villaamil
- Florian Lütkecosmann
- Florian Schandinat
- Hedwig Lipp
- Hendrik vom Lehn
- Hossein Shafagh
- Ines Färber
- Ingmar Gebhardt
- Ingolf Segger
- Jacob Schmiedt
- Jan Bußmann
- Janine Repke
- Jens Forster
- Jolande Fooken
- Julian Meichsner
- Laura Neisius
- Lukas Middendorf
- Manuel Rispler
- Marcel Straub
- Mareike Ahl
- Martin Henze
- Martin Weusten
- Matthäus Podgorski
- Matthias Botzen
- Michael Nett
- Nicholas Gray
- Niklas Hoppe
- Nina Thomas
- Nobuyoshi Kuramoto
- Oliver Schitthelm
- Ralph Kube
- Sebastian Siebertz
- Sebastian Wüsten
- Sören Boyn
- Stefan Depenbrock
- Stephan Grap
- Stephan Langer
- Sven Runte
- Thomas Grap
- Thomas Kesselheim
- Tim Leonhardt
- Tobias Schäfer
- Tobias Vaegs
- Vera Klinke
Postal address
Fachschaft I/1, Templergraben 55, 52056 Aachen

Visiting address
Kármánstraße 7, 3rd level

e-mail: fs@fsmpi.rwth-aachen.de
WWW: http://www.fsmpi.rwth-aachen.de/
Tel. 0241 80-94506

Opening hours
during lecture period: Mon-Fri 12-14 h
during lecture free period: Tue & Thu 12-14 h

Meetings of the Fachschaft: Mon 19 h in the rooms of the Fachschaft
Plenary meetings: at the beginning of each semester
Overview

The Fachschaft (group of student representatives) represents the interests of all students of mathematics, physics and computer science at RWTH Aachen University.

At the beginning of each semester a plenary meeting is held where every student of mathematics, physics or computer science is invited. This is where the major topics concerning the upcoming semester and the work of the Fachschaft in general are discussed. Furthermore the students responsible for the accomplishment of the aspired goals and tasks are elected there.

We have weekly meetings where current concerns are discussed and work is coordinated. Any student of mathematics, physics or computer science is welcome to participate, to express his or her opinion and to take part in all decisions.

Service

The Fachschaft has regular opening hours to offer support to students by students concerning their course of study but also on issues not directly related to university topics. We have a collection of former exercises and transcripts of exams to be copied in our rooms.

Since January 2008 we offer these services once a week in a room in the Computer Science building as well.

Work in committees

Most of the work done by the Fachschaft is not that obvious. We represent the students in a lot of committees, especially Fakultätsrat (faculty board), Fachkommissionen, Prüfungsausschüsse (examination boards) and Berufungskommissionen (search committees). Additionally we attend all committees deciding on how to spend the tuition fees.

We are not only looking out for students' interests, but also aim to cooperate with professors and staff.

Students' garden

Since this summer, the students' garden at the Computer Science building has been opened again. When the weather is fine, students can sit outside enjoying their breaks. Active members of the Fachschaft voluntarily have an eye on the garden.

Introduction of new students

To introduce the new students to their new environment, the ErstsemesterInnen-AG, a working group of the Fachschaft, arranges tutoring groups. These groups consist of several beginners and two advanced students as their tutors, who invite the freshmen to get to know each other.

Furthermore, a weekend at a youth hostel and a welcome party are organized. Every year the ErstsemesterInnen-AG publishes a magazine containing information for people planning to study mathematics, physics or computer science at RWTH Aachen University.

The goals of these activities are:

- Building social contact after leaving behind the former environment.
• Helping to cope with the first steps at university (learning on one’s own responsibility and in a team).
• Support in managing their studies.
• Basic approaches to reflect on their study situation.
• Information/Discussion on opportunities to take influence in the university (academic self-management).

**Working groups**

There is a number of working groups dealing with special tasks apart from the main topics.

**ErstsemesterInnen-AG:** Supports the beginners. See above.

**Interdisziplinäres Diskussionsforum:** The IDF (interdisciplinary discussion forum) organizes discussion events on topics beyond the area of mathematics, physics and computer science; e.g. the last event on privacy and online identity. Lexi Pimenidis (Chair for Computer Science 4) and Ralf Bendrath (TU Delft) were invited as speakers.

**Geier:** The Geier (engl. *vulture*) is a leaflet with newsworthy information and references to events. The Geier is published every two weeks.

**Video-AG:** The "Video-AG" working group records lectures and other events to make them available online. As of now, they have been recording:

The Video-AG is still looking for sponsors to make additional video cameras and other supporting equipment available to them, allowing them to record more lectures in higher quality.
Co-operations
Overview

TGGS is a joint institution established by RWTH Aachen University and her Thai partner KMUTNB (King Monukut’s University of Technology North Bangkok) in order to transfer the RWTH Aachen Model of Graduate industry-oriented Engineering Education, Technology Innovation and Business Development to South East Asia. It was founded in 2004.

TGGS’ main activities include:

1. Industry-oriented engineering education following the RWTH Aachen Model
   - International M.Sc. courses with RWTH lecturing support
   - Co-operative engineering education with mandatory industry-internships
   - Training and guidance of Thai lecturers in Aachen
   - Human resource development, scholarships, Alumni activities

2. Technology Innovation
   - Expansion of internship and collaboration links with industry in Thailand and Germany for Thai students/Ph.D.s, third-party funded projects
   - Technology-upgrading for Thai industry
   - Development of TGGS labs and R&D activities
   - Build up TGGS as a platform for R&D projects in whole South-East Asia

3. Business Development
   - Expansion of and support for Thai-German industry links (e.g. recruiting)
   - Establishing of technology spin-offs in Thailand (SMEs)
   - Business development in new technical fields (PPP)
   - Industry links in South East Asia used to create joint Thai-German business development projects

For more information please see http://www.tggs.rwth-aachen.de/en/.

Computer Science’s Involvement

Members of the Computer Science Department are primarily involved in TGGS’ MSc programme on ‘Software Systems Engineering’ (SSE) that was established in 2005. The programme is putting strong emphasis on the fact that modern industrial software usually is part of a complex system with deep connections to application specific environments and possibly special hardware. The SSE curriculum prepares the students for the challenges arising from the system-orientation of software by offering specifically tailored courses like, e.g. human computer interaction or software for embedded systems as electives additionally to the classic software engineering topics. Another characteristic of the program is the solid theoretical foundation which improves the participants' ability to abstract from domain-specific problems and transfer the acquired methodical concepts to new fields of applications.
The programme is “Putting strong emphasis on complex systems with deep connections to application specific environments in the modern industrial business world”. Topics of interest include, but are not limited to

- Software Engineering
- Software Architecture
- Data Communications & Internet Technology
- Radio Frequency Identification (RFID)
- Wireless Technology
- Multimedia systems
- Security systems
- Computer Graphics
- Embedded Systems
- Advanced Database System
- Efficient Algorithms
- Image Processing
- Compilers for Scientific Computing

RWTH’s Computer Science Chairs and Research Groups that contribute to the Programme include

- Software for Embedded Systems (Prof. Dr. Kowalewski)
- Communication Systems (Prof. Dr. Spaniol)
- Software Engineering (Prof. Dr. Nagl)
- Software Modeling and Verification (Prof. Dr. Katoen, Prof. Dr. Indermark)
- Computer Graphics and Multimedia (Prof. Dr. Kobbelt)
- Software and Tools for Computational Engineering (Prof. Dr. Naumann)
- Computer Science V (Prof. Dr. Jarke, Prof. Dr. Schröder)
- Media Computing (Prof. Dr. Borchers)
- Theoretical Computer Science (Prof. Dr. Rossmanith)
- Software Construction (Prof. Dr. Lichter)

In 2007/2008, these lectures were given in Thailand by Computer Science Professors:

- Software Engineering, Prof. Lichter, June 2007
- Embedded Software, Prof. Kowalewski, June 2007
- Efficient Algorithms, Prof. Rossmanith, August 2007
- Data Communications & Internet Technology, August 2007
- Compilers for Scientific Computing, Prof. Naumann, February 2008
- Software Architecture, Prof. Nagl and Daniel Redkovitz, February 2008
- Data Communications & Internet Technology, Prof. Spaniol, August 2008
- Efficient Algorithms, Prof. Rossmanith, September 2008
- Software Engineering, Prof. Lichter, September 2008
- Compilers for Scientific Computing, Prof. Naumann, November 2008
- Embedded Software Systems, Prof. Kowalewski, December 2008

A number of TGGS students are working (mostly on their theses) at various Computer Science Chairs:

- Mr. Tote Gasomson, master student, Computer Science XI (Prof. Kowalewski)
- Ms. Tassawan Phunkaew, master student, Computer Science IV (Prof. Spaniol)
- Mr. Chayakorn Piyabunditkul, PhD candidate, Computer Science III (Software Construction, Prof. Lichter)
- Ms. Pathareeya in-Opat, Computer Science XI (Prof. Kowalewski)
- Mr. Chaichan Kusoljittakorn, Computer Science XII (Prof. Naumann)
Bonn-Aachen
International Center for Information Technology

Overview

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, BIT offers highly selective English-language master programmes in Media Informatics, Life Science Informatics, and Autonomous Systems. Moreover, B-IT offers summer and winter schools for qualified undergraduate students from Bonn and RWTH Aachen University. The B-IT programmes are distinguished by a deep integration of teaching and research through close cooperation with the participating Fraunhofer institutes of Applied Information Technology (FIT), Autonomous Intelligent Systems (AIS), Media Communication (IMK), and Scientific Computing and Algorithms (SCAI).

From RWTH Aachen University, Prof. Dr. Matthias Jarke serves as Founding Director (together with Prof. Dr. A.B. Cremers, Bonn, and Prof. Dr. K. Witt, FH Bonn-Rhein-Sieg), whereas Prof. Dr. Otto Spaniol is Study Coordinator of the Media Informatics programme and Dr. Jürgen Rapp serves as study advisor.

Teaching

Well before the current debate on how to make Germany more competitive in the worldwide “battle for the best brains”, B-IT has been active in attracting the best international Bachelor graduates in the ICT sector. Due to intense international networking, applicants from some of the best international undergraduate programs, e.g. from top Chinese universities such as Tsinghua, Nanjing, or Zheijiang, have been attracted to the program. B-IT students have been unusually successful in obtaining attractive competitive scholarships, ranging from university scholarships via industrial ones to the prestigious Erasmus-Mundus program of the European community.

All study programs are now operating at full capacity. Despite careful selection of applicants, the number of beginners in 2007 and 2008 were even higher than planned; it appears that B-
IT has become first choice for many of our international applicants from over 40 countries. One reason may be the excellent placement record B-IT is building up. Our master graduates have been accepted as doctoral candidates in many leading universities and research institutes worldwide. Significant third-party funding acquired by B-IT faculty also offers local opportunities.

The B-IT Universities Institute offers English language Master of Science (M.Sc.) programs in

- Media Informatics
- Life Science Informatics,

Additionally, the University of Applied Sciences offers a Master Program in Autonomous Systems.

The Master Programs prepare students for successful international careers that require technical excellence and leadership, creativity and the ability to innovate. B-IT master programs are distinguished by their international orientation (structured according to the European ECTS standard), their focus on IT competence, and the deep integration of teaching and research. They include a significant share of research lab courses in the participating Fraunhofer institutes. A second goal of B-IT is the optimization and acceleration of existing undergraduate computer science curricula at University of Bonn and RWTH Aachen University for selected top students. B-IT’s International Program of Excellence (IPEC) pursues this goal by compact course modules delivered in summer and winter schools during the semester breaks.

**Highlights in 2007/2008**

- The Ministry for Innovation, Science, Research and Technology of North Rhine-Westphalia approved B-IT Research School on March 19, 2008. B-IT Research School will offer new opportunities for excellent students of B-IT master programs in Media Informatics and Life Science Informatics to continue their studies in a PhD program, but also addresses outstanding international students from outside B-IT to apply. The PhD programs will entirely be taught in English.
- 28 July – 1 August 2008: crypt@b-it 2008 – Summer School on Cryptography
  This summer school on cryptography offers undergraduate and graduate students and researchers the opportunity to crypt a bit. It provides acquaintance and interaction in an intellectually stimulating and informal atmosphere in pleasant surroundings.
- 29 – 30 May 2008: B-IT hosts the International Symposium on Mobile Information Technology for Emergency Response
- 14 – 15 March 2008: Special Courses for Excellent Graduate and Doctoral Students held in B-IT in conjunction with the Informatiktage 2008
- 18 – 20 February 2008: B-IT hosts the "Tangible and Embedded Interaction 2008" Conference
- 24 – 25 September 2007: B-IT hosts 5th Fraunhofer-Symposium on Text Mining
Cluster of Excellence
”Ultra High-Speed Mobile Information and Communication” (UMIC)

Overview

“Ultra High-Speed Mobile Information and Communication (UMIC)” is the only cluster of excellence in the areas of Electrical Engineering and Computer Science approved under the excellence initiative of the German Federal and State government.

The focus of UMIC research is on mobile information and communication systems of the next decade. The service quality as perceived by the users must be at least an order of magnitude over that of today's systems with lower cost. This goal can only be achieved by joint interdisciplinary research, taking all aspects into account from mobile applications to ultra-highly integrated implementation. Key pillars of the cluster research include

- Mobile Application and Services,
- Wireless Transport Platform,
- RF Subsystems and SoC (System on a Chip) Design.

The close interdisciplinary cooperation of the participating teams is essential for the success of the cluster (see figure below).

Research targets of “Wireless Transport Platform” are smart, mobile, broadband and low-cost systems, which provide adaptive configuration and seamless connectivity, balancing between
conflicting targets like data-rate, radio range and power consumption by continuous joint optimization.

Matching requirements and features of applications and services on the one hand and of the wireless transport platform on the other hand is a key approach of the research area “Mobile Applications and Services”.

Design methodology and implementation are addressed by “RF Subsystems and SoC Design”. Major challenges to be addressed are the nanometre-CMOS integration of flexible radio frequency subsystems required for cognitive terminals and “Multi-Processor-System-on-Chip” (MPSoC) platforms, designed for maximum performance and energy efficiency, taking into account the features and issues of future silicon technology generations.

Research topics like performance and reliability of complex systems, privacy and security, energy efficiency, and software architecture affecting all pillars of the UMIC research are grouped within the research “Interdisciplinary Methods and Tools”.

Nucleus of the cluster research is the UMIC centre, hosting the interdisciplinary research teams headed by Junior Professors and UMIC Distinguished Researchers, the prototyping labs and a demonstrator space. More than 20 chairs and institutes from the Electrical Engineering and Information Technology Faculty and the Computer Science Department of RWTH Aachen are active members of the UMIC research cluster.

The UMIC Kick-Off Meeting took place on 20 February 2007.

**Laying of the Foundation Stone of the UMIC Research Centre**

The Foundation Stone for the UMIC Research Centre was laid on 17 April 2008. The Centre will offer over 2,300 m² for UMIC’s interdisciplinary research groups, comprising offices, conference facilities, labs, and a demonstration room. The building will be ready for occupancy in early 2009.

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**Constitution of the Advisory Board**

The UMIC Advisory Board has been established to perform regular evaluation of the research progress and provide recommendations. The members of the Advisory Board are:

- Prof. Ed Brinksma, Embedded Systems Institute, Eindhoven University of Techn.

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The Advisory Board was constituted, and its first meeting took place, on 23 April 2008.

**UMIC Day 2007**

The first ‘UMIC Day’ took place on 16 October 2007. These events, which will be held on an annual basis, serve to highlight the Cluster’s achievements, and to present them to the interested public.

In 2007, the Keynote Speech was given by the President of the VDE, the German Association for Electrical, Electronic & Information Technologies, Prof. Dr. J.A. Nossek of the TU Munich. The talk was entitled ‘The Cellular Gaussian Broadcast Channel’.
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.

FIT has a staff of about 115 researchers from Computer Science, the Social Sciences, Psychology, Business Administration, Economics and Engineering. They are organized in four departments:

- **Cooperation Systems (Prof. Wolfgang Prinz, PhD)**
  FIT.CSCW develops and evaluates novel groupware, community and knowledge management systems for distributed organizations and teams. The guideline are intuitive, situated tools that can be used ad-hoc, yet be seamlessly embedded in processes and technical environments, together with concepts for organizational implementation and usage. FIT's collaborative workspace system BSCW is also used in the Synergeia platform for collaborative learning that we developed in the EU-funded ITCOLE project and offer now as a web service. In the MILK project a BSCW based knowledge management solution has been developed that integrates interactive large screen displays and mobile devices. Our Mixed Reality approach extends the natural modelling and cooperation environments of, e.g., city planners and event managers to foster easy collaborative change management. The application in pervasive games turns our real environment into an augmented playground.

- **Information in Context (Prof. Dr. Reinhard Oppermann)**
  The research department Information in Context (ICON) investigates the dynamic consideration of usage contexts: the adaptation of information content, presentation and
interaction to the knowledge, interests, preferences, and environment of users. Nomadic information systems, such as mobile fair guides or air quality warning systems, offer situation-adapted access to public, business, or private information sources. Personalized learning systems analyze learning styles, processes, and knowledge status, to adapt to the learners' personalities as well as to the present qualification needs of the companies they work for. Methods for scenario-driven system design and usability analysis support user-oriented information systems design. However, usability and utility change over time; the EU Roadmap for End-User Development developed by FIT addresses the need for lifecycle-wide adaptability.

- **Life Science Informatics (Prof. Dr. Thomas Berlage)**
  The department Life Science Informatics (LIFE) started research in the fields of diagnostic and interventional medical imaging, minimally invasive and robot assisted surgery, pharmacology, biotechnology, assistive information systems and compensatory user interfaces in the early 90ies. The focus is on the interdisciplinary development of interactive systems based on experiences from cooperation in various application areas and the integration of relevant technologies (image analysis, dynamic modelling and visualization, distributed web information systems).
  The department comprises some 30 researchers from various disciplines (computer science, physics, mathematics, cognitive psychology) who are engaged as a team in the integration of technologies and applications.

- **Process Management (Prof. Dr. Thomas Rose)**
  This business area focuses on decision and process support for application domains whose processes can be characterized by their high level of complexity as well as their weak determination of process structures. The research and engineering emphasis of projects is put on
  - methods and tools for the capture on process know-how,
  - customization methods for process know-how due to project-specific constraints,
  - media processes for context-specific dissemination processes of information,
  - agent-oriented software engineering for the support of distributed processes, and
  - methods and tools for data and document mining in complex information spaces with structured as well as unstructured information sources.

The institute cooperates closely with Prof. Jarke’s Information Systems group (Informatik 5) at RWTH Aachen University. The co-operation focuses on the ‘Zentrum für Softwarekonzepte’ (Centre for Software Concepts). This is an initiative by Microsoft in conjunction with a number of German academic and research institutions. It aims to support Small and Medium-sized Enterprises (SMEs) through improved knowledge transfer from research to industry.
Graduiertenkollegs – Research Training Groups

General

A Graduiertenkolleg (Research Training Group) is a university graduate training programme established at a centre of scientific excellence in a specific field. It is designed for up to 15 PhD students by several faculty members. The students work on their theses within the framework of a coherent and often interdisciplinary research programme; they participate in an accompanying study programme organised by the faculty members and to some extent by the students themselves.

The concept of “Graduiertenkolleg” was established in 1990 to improve the quality of doctoral training in Germany and 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.

At the Faculty for Mathematics, Computer Science, and Natural Sciences at RWTH Aachen University there are two GKs which are both in the area of computer science:

GRK 643 “Software for Mobile Communicationsystems”, speaker Prof. Spaniol and
GRK 1298 “AlgoSyn”, speaker Prof. Thomas.

Every year all GKs with research background computer science meet in Dagstuhl for a workshop.

Graduiertenkolleg ”AlgoSyn“

The Graduiertenkolleg “AlgoSyn” 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.

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.
There is a unit working on foundations comprising two branches, 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:

- Algorithmic for agent-based, probabilistic, and hybrid systems
- Formal methods of reactive systems and game-theoretic methods
- Software development and modeling languages and
- Applications and demonstrators, in the fields of processor architectures, automatic control, process control engineering and train traffic systems.

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.

For a full version of the proposal (in German language) please see: http://www.algosyn.rwth-aachen.de/

AlgoSyn has 15 positions for PhD students and one additional postdoc position. 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.

All positions have been taken by highly qualified students. The current (September 2008) grant holders include:

- Dipl.-Inform. Kai Dominik Bollue
- Dipl.-Inform. Dominique Gückel
- Dr. Martin Hoefer (Postdoc)
- Dipl.-Inform. Jörg Holtmann
- Dr. Lukasz Kaiser
- Dipl.-Ing. Sebastian Klabes
- Alexandru Mereacre, MSc
- Dipl.-Math. Lars Olbrich
- Gustavo Arutro Quieros Araya, MSc
- Weihua Sheng, MSc
- Dipl.-Inform. Michaela Slaats
- Dipl.-Inform. Jacob Spönemann
- Dipl.-Inform. Stephan Swiderski
- Dipl.-Inform Michael Ummels
- Dipl.-Inform. Daniel Willems

One student left the ’Graduiertenkolleg’ during the reporting period. Lukasz Kaiser completed successfully his theses.

Graduiertenkolleg ”Software for Mobile Communication Systems”

The ideas of Graduiertenkolleg “Software for Mobile Communication Systems” are as follows:

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'.

For a full version of the proposal (in German language) please see: http://www-i4.informatik.rwth-aachen.de/Kolleg/

All positions have been taken by highly qualified students. The current (August 2008) grant holders include:

- Vaishak Belle, MSc; Chair Informatik IV Lab, Prof. Dr. Lakemeyer
- Juan Miguel Espinosa Carlin, MSc; 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
- Elena Meshova, MSc; Chair Mobilfunknetze, Prof. Dr. Mähönen
- Dipl.-Inform. Ulrich Meis; Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Inform. Cem Mengi; Chair Informatik III, Prof. Dr. Nagl
- Andriy Panchenko, MSc; Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Inform. Torsten Sattler; Chair Informatik VIII, Prof. Dr. Kobbelt
- Dipl.-Inform. Stefan Schiffer; Chair Informatik IV Lab, Prof. Dr. Lakemeyer
- Dipl.-Inform. Benjamin Schleinker; Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Inform. Elias Weingärtner; Chair Informatik IV Lab, Prof. Dr. Wehrle
- Milan Zivkovic, MSc; Chair Theoretische Informationstechnik, Prof. Dr. Mathar
- Xiang Xu, MSc; Chair Theoretische Informationstechnik, Prof. Dr. Mathar

Seven students left the 'Graduiertenkolleg’ during the reporting period. By now, they have successfully completed their theses, or are near completion.

- Dipl.-Inform. Ibrahim Armac, Chair Informatik III, Prof. Dr. Nagl
- Dipl.-Inform. Gernot Fabeck, Chair Theoretische Informationstechnik, Prof. Dr. Mathar
- Dipl.-Inform. Christof Mosler, Chair Informatik III, Prof. Dr. Nagl
- Satish Narayana Srirama, MSc; Chair Informatik V, Prof. Dr. Jarke
• Dipl.-Inform. Arne Schmitz, 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
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 synergistically integrated. The development environment also uses existing tools to avoid the reimplemention 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 Transfer Center 61 within CRC 476

After the fourth successful peer review in 2006 a new Transfer Center “New Concepts and Tools for Chemical Engineering Practice” as the fourth phase of the CRC was established. Six subprojects were accepted. Another transfer project is – being financed from another source – loosely 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 2007 was completed (see below).

There is a series of workshops together with industry, organized by Prof. Marquardt and Prof. Wozny, which is held on an annual basis. Furthermore, an international workshop is
scheduled for 2009 which is going to present the research results of TC 61 in relation to other big research projects.

**Book summarizing the results**

A volume, containing all scientific results of the CRC up to the end of 2007 was published in April 2008. It is a comprehensive book demonstrating the advantage of a long-term project. Thanks go to German Research Foundation (DFG) for 12 years of financing.

The results are not only valuable for Chemical Engineering. Most of them are also applicable to Mechanical Engineering, Electrical Engineering, Software Development, Civil Engineering, or any discipline where complex results have to be designed/developed.


**Sub projects**

Transfer Project T1: Process Engineering (LPT) [http://www.lpt.rwth-aachen.de](http://www.lpt.rwth-aachen.de)

*Ontology-Based Integration and Management of Distributed Design Data*

Industrial partners: Degussa AG Engineering, Ontoprise GmbH

Transfer Project T2: Process Engineering (LPT) [http://www.lpt.rwth-aachen.de](http://www.lpt.rwth-aachen.de)

*Computer-Assisted Work Process Modeling*

Industrial partners: Air Products and Chemicals Inc., BASF AG, Bayer Technology Services GmbH, Siemens AG

Transfer Project T3: Labour Research (IAW) [http://www.iaw.rwth-aachen.de](http://www.iaw.rwth-aachen.de)

*Simulation-supported Workflow Optimization in Process Engineering*

Industrial partners: Bayer Business Services AG, Bayer Technology Services AG, ConSense GmbH, InfraServ GmbH & Co. Knapsack KG

Transfer Project T5: Software Eng. (Inf. 3) [http://www-i3.informatik.rwth-aachen.de](http://www-i3.informatik.rwth-aachen.de)

*Tools for Consistency Management between Design Products*

Industrial partner: innotec GmbH

Transfer Project T6: Software Eng. (Inf. 3) [http://www-i3.informatik.rwth-aachen.de](http://www-i3.informatik.rwth-aachen.de)

*Dynamic Process Management Based Upon Existing Systems*

Industrial partners: AMB Generali Informatik Services GmbH, innotec GmbH

Transfer Project T7: Software Eng. (Inf. 3) [http://www-i3.informatik.rwth-aachen.de](http://www-i3.informatik.rwth-aachen.de)

*Service-oriented Architectures and Application Integration*

Industrial partner: AMB Generali Informatik Services GmbH

**Contact**

Prof. Dr.-Ing. M. Nagl (Software Engineering, Inf. 3; speaker of CRC/TC)

Tel. +49-241/80-21300, Fax +49-241/80-22218

e-mail: nagl@i3.informatik.rwth-aachen.de

Web sites for CRC 476: [http://www-i3.informatik.rwth-aachen.de/sfb476](http://www-i3.informatik.rwth-aachen.de/sfb476)

Aachen Institute for Advanced Study in Computational Engineering Science (AICES)

AICES is a new doctoral program established in November 2006 under the auspices of the Excellence Initiative of the German state and federal governments in the funding line graduate schools. The program sets out to advance the computational engineering in three critical areas of synthesis: model identification and discovery supported by model-based experimentation, understanding scale interaction and scale integration, and optimal design and operation of engineered systems.

Since 2002, RWTH Aachen University has been establishing educational structures to meet the future research challenges in computational engineering science (CES). In 2004, the Center for CES has been established. Bachelor and Master programs in CES are now operating, and were joined by the AICES doctoral program in the summer semester of 2007.

AICES is spearheaded by 15 RWTH institutes from four departments including Computer Science and enjoys participation from Forschungszentrum Jülich and the Max Planck Institute for Iron Research in Düsseldorf. Today, approximately 15 doctoral fellows pursue their doctoral degrees funded through AICES scholarships and recruitment of additional fellows is still ongoing. Currently, three of the 15 dissertation projects are carried out in computer science under the supervision of Prof. Bientinesi and Prof Wolf.

More information
www.aices.rwth-aachen.de

Contact
Scientific Director
Prof. Marek Behr, Ph.D.
Chair for Computational Analysis
of Technical Systems
Steinbachstraße 53B
52074 Aachen
Tel.: +49(0)241/80-28430
e-mail: behr@cats.rwth-aachen.de

Managing Director
Dr. Nicole Faber
Graduate School AICES
Pauwelsstraße 12
52074 Aachen
Tel.: +49(0)241/80-28491
e-mail: faber@aices.rwth-aachen.de
Virtual Institute – High Productivity Supercomputing (VI-HPS)

The Virtual Institute - High Productivity Supercomputing is a joint initiative of Forschungszentrum Jülich, RWTH Aachen, TU Dresden, University of Tennessee, and Universität Stuttgart. Funded by the Helmholtz Association, the mission of this virtual institute is to improve the quality and accelerate the development process of complex simulation programs in science and engineering that are being designed for the most advanced parallel computer systems such as the IBM Blue Gene/P in Jülich. For this purpose, the partners develop and integrate state-of-the-art programming tools for high-performance computing that assist domain scientists in diagnosing programming errors and optimizing the performance of their applications. Besides the purely technical development of such tools, the virtual institute also offers training workshops with practical exercises to make more users aware of the benefits they can achieve by using the tools. In 2008, two tuning workshops with hands-on sessions were organized in Aachen and Dresden, respectively. A third workshop in Jülich is scheduled for spring 2009.

More information

www.vi-hps.org

Contact

Prof. Dr. Felix Wolf
Jülich Supercomputing Centre
Institute for Advanced Simulation
Forschungszentrum Jülich, 52425 Jülich
Tel +49 2461 61-1583
Email: f.wolf@fz-juelich.de
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, virtually all faculties have turned their attention to the possibilities of this technology and its application. Therefore, a major task of the Forum Information Technology is to provide a 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 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”. It is one of six Interdisciplinary Forums at RWTH Aachen University. The other five are Forum Mobility and Transport, Forum Environmental Science, Forum Material Science, Forum Technology and Society and Forum Life Sciences. The figure below shows the member structure of all forums. Naturally, there is not only cooperation inside of one special forum, but between different forums. Between the Forum Information Technology and the Forum Mobility and Transport for example there are joint activities regarding the future navigation system Galileo or regarding research on intelligent roads.

As a result of the Excellence Initiative at RWTH Aachen University considerably more emphasis is put on interdisciplinary research. The well-established six Interdisciplinary Forums are complemented by new measures like the Exploratory Research Space (ERS) and Project Houses as well as several different funds for interdisciplinary research. In this context the Forums have given themselves a new organisational structure: three full-time managers – located at the Department 4.0 Technology Transfer and Research Funding – work closely together across the forum borders and benefit from synergies with the Department 4.0. Additionally, the forums can make use of a new fund especially for forum members. This fund was introduced to initiate and foster interdisciplinary project ideas.

The changes in the environment of the forums and the new management structure require an update of the strategic planning regarding content and organization of the working areas of the forums. This process was introduced in May 2008 and will be finished at the beginning of 2009 with the publication of a strategy plan for the next three to five years.
Organisation

Board

- Univ.-Prof. Dr. rer.nat. Otto Spaniol (Chairman of the board)
- Univ.-Prof. Dr.-Ing. Dirk Abel
- Univ.-Prof. Dr.-Ing. Gerd Ascheid
- Univ.-Prof. Dr.-Ing. Christian Brecher
- Univ.-Prof. Dr.-Ing. Stefan Kowalewski
- Univ.-Prof. Dr.-Ing. Wolfgang Marquardt
- Univ.-Prof. Dr.-Ing. Jens-Rainer Ohm
- Univ.-Prof. Dr. rer. pol. Kai Reimers
- Univ.-Prof. Dr.-Ing. Dipl.-Wirt.Ing. Thomas Gries, University Representative of the Interdisciplinary Forums
- Univ.-Prof. Dr.med. Rolf Rossaint, Vice Rector for Structural Development and Research

Office

Dr. Regina Oertel (Coordinator Interdisciplinary Forums)
Members

Industrial partner
REGINA e.V. – Kompetenznetz IT/Informatik Aachen

Working Groups
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.

Contact: Dr. Torsten Kuhlen, Center for Computing and Communication, kuhlen@rz.rwth-aachen.de, http://www.rwth-aachen.de/vrca.

The Working Group “eLearning” focuses on concepts of blended learning – that is the integration of classical learning and media based learning. The Working Group would like to use the possibilities of media based learning to improve the quality of learning at the RWTH Aachen University. They do this by defining essential and pragmatic steps towards eLearning, by forming a network of expertise which can support newcomers, and by building a platform to exchange information.

Contact: Univ.-Prof. Heribert Nacken, Section of Engineering Hydrology, nackte@lfi.rwth-aachen.de, http://www.elag.rwth-aachen.de/

Selected activities and projects
Foresight-Monitoring

The Fraunhofer Institute for System and Innovation Research (ISI) and the Fraunhofer Institute for Industrial Engineering (IAO) coordinate the so-called Foresight Process. The project aims at the identification of long-term funding areas of the Federal Ministry of Education and Research (15-year-perspective). The Interdisciplinary Forums are integrated as sub-contractor. The works are coordinated by the manager of the Forum Information Technology. The tasks comprise investigations in order to focus special future research themes, identification of experts, and expert interviews. The project duration is from 9/2007 until 7/2009.

Lecture Series Forum Information Technology in winter semester 2006/07

In winter semester 2006/07 the interdisciplinary lecture series Forum Information Technology featured the following presentations:

- **Bioinformatics: Help for AIDS patients from the Computer**  
  Prof. Dr. Thomas Lengauer, Max-Planck-Institut für Informatik, Saarbrücken

- **Excellency at RWTH Aachen University: UMIC**  
  Prof. Dr. Gerd Ascheid and UMIC co-ordinators, RWTH Aachen University

- **Demographic Change: strategic necessities and chance**  
  Dr. Johannes Meier, Bertelsmann-Stiftung

- **Embedded Systems: system architecture in motor vehicles – basis for quality, innovation and economic efficiency**  
  Dr. Günther Reichert, BMW München

RWTH Themen: Informatics / Information Technology

In winter semester 2006/2007 an issue of the science magazine „RWTH Themen“ was published with the main focus on informatics and information technology. 25 articles cover current research from the areas informatics and electrical engineering (http://www.rwth-aachen.de/global/show_document.asp?id=aaaaaaaaaaadxry).

Information Day Informatics / Information Technology for schools from the Netherlands

In May 2007 and in May 2008 the Forum Information Technology organized a visit at the institutes of forum members for pupils from six schools from the Dutch province Limburg. This visit was part of a cooperation between the province Limburg, the IHK Aachen, and RWTH Aachen University. The Dutch pupils should learn about the IT study opportunities at RWTH. The programme is going to be continued next year.

Visit of a TATA delegation at RWTH Aachen University

At the end of May 2008 a high-ranking delegation of the Indian conglomerate TATA visited RWTH Aachen University in order to explore the possibilities of future cooperation – on the one hand with RWTH on the whole, on the other hand with special institutes. One part of the delegation got together with professors from the area covered by the Forum Information Technology and was shown around in several chairs if the informatics department. A follow up meeting is already scheduled.
REGINA e.V.
Competence Network Information Technology
Aachen

Overview

• over 80 companies based in the Aachen region
• 22 chairs and institutes of RWTH Aachen University
• Aachen University of Applied Sciences
• Research Centre 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 collaborations 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
• Controlling/Optimization
• Infrastructure, Internet, e-commerce
• IT consulting
• IT personnel management
• 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)
Dipl.-Math. R. Geisen (chairman substitute)
Dipl.-Ing. M. Wallrath, Ascom Deutschland GmH (chairman substitute)
Dr. R. Oertel, Head of Department 4.0., technology transfer and research funding, RWTH Aachen
Dipl.-Ing. M. Bayer, Chamber of Industry and Commerce Aachen
Dr.-Ing. J. Mansfeld
Prof. Dr. St. Kowalewski, Chair of CS 11, Software for embedded systems, RWTH Aachen
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 2007-2008
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 2007:

- Management Get-togethers: voice recognition, spam-mails, Europe’s fastest supercomputer, process-oriented knowledge management, mobile and adaptive Internet, industrial espionage, exchange of experiences about recruitment, mobile TV-mobile trends, schooling and further education by the chamber of Industry and Commerce Aachen, presentation of the UMIC-Cluster (Ultra-high-speed Mobile Information and Communication systems), …
- Round-table Discussion: Paradigm shift - go for future for all
- INFOmatica 2007: Annual ICT-company presentation event
- Coaching by experienced managers & researchers
- Recruiting Support
- Social Event

International Activities
The opportunity to exchange experience and to establish contacts offers many advantages to all concerned. The close cooperation with the regional group of GESELLSCHAFT FÜR INFORMATIK, the Dutch partner organization REGITEL, the Belgium partner organization Multi Valley Flandern and the FORUM INFORMATIK of Aachen University of Technology contributes to this process.

Transfer of personnel from universities to regionally based companies
Research institutions such as RWTH Aachen University, Aachen University of Applied Sciences, and the Research Centre Jülich, as well as the major development laboratories of industrial companies provide the Aachen region with a density of research and development which is almost unique in Europe. The IT sector is one of the most promising focal fields.

REGINA is engaged in developing strong links between research and industry. The aim is to educate highly qualified young talents as future employees in regional IT companies, so that expertise is rooted in the Aachen region in the long term. This effort is supported by REGINA's own Internet-based job-placement exchange, which not only advertises jobs for graduates but also training, work-experience opportunities, and postgraduate internships. Finally, grants for graduate students have been donated by REGINA companies.

Copies of these reports may be obtained through
http://www.informatik.rwth-aachen.de/Forschung/aib.php

2007
2007-01 Fachgruppe Informatik: Jahresbericht 2006
2007-02 Carsten Fuhs, Jürgen Giesl, Aart Middeldorp, Peter Schneider-Kamp, René Thiemann, and Harald Zankl: SAT Solving for Termination Analysis with Polynomial Interpretations
2007-03 Jürgen Giesl, René Thiemann, Stephan Swiderski, and Peter Schneider-Kamp: Proving Termination by Bounded Increase
2007-04 Jan Buchholz, Eric Lee, Jonathan Klein, and Jan Borchers: coJIVE: A System to Support Collaborative Jazz Improvisation
2007-05 Uwe Naumann: On Optimal DAG Reversal
2007-06 Joost-Pieter Katoen, Thomas Noll, and Stefan Rieger: Verifying Concurrent List-Manipulating Programs by LTL Model Checking
2007-07 Alexander Nyßen, Horst Lichter: MeDUSA - MethoD for UML2-based Design of Embedded Software Applications
2007-08 Falk Salewski and Stefan Kowalewski: Achieving Highly Reliable Embedded Software: An empirical evaluation of different approaches
2007-09 Tina Kraüßer, Heiko Mantel, and Henning Sudbrock: A Probabilistic Justification of the Combining Calculus under the Uniform Scheduler Assumption
2007-10 Martin Neuhäusser, Joost-Pieter Katoen: Bisimulation and Logical Preservation for Continuous-Time Markov Decision Processes
2007-12 Uwe Naumann, Jan Rhieme: An L-Attributed Grammar for Adjoint Code
2007-13 Uwe Naumann, Michael Maier, Jan Riehme, and Bruce Christianson: Second-Order Adjooints by Source Code Manipulation of Numerical Programs
2007-14 Jean Utke, Uwe Naumann, Mike Fagan, Nathan Tallent, Michelle Strout, Patrick Heimbach, Chris Hill, and Carl Wunsch: OpenAD/F: A Modular, Open-Source Tool for Automatic Differentiation of Fortran Codes
2007-15 Volker Stolz: Temporal assertions for sequential and concurrent programs
2007-17 René Thiemann: The DP Framework for Proving Termination of Term Rewriting
2007-18 Uwe Naumann: Call Tree Reversal is NP-Complete
2007-19 Jan Riehme, Andrea Walther, Jörg Stiller, Uwe Naumann: Adjets for Time-Dependent Optimal Control
2007-20 Joost-Pieter Katoen, Daniel Klink, Martin Leucker, and Verena Wolf: Three-Valued Abstraction for Probabilistic Systems
2007-21 Tingting Han, Joost-Pieter Katoen, and Alexandru Mereacre: Compositional Modeling and Minimization of Time-Inhomogeneous Markov Chains
2007-22 Heiner Ackermann, Paul W. Goldberg, Vahab S. Mirrokni, Heiko Röglin, and Berthold Vöcking: Uncoordinated Two-Sided Markets

2008
2008-01 Fachgruppe Informatik: Jahresbericht 2007
2008-02 Henrik Bohnenkamp, Marielle Stoelinga: Quantitative Testing
2008-03 Carsten Fuhs, Jürgen Giesl, Aart Middeldorp, Peter Schneider-Kamp, René Thiemann, Harald Zankl: Maximal Termination
2008-04 Uwe Naumann, Jan Riehme: Sensitivity Analysis in Sisyphe with the AD-Enabled NAGWare Fortran Compiler
2008-05 Frank G. Radmacher: An Automata Theoretic Approach to the Theory of Rational Tree Relations
2008-06 Uwe Naumann, Laurent Hascoet, Chris Hill, Paul Hovland, Jan Riehme, Jean Utke: A Framework for Proving Correctness of Adjoint Message Passing Programs
2008-08 George B. Mertzios, Stavros D. Nikolopoulos: The $\lambda$-cluster Problem on Parameterized Interval Graphs (This report is no longer available.)
2008-09 George B. Mertzios, Walter Unger: An optimal algorithm for the k-fixed-endpoint path cover on proper interval graphs
2008-10 George B. Mertzios, Walter Unger: Preemptive Scheduling of Equal-Length Jobs in Polynomial Time
2008-12 Joost-Pieter Katoen, Daniel Klink, Martin Leucker, Verena Wolf: Abstraction for stochastic systems by Erlang’s method of stages
2008-14 Bastian Schlich: Model Checking of Software for Microcontrollers
Hendrik vom Lehn, Elias Weingärtner and Klaus Wehrle: Comparing recent network simulators: A performance evaluation study