Annual Report 2010

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

It is a long standing tradition that the Computer Science Department at RWTH Aachen University provides a detailed yearly report on its broad and many activities. This booklet does that for the academic year of October 2009 to September 2010. You will find ample information not only about our research and teaching activities and our scientific successes, but also about social life and important developments in the department. We, as the current and past speaker of the Computer Science Department, are happy to observe that we are able, again, to report on a very successful year.

At the beginning of this reporting period, our first Master students in Computer Science started their studies. We have had Master students in our international programs before, but now we successfully completed the transition of our main study program from the former Diplom to the new Bachelor/Master system. We expect to congratulate the first MSc Computer Science graduates in 2011 when the next report will be published.

During the year we initiated two major activities to attract school students for computer science. In the so-called Ringvorlesung we offered 15 talks with the objective to communicate the fascination of computer science to a non-expert auditorium. These talks attracted a rather large number of school students so that we decided to continue the series in upcoming years. The newly established Informatik Schülerlabor invites students from grammar to high-school to learn about computer science methods and applications. The lab offers various gateways into the fascinating world of computer science. It is run by the computer-supported learning research group headed by Prof. Ulrik Schroeder.

A major event in this year’s department life was the retirement of Prof. Otto Spaniol in August this year. To mark this occasion, a two day scientific colloquium was held in his honor on September 27 and 28. Several of his former students who are now Professors at other universities and further renowned guests presented scientific and other kinds of highlights. The strong impact of Prof. Spaniol’s work on our department and the communication and distributed systems community was enlightened by the event in an impressive manner.

The high numbers of offers from other universities to colleagues of the past two years continued. In the reporting period, we had to beat enticements to three of our colleagues. We were successful in all three cases.

In the last twelve months, our faculty colleagues and researchers received numerous awards and distinctions. It is impossible to list all of them here. Therefore we will mention only the most important ones, omitting for example the numerous best paper awards and conference chair activities:

• Prof. Matthias Jarke was elected head of the Fraunhofer ICT Group, Europe’s largest combined research unit for information and communication technology, and member of the Fraunhofer Society executive committee, starting January 1, 2010.

• Prof. Nagl was appointed as Vice-Speaker of the Accreditation Committee of the European Quality Assurance Network for Informatics Education (EQANIE).

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

Finally, we thank Kai Jakobs for compiling this report.

Aachen, November 2010

Berthold Vöcking          Stefan Kowalewski
Speaker, Computer Science Department         Past-Speaker
Faculty Life
After 26 years as holder of the Chair ‘Informatik 4’ (Communication and Distributed Systems) Otto Spaniol retired (well, more or less) on 31 July 2010. To celebrate the occasion, a colloquium-cum-dinner&barbecue was organised on 27/28 September.

The more ‘formal’ part of the event, the colloquium, took place at RWTH’s newisch landmark building, the Super-C. The theme of event was ‘Alois geht und Lukas kommt’ (Alois is leaving and Lukas is coming). To many, this may sound a bit cryptic. But it’s quite simple, really, if you know that ‘Alois Potton’ (an anagram of ‘Otto Spaniol’) is one of Otto pen names. As Alois, he gained some notoriety for his regular feature in the PIK journal. And Lukas Herwel is, you guessed it, an anagram of ‘Klaus Wehrle’, Otto’s successor.

Anyway, following a brief welcome by the Speaker of the Computer Science Department, Prof. Kowalewski, the keynote speech was given by Prof. Wolfgang Schröder-Preikschat, of the University of Erlangen-Nürrnberg, in his capacity as member of the German Research Association’s grants committee for Research Training Groups (Graduiertenkollegs). He told some tales out of school, and also didn’t forget to mention Otto’s proposal for a Research Training Group on ‘The crisis of ball games in Germany and how to remedy them, with the help professional football as an example’. For formal reasons, the decision about this proposal had to be postponed until 1 April 2222).

It was not just coincidence that the keynote was given by someone who has been involved in the funding of Research Training Groups. In his time, Otto had raised funds for two such Groups – GRK 195 ‘Informatik und Technik’ (‘Computer Science and Technology’; 1991-2000) and GRK 643 ‘Software für mobile Kommunikationssysteme’ (‘Software for mobile communication systems’; 2001-2010). And in the next session, the question was raised ‘What happened to …?’ To answer this question, three graduates from these GRKs talked about their current work. All three have made their careers in academia; Donald Kossmann is a full professor with the Systems Group at ETH Zurich, Markus Fidler (one of Otto’s ‘academic children’) is a full professor and head of the Communications Networks Group at the Technical University of Hannover, and Peter Reichl (another graduate from Otto’s chair) is currently a Key Researcher for economic and user aspects of telecommunications at the Telecommunications Research Center Vienna.
In a way, the lunch break also marked the transition from the more scientific first part of the day to the somewhat lighter parts to follow. The after-lunch session was entitled ‘Of i4’s Old Boys and Girls’. Accordingly, it featured presentations by i4 alumni who have made (or, in one case, are about to make) their ways in academia and industry.

Prof. Claudia Linnhoff-Popien first gave a light-hearted insight into some of her recent projects at LMU Munich. Prof. Thomas Meuser, of the FH (University of Applied Sciences) Niederrhein informed an amused audience about the various differences and, more astonishingly, similarities between ‘real’ universities and those of Applied Sciences. Dr. Wilko Reinhardt is with the Gartner Group and had the somewhat thankless task to convince the audiences, and specifically Otto (a staunch ‘anti-consultant’), that consultants are not necessarily talking a lot of hot air. Finally, representing the younger generation, Dr. Andriy Panchenko, Otto’s latest, and last, ‘academic child’, who is now with the University of Luxembourg, gave an insight into the work that he had just started in Luxembourg.

For many, the ‘Abschied mit Überraschungen’ (‘A Farewell with Surprises’) probably was the most exciting part (perhaps not least because it was decidedly non-scientific). The session started with a greeting from RWTH’s Rector, Prof. Ernst Schmachtenberg. He talked about the impact Otto has had on the scientific world, at both the national and the international level, not least through the various honorary posts he had taken up throughout his career.

This was followed – quite surprisingly for some – by a sketch performed by the honouree himself. Slightly exaggerating, his talk provided a glimpse into the daily life of a (perhaps not exactly typical) Computer Science chair at a German ‘Elite-Institution’. He also introduced the ‘RWTH Computer Science Alphabet’ (in the form of a poem in his native Saaland-dialect).

Turning slightly more formal again, the Dean of the Faculty of Mathematics, Computer Science and Natural Sciences, Prof. Ulrich Simon, talked about Otto’s achievements that primarily affected RWTH and the region.
Moving back to the lighter side, two of Ottos’s old companions (Prof. Kurt Geihs and Prof. Ralf Steinmetz) presented a sketch that allegedly nobody except one of the actors and Otto could fully understand (apparently, it was full of allusions to a time when said actor Kurt Geihs, was about to become Otto’s first PhD graduate.

It is probably not particularly conducive to talks at length about all the various honorific speeches, greetings, etc. They came from the speaker of the Computer Science Department (Stefan Kowalewski, who had a brain-teaser and a bike for Otto), his successor (Klaus Wehrle, who supplied multi-functional security equipment), the ‘Communication and Distributed Systems’ interest group of the ‘Gesellschaft für Informatik’ (who made Otto Honorary Chairman), the UMIC research cluster (of which he was founding deputy speaker), long-time (former?) colleague Manfred Nagl (who brought gifts from his native desert), the ‘Forum Informatik’ (a platform for the development of interdisciplinary research and education at RWTH that was co-founded by Otto) and, last but not least, his former staff (one of their presents had a spillover effect – you may now find Otto presenting at various poetry slams in the region).

Finally, the key to the Chair Informatik 4 was passed from Otto to his successor (well, at least symbolically; the bloody thing won’t fit).

The various photos should convey a reasonably good idea of the event (including the performance of three Thai dancers).
Open Day – 23. ‘Tag der Informatik’

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. Traditionally, the Open Day is held on the first Friday of December, which this year was 5 December. The event was organized by the Chair of Computer Science 4 (Communication and Distributed Systems).

Following the usual informal chatting, the Open Day was formally declared open by the Dean of the Faculty of Mathematics, Computer Science and Natural Sciences, Prof. Dr. Ulrich Simon, and the Speaker of the Computer Science Department, Prof. Dr. Stefan Kowalewski.

This was followed by presentations of the Department’s new professors. These include

Erika Ábrahám  
(Theory of Hybrid Systems)

Thorsten Kuhlen  
(Virtual Reality)

Bernhard Rumpe  
(Software Engineering)

One of the day’s highlights was the invited talk by Prof. Dr. Dr. h.c. mult. Reinhard Wilhelm (University of Saarbrücken), who talked about ‘Zeitanalyse und Zeitvoraussagbarkeit’ (‘Time Analysis and Time Predictability’). He addressed the problem how to formally prove the accuracy of embedded systems with hard real-time requirements.
Next on the agenda was a true innovation – the ‘One Minute Madness’. Presenters had 100 seconds (ok, slightly more than a minute) and one slide to tell the – more or less uninitiated – audience why their respective project is relevant, exciting, and fun. Obviously, such a format was a challenge to the imagination and the creativity of the presenters. On the other hand, the session provided some nice impressions of the department’s activities. And it was good fun watching the presentations.

The Rektor of RWTH Aachen University, Prof. Dr.-Ing. Ernst Schmachtenberg, addressed the audience after the break. Obviously, he is well aware of the importance of the Computer Science Department for RWTH Aachen University. Something one always likes to hear ….

Subsequently, Prof. Dr. em. Klaus Indermark gave a most enthusiastic presentation on some historic aspects of the Aachen region, entitled “Von der aachener Heide zum Vierländereck”.

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His talk was followed by a presentation, by Prof. Dr. em. Lutz Hornke, on the RWTH Alumni Club.

Eventually, the more formal ‘ceremony’ of the presentation of the graduation certificates to the new graduates commenced (probably the most important bit for the numerous family members in the audience).

Also, the winners of the various awards were announced and honoured. These awards were extremely plentiful this year, including the Schönebornpreise (for excellent BScs), the Ericsson-Umic-Award for the best Thesis written in the context of the Umic Cluster of Excellence, and the AMB Generali Award, the DSA Award, the CAPgemini+ sd&m-Award, and the SOPTIM Award, all for excellent Diploma/Master theses.
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(ish) buffet and plenty of drinks were on offer. The typical crowd of about 500 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.
InfoCup 2010
by

The InfoCup is the CoSc department’s traditional football tournament. In 2010, it was once again sponsored by Soptim AG. The event took place on 27 June. Nine teams had registered, with the i12-team making a welcome debut.

The group phase comprised two groups with 4 and 5 teams, respectively. Group A (5 teams) saw a neck-and-neck race between LuFG i4, i6, and i12 that was decided only in the final match. Eventually, it was ‘all’s well that ends well’ for the former two teams.

Also in group B the final match was decisive. Here, i3 and i5 gained the upper hand.

Both semi-finals (LuFGi4 vs i3; i5 vs i6) could be decided only through a penalty shootout; with scores of 1:1 after regular playing time. i3 and i5 prevailed, but i6 threw in the towel only after 16 penalties.

i6 won the petite finale against LuFG i4 by 1:0. This was all the more remarkable as i6 didn’t have any substitutes.

The finals i3 vs i5 was a classic – a repetition of those from 2007 and 2009. And, again following tradition, i5 won (1:0); their third success.

The After-Cup-Party was perhaps even more important than the matches. In addition to the usual food and drink there was a public viewing of the World Cup match between Germany and England. With the crowd being largely computer scientists, this was also used to study asynchronicity of distributed multi-media applications – there was a clear delay between the video signals to the monitor on the lawn and the seminar room, respectively. Regardless, Germany’s 4:1 victory made for a perfect day.
Bright Minds in Computer Science – Helle Köpfe in der Informatik

Starting five years ago, 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 since then. An external steering committee selected 16 children who attend the new program called Helle Köpfe in der Informatik – Bright Brains in Computer Science. During eight course meetings, faculty members of the Department of CS introduced the talented pupils to basic topics of computer science.

They particularly lay tress on the deeper insight that computer science exceeds simply working with computers by far.

The 2010 seminar addressed the following topics:

- Computer, Campus, Cleverness – the first rendezvous with RWTH (Helen Bolke-Hermanns)
- Why is it possible to scratch a CD? (Peter Rossmanith)
- Searching and Sorting (Thomas Seidl)
- The needle in the haystack (Thomas Noll)
- Kara, the programmable ladybug (Horst Lichter)
- Chquered is my favourite colour (Jan Borchers)
- How does the Internet work? (Klaus Wehrle)

More Information and photos of all events can be found in the web: http:///www.helle-koepefe.informatik.rwth-aachen.de/

The experiences made were very positive, and the programme will be continued.
Informatics School Laboratory—Extracurricular Place of Learning for Pupils of all Ages

The school laboratory for computer science InfoSphere opened in summer 2010 at RWTH Aachen University. It offers several ways to numerous facets and applications of computer science for children and teenagers. It should even awake interest in those who are not technology-friendly. There are offers lasting half a day, a full day, or courses for several days. The modules provide experimental and action-oriented learning with connection to everyday experiences. Some examples are “A journey into a computer”, “Android programming” and “Diffie-Hellman key exchange”.

The modules can be booked by teachers for their classes for free. There is no previous knowledge for many of our modules developed for lower and middle grade pupils necessary. That is the reason why these courses fit for pupils of different types of schools. Other offers are especially suited for their integration in higher secondary computer science education. They can be used as an alternative course type or as an interesting continuation of the school topic with smooth transition to actual computer science research.

The main aim of InfoSphere is to strengthen pupils in the well-founded uses of technology and information in different fields of activity. The pupils should acquire skills in technical analysis and design to solve computational problems. Especially open questions, which allow different and creative solutions, are to be processed. Teamwork is one of the most important factors in order to achieve a goal.

InfoSphere is the only school laboratory in Germany, which does not only deal with applications, but with the root of computer science. The goal of the facility is to visualize aims, concepts, methods and tools of computer science which are not perceived by the public. Our school laboratory presents an ideal complement for classical computer science lessons and connects current computer science research topics with school lessons and all-day experiences of pupils.

Concept

Our school laboratory is open for school classes, computer science projects or interested individuals. InfoSphere provides the opportunity to learn about current computer science topics very attractively which cannot be taught in school because of their technical or temporal limits.

The topics of modules are attached to the living environments of the pupils (for example mobile programming for smart phones, GPS systems or social networks). The modules broaden their horizons to other fascinating contents of computer science as visual encryption or strengths and limits of computation.
To close the big gap between school and university InfoSphere provides the opportunity to bring the pupils closer to actual fields of research. Therefore pupils can come into contact with the university and can gain impressions of research in computer science, which will be an advantage for their further choice of university studies or work fields.

http://schuelerlabor.informatik.rwth-aachen.de
Software Engineering Research Camp

The Software Engineering Research Camp provides computer science students the opportunity to experience agile software development at first hand, and to learn about new and emerging technologies. For a fixed period of time, the students organize themselves in order to brainstorm about their own ideas, and then plan, design, and implement their own applications. During all phases, the students are extensively supported by members of the academic staff of the organizing chairs. The Research Camp is founded and organized by the Software Engineering chair (I3) in cooperation with the Research Group Software Construction (LuFGI3). The two iterations of the Research Camp so far were attended by 35 students.

In 2009, the Research Camp was scheduled for two days. The students were invited to a hotel in the Eifel, where they designed and implemented an application to manage the results of table football matches. This first iteration of the Research Camp received positive feedback by all participants and organizers. As expected, the two-day timeframe was way too short to implement a functional prototype. Nevertheless, the students gained insight into a software project with about 25 members, and experienced typical development problems like time pressure, communication overhead or social conflicts within a group. In addition they experienced a crash course in technologies like Android and J2EE. As a result, the concept was further refined for the next iteration of the camp in 2010.

In 2010, the time-frame for the Research Camp was extended to ten days. In contrast to 2009, the Camp started with a technology day at the chair of Software Engineering. The students were introduced to the employed technologies Android, iPad, Web Services and J2EE. After this half-day workshop, the students spent two days in a hotel in the Eifel in order to develop their own ideas. During the course of several brainstorming sessions they decided to build mobile Android and iPad applications that allow students and visitors to find and navigate to the rooms of the computer science building more easily. In order to implement these applications, the students decided to build on a stationary prototype for room navigation, called GISELA, which was developed at a prior computer science lab class. After a week of implementation, the students presented their application prototypes, and some of the students announced their plan to continue developing in order to establish a real product.
Two special editions of *Informatik Spektrum*

2010 were two special editions of *Informatik Spektrum* published in editorial responsibility of Prof. Spaniol/ Prof. Oberschelp and Prof. Thomas.

At the end of 2009 a special issue of *Informatik-Spektrum* on Computer Science and Astronomy was published.

Among several other interesting articles, this journal issue starts with a review of the topic by Prof. Oberschelp. Later on, a second contribution from Aachen is by Helen Bolke-Hermanns: “Irdische Klänge für kosmische Intelligenzen”. This paper describes the rummy idea of communication to aliens by means of mathematical-physical language burned on a disk – for instance a golden venyl disk.

A special issue on the field of Theoretical Computer Science was released in October 2010.

Prof. Thomas wrote the leading article “Theoretische Informatik - ein Kurzprofil” and a historical note “When nobody else dreamed of these things - Axel Thue und die Termersetzung”. Another paper by members of Fachgruppe Informatik in this issue is the paper by Dr. Martin Hoefer and Prof. Berthold Vöcking explaining “Berechnung von Nash-Gleichgewichten”.

TACO Day 2010

The international workshop ‘Treewidth and Combinatorial Optimization’ (TACO) brings together researchers from the fields of computer science and economics who work in the research areas of Combinatorial Optimization and Treewidth. There is hence a broad spectrum of topics ranging from pure theoretical research to practical applications.

Supported by a financial grant of proRWTH, for the first time the ‘TACO Day’ took place at RWTH Aachen University at June 10th, 2010. This is the first time the workshop left the Netherlands, where all previous TACO Days took place. The workshop was organized by the Lehr- und Forschungsgebiet Theoretische Informatik.

Located in the ‘Ford-Saal’ of the SuperC, participants from the universities of Utrecht, Maastricht, Amsterdam, Bergen and Aachen could listen to excellent talks from the research areas of operations research, exact algorithms as well as approximation. The workshop was completed with an "open problems" session. After the official program had ended, there were plenty of additional possibilities to discuss the results and impressions of the day at a workshop dinner in Aachen down town.
Teaching
Contents and curriculum of the
Computer Science Programme (Diploma)

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.

Required qualifications

Multifaceted methods concerning the structuring, modelling, 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!
Contents and curriculum of the Computer Science Programme (BSc/MSc)

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, modelling, 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, methodological 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!
Contents and curriculum of the Principles of Computer Science as second major of the Technik-Kommunikation (Magister/Magistra Artium) programme

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 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 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.

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 as 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 pro-seminar 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 acquaintace 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 Multimedia, 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 Programme

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

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

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

General Description of the Programme
The international Master Programme in Media Informatics was introduced in 2002 at the Bonn-Aachen International Center for Information Technology (B-IT). Media Informatics is offered by RWTH Aachen University and the University of Bonn in co-operation with the Fraunhofer Institutes at Sankt Augustin near Bonn. This interdisciplinary programme will educate the participant to successfully master the novel technical and economic challenges at the crossroads of computer science, software engineering, next-generation communication systems, and media. The programme is distinguished by its international orientation, its focus on IT competence, and its high level of integration of research and teaching. The master’s programme in Media Informatics consists of three main blocks: computer science and mathematical foundations, basic principles in media science and business, media informatics.

The programme is characterised by a significant proportion of research lab courses embedded in both basic and applied research of the participating Fraunhofer Institutes of Applied Information Technology (FIT), and Media Communication (IMK). Major topics include: digital interactive media, internet infrastructures, management of information, communication and security, knowledge management, visualisation, and virtual engineering on the basis of augmented reality. Special courses on modelling of spatial and mobile aspects, and on usage,
annotation, and retrieval of spatial data provide for a special focus in the important application domain of Geographical Information Systems. The programme of study also includes methodological aspects of designing media informatics systems from the perspectives of software engineering, usability, media design, and business requirements.

The final six months of the programme are dedicated to the master thesis which can be done in co-operation with industry. The course contents is structured according to the ECTS (European Credit Transfer System).

**Career Opportunities**

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

**Language of Instruction**

The Programme will be taught completely in English

**Duration of the Programme**

Two years

**Beginning of the Programme**

October

**Deadline for application:**

March 1st the same year the programme starts

**Further information**

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

RWTH Aachen University
Chair Informatik 4
Media Informatics Team
52056 Aachen, Germany
E-Mail: msc-mi@b-it-center.de
Webpage: [http://mi.b-it-center.de/](http://mi.b-it-center.de/)
## Courses Taught in 2010

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<td>Angewandte Automatentheorie</td>
<td>Thomas</td>
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<td>Thomas, Löding</td>
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<td>Thomas, Nieder</td>
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<tr>
<td>Algorithmen auf Graphen</td>
<td>Unger, Ochel, Keßelheim</td>
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<td>Distributed Systems Seminar</td>
<td>Wehrle, Aktas, Hummen</td>
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<tr>
<td>Grundlagen Rechnernetze und Internet</td>
<td>Wehrle, Espinosa Carlin, Susnauskas</td>
<td>PST (2)</td>
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<tr>
<td>Mobile Communication &amp; Sensor Networks (vormals)</td>
<td>Wehrle, Heer, Bitsch Link, Wirtz</td>
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<tr>
<td>Softwarepraktikum &quot;Neue Algorithmen in Data-Mining-Frameworks&quot;</td>
<td>Abraham, Giesl, Brockschmidt, Chen, Emmes, Fuhs, Jansen, Loup, Otto, Ströder</td>
<td>P</td>
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<tr>
<td>Satisfiability Checking</td>
<td>Abraham, Giesl, Brockschmidt, Chen, Emmes, Fuhs, Jansen, Loup, Otto, Ströder</td>
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<tr>
<td>Erfüllbarkeitsüberprüfung (Satisfiability Checking)</td>
<td>Abraham, Loup, Jansen</td>
<td>VÜT</td>
<td>V (V3 Ü1)</td>
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<td>Introduction to Scientific Computing Languages</td>
<td>Bientinesi</td>
<td>VPT</td>
<td>V (V3/ÜE1)</td>
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<tr>
<td>Programmierung (Übung - Tutorium)</td>
<td>Bischof, Brockschmidt, Emmes, Lülfesmann, Willkomm</td>
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<td>Programmierung (Globalübung)</td>
<td>Bischof, Brockschmidt, Emmes, Lülfesmann, Willkomm</td>
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<td>Programmierung</td>
<td>Bischof, Brockschmidt, Emmes, Lülfesmann, Willkomm</td>
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<td>iPhone Anwendungsprogrammierung</td>
<td>Borchers, Heller, Diehl</td>
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<td>VU (V3U2)</td>
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<td>Designing Interactive Systems I</td>
<td>Borchers, Herkenrath, Wacharamanotham</td>
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<td>VU (V3U2)</td>
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<td>Post-Desktop User Interfaces</td>
<td>Borchers, Lichtschlag, Wittenhagen</td>
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<td>Logikprogrammierung</td>
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<td>Logikprogrammierung</td>
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<td>Numerisches Rechnen (Großübung)</td>
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<td>Algorithmen und Datenstrukturen</td>
<td>Katoen, Noll</td>
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<td>Basic Techniques in Computer Graphics</td>
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<td>Seminar Current Research Topics in Computer Graphics, Geometry Processing, and Computer Vision</td>
<td>Kobbelt, Habbecke,</td>
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<td>Softwarepraktikum &quot;Virtual Board Game Design&quot;</td>
<td>Kobbelt, Schmitz, Möbius, Zimmer, Campen</td>
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<td>Basic Techniques in Computer Graphics</td>
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<td>Computer Graphics and Computer Vision</td>
<td>Kobbelt, Sibbing, Sattler</td>
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<tr>
<td>Einführung in die Technische Informatik</td>
<td>Kowalewski Franke, Bialas</td>
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<td>Einführung in die Technische Informatik</td>
<td>Kowalewski Franke, Bialas</td>
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<td>Design Patterns für Mobile Eingebettete Systeme</td>
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<td>Vorlesungs- und Übungstermine</td>
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<td>Anwendung und Nutzen von Prozess- und Reifegradmodellen in der Praxis</td>
<td>Lichter, Vianden, Pricope</td>
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<td>Seminar Personal and Mobile Health Care</td>
<td>Lorenz, Quix, Jarke, Li, Geisler</td>
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<td>Selected Topics in Mobile Security</td>
<td>Meyer, Barnickel, Egners, Neugebauer</td>
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<td>Selected Topics in Human Language Technology and Pattern Recognition</td>
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<td>Diskrete Strukturen (offene Sprechstunde bei Bedarf und nach Anmeldung)</td>
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<td>Diskrete Strukturen</td>
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<td>Noll</td>
<td>V (BSc/MSc:3, D:4)</td>
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<td>Compilerbau</td>
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<td>Software-Entwicklung für ein Schülerpraktikum</td>
<td>Rossmann, Abraham, Borchers, Gross, Kobbelt, Leibe, Rumpe, Schroeder, Wehrle</td>
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<td>Softwaretechnik</td>
<td>Rumpe, Haber, Navarro Perez</td>
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<td>Einführung in die Softwaretechnik</td>
<td>Rumpe, Haber, Navarro Perez</td>
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<td>Softwaretechnik</td>
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<td>Software-Projektpraktikum (Bachelor) : Global Software Engineering (GloSE)</td>
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<td>Softwaretechnik</td>
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<td>Modellbasierte Softwareentwicklung</td>
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<td>Automatic Speech Recognition</td>
<td>Schlüter, Ney</td>
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<td>Automatic Speech Recognition</td>
<td>Schlüter, Ney, Nußbaum</td>
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<tr>
<td>Web Technologien und Webprogrammierung (WebTech 1)</td>
<td>Schroeder, Chatti, Brauner, Herding</td>
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<td>Seminar &quot;Data Mining und Multimedia Retrieval&quot;</td>
<td>Seidl</td>
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<td>Berechenbarkeit und Komplexität für Lehramt und TK</td>
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<td>Randomisierte Algorithmen</td>
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<td>Übung: Massively Distributed Systems I (Advanced Internet Technology)</td>
<td>Wehrle, Schleinzer, vom Lehn, Bitsch Link, Kunz</td>
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<tr>
<td>Massively Distributed Systems I (Advanced Internet</td>
<td>Wehrle, Schleinzer, vom Lehn,</td>
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Postgraduate Courses – Summer Term

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<td>Master-Mentorenprogramm: Angewandte Informatik</td>
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<td>Abraham, Chen</td>
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<td>Seminar: Mobile-Anwendungen &amp; Location Based Services</td>
<td>Akbari, Schroeder</td>
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<td>Betriebssysteme II</td>
<td>Bemmerl, Clauß, Reble</td>
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<td>Bientinesi</td>
<td>VPT (V3/UE1)</td>
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<td>Einführung in High-Performance Computing</td>
<td>Bischof, Fortmeier</td>
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<td>Club i10</td>
<td>Borchers</td>
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<td>CHI Club (internal)</td>
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<td>Designing Interactive Systems II</td>
<td>Borchers, Heller, Wittenhagen</td>
<td>VUT (V3/UE2)</td>
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<td>Borchers, Lichtschlag, Weiß</td>
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<td>Medizinische Bildverarbeitung</td>
<td>Deserno, Kobbelt, Ney, Rossmanith, Seidl, Spitzer</td>
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<td>Einführung in High- Performance Computing</td>
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<td>Arbeitsgemeinschaft Programmverifikation</td>
<td>Giesel, Emmes, Fuhs, Otto, Plücker</td>
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<td>Automatische Terminierungsanalyse</td>
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<td>Seminar: Logik, Komplexität, Spiele</td>
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<td>Algorithmische Modelltheorie</td>
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<td>Interferenz in drahtlosen Netzen</td>
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<td>Arbeitsgemeinschaft Metadata in Community Information Systems</td>
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<td>Datenbanken und Informationssysteme</td>
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<td>Arbeitsgemeinschaft Model Management</td>
<td>Jarke, Quix, Li</td>
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<td>Advanced Data Models</td>
<td>Jarke, Quix, Li</td>
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<td>Mobile Multimedia</td>
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<td>Einführung in eingebettete Systeme</td>
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<td>Arbeitsgemeinschaft Softwaretechnik: Sprachen, Methoden, Werkzeuge</td>
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<td>Die Softwaretechnik-Programmiersprache Ada 95</td>
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<td>Rumpe, Armac, Ringert, Kurpick</td>
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<td>Meyer, Barnickel, Neugebauer</td>
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<td>Mustererkennung und Neuronale Netze</td>
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30.09.2010: *Affective Computing, Fun and User Experience in Digital Gaming*
Dr. Lennart Nacke, University of Saskatchewan, Canada

09.07.2010: *Tuning the ensemble selection process of schema matchers*
Prof. Dr. Avigdor Gal, Technion Haifa, Israel

22.07.2010: *Software und Hardware für effiziente, realitätsnahe Bildsynthese in Interaktiven Umgebungen*
Prof. Dr. André Hinkeljann, Computer Graphics Lab University of Applied Sciences Bonn-Rhein-Sieg

15.07.2010: *Computerspiele und "Spielsucht"*
Prof. Dr. Helmut Lukesch, Institut für experimentelle Psychologie, Universität Regensburg

08.07.2010: *Studentisches Mentoring für Studienanfänger - Lösung gegen Studienabbruch?*
Benjamin Espe, UniMentor e.V., Univ. Magdeburg
Nico Haase, Fachschaft Informatik, TU Darmstadt

11.03.2010: *Agent-Based (Individual-Oriented) Models: Simulating Fish School and Hospital Emergency Departments*
Prof. Dr. Emilio Luque, Universitat Autonoma de Barcelona

02.03.2010: *Clustering in Subspaces of High-Dimensional*
Dr. Arthur Zimek, Ludwig-Maximilians-Universität München

11.03.2010: *p-Automata: New Foundations for Discrete-Time Probabilistic Verification*
Dr. Michael Huth, Imperial College, London

26.01.2010: *Behavioural Pseudometrics*
Prof. Dr. Franck van Breugel, York University, Toronto

14.01.2010: *Programming Model Development - How DSLs and language workbenches can help in modern Software Engineering*
Dr. Axel Uhl, SAP AG

17.12.2009: *Effiziente übergreifende Fahrzeugdiagnoseprozesse durch flexible IT-Architekturen und standardisierte Datenformate*
Dr. Ansgar Schleicher, DSA - Daten- und Systemtechnik GmbH, Aachen

15.12.2009: *Physics-Based Models for Human Motion Analysis*
Prof. David J. Fleet, PhD, University of Toronto

06.11.2009: *Progress in Real-Time Stereo Vision*
Dr. Uwe Franke, Daimler AG, Böblingen
05.11.2009:  *Wirtschaftliche Entwicklung sicherheitsrelevanter Systeme*
Dr. rer. nat. Stefan Kriebel, BMW Group, München

15.10.2009:  *On Quantitative Software Verification*
Prof. Dr. Marta Kwiatkowska, University of Oxford, UK

Professor Dr. rer. nat. Andreas Henrich, Universität Bamberg

07.10.2010:  *Optimale Beweissysteme und PTIME-Logiken*
Prof. Dr. Jörg Flum, Albert-Ludwigs-Universität Freiburg
### Diploma and Master Theses

#### Diploma theses

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| Josef   | Hahn            | Entwicklung einer temporalen Logik für regelbasierte Systeme  
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| Alexander| Hahne          | Zertifizierung von Diensten mittels der Analyse von Begutachtungen  
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| Andreas | Hannig          | Planspiel: Praxisgründung - Eine webgestützte regelbasierte Bewertung einer Praxiseinrichtung  
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| Felix   | Heidrich        | Development and Evaluation of Multimodal User Interfaces for Ambient Assisted Living Environments                                                                                                   |
| Ulrich  | Helker          | Integration der Objekt Constraint Language in die UML/P  
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| Roland  | Hildebrandt     | Profile für bidirektionale Qualitätsmodelle in QMetric  
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| Daniel  | Holz            | Echtzeit-Simulation und-Visualisierung von Terrain-Deformationen  
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| Piotr   | Irla            | Design, Entwicklung und prototypische Realisierung einer Kommunikationseinheit mit Unterstützung mehrerer paralleler Kommunikationswege und geeigneter Verkehrsflusssteuerung  
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| Christina Maria | Jansen      | Entwicklung eines Inferenzalgorithmus für Hyperkantenersetzungsgrammatiken  
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<td>Takhmina</td>
<td>Namozova</td>
<td>Verteilte Aggregation und Analyse von Produktionsdatenströmen (Distributed Aggregation and Analysis of Production Process Data Streams)</td>
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<tr>
<td>Jan</td>
<td>Newger</td>
<td>Automatische Rekonstruktion von X8G Code von eingebetteten, verschleierten CPU Interpretern in ausführbaren Dateien (Automatic Reconstruction of X8G Machine Code from Embedded, Obfuscated CPU Interpreters in Executable Files)</td>
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<tr>
<td>Tim</td>
<td>Niemüller</td>
<td>Entwicklung einer Verhaltenssteuerung für die FAWKES Roboterkontroll-Software und dessen Anpassung an die humanoiden Plattform Nao (Developing a Behavior Engine for the FAWKES Robot-Control Software and its Adaptation to the Humanoid Platform Nao)</td>
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<tr>
<td>David</td>
<td>Nolden</td>
<td>Analyse des Suchraums für Kontinuierliche Spracherkennung mit großem Vokabular (Analysis of the Search Space in Large Vocabulary Continuous Speech Recognition)</td>
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<tr>
<td>Lars A.</td>
<td>Noschinski</td>
<td>Automatische Komplexitätsanalyse von Termersetzungssystemen (Automated Complexity Analysis of Term Rewrite Systems)</td>
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<td>Maximilian Reinhard</td>
<td>Odenbrett</td>
<td>Explicit-State Model Checking einer Architekturbeschreibungssprache mit SPIN (Explicit-State Model Checking of an Architectural Design Language using SPIN)</td>
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<td>Sami</td>
<td>Okasha</td>
<td>Effiziente Ähnlichkeitssuche für Quadratische Form Distanzen auf hybriden Signaturen (Efficient Similarity Search for Quadratic Form Distances on Hybrid Signatures)</td>
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<td>Stephan</td>
<td>Peitz</td>
<td>Erweiterung statistisch-maschineller Übersetzung mit Syntax (Extending Statistical Machine Translation Using Syntax)</td>
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<tr>
<td>Yanhuai</td>
<td>Peng</td>
<td>Integration einer digitalen Karte im Versuchsfahrzeug für vorausschauende Fahrzeuglängs- und querführung (Realization of a Road Event Predictive Application Using Digital Maps for ADAS)</td>
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<td>Monika</td>
<td>Pienkos</td>
<td>Semantische Spezifikation und Adaption von eHome-Diensten (Semantic Specification and Adaptation of eHome Services)</td>
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<td>Oliver</td>
<td>Preuschl</td>
<td>Kollaborative Parametrisierung dynamischer Simulation Workflows (Collaborative Parametrization of Dynamic Simulation Workflows)</td>
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<td>Pascal</td>
<td>Richter</td>
<td>Simulation und Auslegungsoptimierung solarthermischer Kraftwerke (Simulation and Optimization of Solar Thermal Power Plants)</td>
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<td>Philip</td>
<td>Ritzkopf</td>
<td>Entwicklung von MeDUSA Task-Wizards für die ViPER Plattform (Developing MeDUSA Task-Wizards for the ViPER Platform)</td>
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<tr>
<td>Jan</td>
<td>Scherer</td>
<td>Ein Eclipse-basierter Debugger für eingebettete Systeme (An Eclipse-Based Debugger for Embedded Systems Software)</td>
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<tr>
<td>Marc</td>
<td>Schlüter</td>
<td>Parallelisierung von Algorithmen für die Echtzeit-Raumakustiksimulation (Parallelization of Algorithms for Real-Time Room Acoustics Simulation)</td>
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<tr>
<td>Peter</td>
<td>Schmitz</td>
<td>Erhöhung des Schutzes vertraulicher Daten bei entfernter Datenhaltung - Systemdesign und Implementierung (Enhancing Privacy on Remote Datastorage - System Design and Implementation)</td>
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<td>Christoph Terwelp</td>
<td>Schmitz</td>
<td>Anwendung informationstheoretischer Maße in der Genetik (Application of Information-Theoretic Measures in Genetics)</td>
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<td>Stefan</td>
<td>Schulz</td>
<td>Logik erster Stufe mit Erreichbarkeitsprädikaten über unendlichen Systemen (First-Order Logic with Reachability Predicates over Infinite Systems)</td>
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<tr>
<td>Daniel</td>
<td>Slot</td>
<td>Modification and Evaluation of TCP's Behaviour in Face of Reordering</td>
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<tr>
<td>André</td>
<td>Stein</td>
<td>Adapatives Clustering in Wireless-Mesh-Netzwerken (Adaptive Clustering in Wireless Mesh Networks)</td>
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<tr>
<td>Thomas</td>
<td>Ströder</td>
<td>Towards Termination Analysis of Real Prolog-Programs</td>
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<tr>
<td>Christoph</td>
<td>Terwelp</td>
<td>On-Line Konstruktion und Optimierung von Diskriminierungsnetzwerken für regelbasierte Systeme (On-Line Construction and Optimization of Discrimination Networks for Rule-based Systems)</td>
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<tr>
<td>Tansel</td>
<td>Tezeroglu</td>
<td>Rückführung von NC-Informationen durch eine CAM-basierte direkte Maschinensteuerung (NC-Informationen Feedback trough a CAM-based direct Machine Control)</td>
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| Selly    | Thong    | Ein semi-automatisches Mapping-System zur Konstruktion und Weiterentwicklung eines CCTS-basierten Kanonischen Formats (A Semi Automatic Mapping System for Building and Improving a
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<tbody>
<tr>
<td>Jörg</td>
<td>Toborg</td>
<td>Statische Analyse von Assembler Code für den Renesas R8C/23 Mikrocontroller (Static Analysis of Assembly Code for the Tenesas R8C/23 Microcontroller)</td>
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<td>Tobias</td>
<td>Vaegs</td>
<td>Entwurf und Entwicklung eines Routing-Protokolls auf Basis statistischer Vektoren (Design and Implementation of a Statistival Vector-based Routing Protocol)</td>
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<tr>
<td>Christian</td>
<td>von Eßen</td>
<td>Automatische Terminierungsanalyse von Java Bytecode: Vom Finite Interpretation Graph zur Termersetzung (Automated Termination Analysis of Java Bytecode: From the Finite Interpretation Graph to Term Rewriting)</td>
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<tr>
<td>Sabrina</td>
<td>von Styp-Rekowski</td>
<td>Towards a Testing Theory for Timed and Symbolic Systems</td>
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<tr>
<td>Lei</td>
<td>Wang</td>
<td>Anwendung der Spieltheorie im lebenslangen Lernen (Application of Game Theory in the Long Tail of Learning)</td>
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<tr>
<td>Cristian</td>
<td>Wente</td>
<td>Efficient Algorithms for the Simulation of Pedestrian Movement</td>
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<tr>
<td>Ingo</td>
<td>Zander</td>
<td>Verteilung von Seminarplätzen mittels stabiler Matchings (Allocation of Seminar Slots Using Stable Matchings)</td>
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<td>Lingjie</td>
<td>Zheng</td>
<td>Planungs- und Steuerungsstrategie in der Produktion bei Airbus mit MES (Manufacturing Execution System)</td>
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<td>(Planning and Control Strategy in Production at Airbus with MES)</td>
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**Master Theses Software Systems Engineering**

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<tr>
<td>Eldar</td>
<td>Akchurin</td>
<td>Cognitive Radio Management for Wireless Sensor Networks</td>
</tr>
<tr>
<td>Muhammad</td>
<td>Ali</td>
<td>An Obligation Framework &amp; Language for Data Handling in Service Composition</td>
</tr>
<tr>
<td>Afshan</td>
<td>Aman</td>
<td>Efficient Implementation of a Platoon Controller Using a Rapid-Prototyping System</td>
</tr>
<tr>
<td>Dimitrios</td>
<td>Andrikopoulos</td>
<td>Mobile Storytelling for Social Software Engineering</td>
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<tr>
<td>Ivica</td>
<td>Bogosavljevic</td>
<td>Synthesizing an Instruction Set Simulator for Model Checking Embedded Systems Software</td>
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<tr>
<td>Venkatsh</td>
<td>Bommasandra Sadasiva</td>
<td>Deployment Algorithm for Programming Distributed Heterogeneous Sensor Environment</td>
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<tr>
<td>Samer</td>
<td>Catalan</td>
<td>Combining Social Networks with Context Awareness</td>
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<tr>
<td>Galia</td>
<td>Hasanova</td>
<td>Masterarbeit an der Universität Trento/Italien (Erasmus Studentin)</td>
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<tr>
<td>Julia</td>
<td>Hoxha</td>
<td>Query Rewriting using Generic Schema Mappings</td>
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<tr>
<td>Martin</td>
<td>Hristov</td>
<td>A Hero's Journey - A Template Engine for Non-linear Storytelling</td>
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<tr>
<td>Gang</td>
<td>Huang</td>
<td>Security for Body Sensor Networks</td>
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<tr>
<td>Olena</td>
<td>Kaliberdina</td>
<td>Dynamic Identity Provider Selection in a Context-Aware Information Rights Management System</td>
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<tr>
<td>Zeeshan</td>
<td>Khan</td>
<td>Development of a Fault-Tolerant Communication Protocol for a Safety-Exitable Medical Application</td>
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<tr>
<td>Pscar</td>
<td>Mendoza Vargas</td>
<td>Mobile Access to LAS Services with Mobile Web Services</td>
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<tr>
<td>Waqas</td>
<td>Munawar</td>
<td>Design and Implementation of Adaptivity Extensions of TinyOS</td>
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<tr>
<td>Dongsu</td>
<td>Park</td>
<td>Handover Optimization in Cooperative Wi-Fi Networks</td>
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<tr>
<td>Mudassir</td>
<td>Rasool</td>
<td>Model Checking Programs for the Renesas R8C/23 Microcontroller using [mc]square</td>
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<tr>
<td>Emine</td>
<td>Sagbas</td>
<td>An Analysis of Application Scenarios for Network of Information</td>
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<tr>
<td>Anbalagan</td>
<td>Sonaimuthu</td>
<td>Concept and Prototype for the Automated Test Case Execution in a Mobile Environment</td>
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<tr>
<td>Hakan</td>
<td>Soncu</td>
<td>Web-based Administration Interface for Wireless Mesh Network Testbed</td>
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<tr>
<td>Velina</td>
<td>Zaimova</td>
<td>An Approach for Ontology Learning with Text Mining using Customer Reviews for Home Textile Products</td>
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<tr>
<td>Dan</td>
<td>Zhou</td>
<td>Data Mining Algorithms on Multicare Architectures</td>
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<tr>
<td>Chong</td>
<td>Zhu</td>
<td>Schema Integration Using Conjunctive Mappings</td>
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Master Theses Media Informatics

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<td>Meng-Fang</td>
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<td>Realistic Garment Replacement in Images</td>
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<td>Dezfuli</td>
<td>Exploring Task Information through BSCW with Interactive Visualization</td>
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<td>Hichem</td>
<td>El Mokni</td>
<td>Coupled Sonar Inertial Navigation System for Pedestrian Tracking</td>
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<td>Nan</td>
<td>Li</td>
<td>Supporting Collaboration in Meetings based on Interactive Paper Documents and a Tabletop Surface</td>
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<td>Oleksandar</td>
<td>Lobunets</td>
<td>Design and Evaluation of a Mobile Device as a Smart Metering Display</td>
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<td>Elda</td>
<td>Paja</td>
<td>Modeling Design Patterns with Description Logic</td>
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<td>Wen</td>
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<td>Semi-Formal Process Models to Executable Workflows</td>
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<tr>
<td>Alexandru</td>
<td>Rugina</td>
<td>A Platform for Event-Based Provisioning of NGN Services</td>
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<td>Alpesh</td>
<td>Tarapara</td>
<td>Web-based Mobile Text Retrieval</td>
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<td>Yohanes Baptista</td>
<td>Trinugroho</td>
<td>A SIP-Based Framework for Context-Aware Service Provisioning in Converging Environments</td>
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<tr>
<td>Vina Novfitagari</td>
<td>Wibowo</td>
<td>The Ublens Approach</td>
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<tr>
<td>Yanto</td>
<td>Young</td>
<td>Mobile Contexts: Network Fingerprinting and Auto Configuration</td>
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<tr>
<td>Yan</td>
<td>Zhang</td>
<td>Mobile Interaction in Ubiquitous Computing Environments - Exploration of an Interaction Mechanism Based on Map Views</td>
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Stats

No. of enrolled students in semesters 1 – 13+
### Overall Number of Students and Graduations

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<td>693</td>
<td>70</td>
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</tbody>
</table>
Research
Staff

- **Faculty**
  Univ.-Prof. Dr. Berthold Vöcking (chair)
  Priv. Doz. Dr. Walter Unger
  [http://www-i1.informatik.rwth-aachen.de](http://www-i1.informatik.rwth-aachen.de)

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  Email: jussen@cs.rwth-aachen.de

- **Research Assistants**
  Kamal Al-Bawani, M.Sc. (since June 2010)
  Dipl.-Inform. Johannes Dams (since October 2010)
  Dipl.-Inf. Alexander Fanghänel
  Dipl.-Inform. Sascha Geulen
  Dr. Martin Hoefer
  Dipl.-Inform. Thomas Kesselheim
  Dr. George Mertzios (until March 2010)
  Dipl.-Inform. Marcel Ochel
  Dr. Lars Olbrich
  Dipl.-Math. Klaus Radke (since June 2010)
  Dipl.-Inform. Benjamin Ries (since October 2010)
  Dr. Alexander Skopalik (until August 2010)
  Dipl.-Inform. Melanie Winkler

- **Technical Staff**
  Math.-Techn. Ass. Viktor Keil

- **Student Researchers and Teaching Assistants**
  Nadine Bergner
  Viktor Engelmann
  Oliver Göbel
  Alexander Heinsius
  Benjamin Kaminski
  Simon Keller
  Wied Pakusa
  Thomas Schleiden
  Robert Schulte
  Andreas Tönnis
  Lisa Wagner
  Faried Abu Zaid
• **Guests**
  Petra Berenbrink (Simon Fraser University)
  Patrick Briest (Universität Paderborn)
  Michal Penn (Technion, Haifa)
  Maria Polukarov (University of Southampton)
Overview

Many technological innovations and achievements of the recent decades rely on algorithmic ideas facilitating new applications in science, medicine, production, logistics, traffic, and communication. Efficient algorithms do not only enable personal computers to execute the newest generation of games with features unthinkable only a few years ago, but they were also the key to several recent scientific breakthroughs. The algorithms and complexity group works on the design and analysis of algorithms, especially

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

During the last year, we successfully continued our work in algorithmic game theory and network algorithms. A special focus of this year's work was lying on scheduling and power assignment in wireless networks, focusing on realistic networks models defined by SINR constraints. We obtained several results on the approximation ratio achievable by different power assignments leading to new measures of efficiency and distributed algorithms. We were able to place results about SINR scheduling on major theoretical computer science and distributed computing conferences (e.g. SPAA, SODA, DISC). Together with other researchers working in this field, we organized two workshops on network algorithms and related areas:

- SWAT satellite workshop on Realistic Models for Algorithms in Wireless Networks (WRAWN), June 19 to 20, Bergen, Norway. The workshop was organized by Magnús M. Halldórsson (Reykjavik University) and Berthold Vöcking (RWTH Aachen University).
- Dagstuhl seminar on Flexible Network Design, May 24-28. The seminar was organized by Anupam Gupta (CMU Pittsburgh), Stefano Leonardi (Università di Roma "La Sapienza"), Berthold Vöcking (RWTH Aachen University), Roger Wattenhofer (ETH Zürich).

As a new research direction we studied learning algorithms for online buffering processes. We investigated how well-known no-regret learning algorithms like the Randomized Weighted Majority Algorithm can be adapted to processes in which the observed experts have states with the consequence that switching between experts comes at some cost. Our first article in this interesting research direction was accepted at COLT, the leading conference on theoretical aspects of machine learning and empirical inference.
Considerate Equilibrium
M. Hoefer, A. Skopalik, B. Vöcking

joint work with M. Penn (Technion, Haifa) and M. Polukarov (University of Southampton)
funded by the German Israeli Foundation (G.I.F.).

Game theory provides tools for the analysis of social interaction of self-motivated, rational agents. Rationality is usually captured in a way that agents are acting autonomously in order to maximize a utility function. This leads to much interest in the study of stable outcomes in games, making it the central topic in game theory. In strategic games the standard concept of stability is the Nash equilibrium - a state resilient to unilateral strategy changes of players. A drawback of Nash equilibrium is that it neglects coalitional deviations by groups of players; these are captured most prominently by the notion of strong equilibrium (SE) in which no coalition can strictly improve the utility of all participants, or even stronger concepts, such as super-strong equilibrium (SSE), where no coalition can deviate so that the utility of at least one participant strictly improves and for the others it does not get worse.

In contrast to the assumptions underlying SE and SSE, many real-life scenarios allow only certain subsets of players to cooperate because a group of players has to find a deviation, agree on it, and coordinate individual actions. This is impossible for a subset of players that are completely unrelated to each other. A promising recent approach for limited coalitional deviations was studied prominently in resource selection game. In this case, there is a given partition of the set of players such that only sets of the partition can implement coalitional deviations. The power of this restriction was demonstrated on the concept of SSE - a partition equilibrium is a SSE subject to coalitional deviations by player sets in the partition only.

The restriction of coalitional deviations in partition equilibrium essentially postulates two structural properties: (1) coalitions of players that execute a strategy change have to be close to each other, and (2) their decision must strictly benefit at least one of them but not strictly deteriorate any other player close to them. The notion of closeness is defined in both cases simply as being in the same partition.

In this project, we significantly strengthen the partition equilibrium concept by considering coalitional deviations and equilibria based a rich combinatorial structure derived from a social network among the players rather than just partitions. In our case, (1) coalitions of players that execute a strategy change must be cliques in the graph, and (2) their decision must not strictly deteriorate any neighboring players. We introduce and study the solution concept naturally corresponding to considerate behavior: considerate equilibrium i.e., a state in which (1) no coalition formed by a clique in the social network can deviate so that the utility of at least one member of the coalition strictly improves and (2) none of the players neighboring the clique gets worse. Our study is focused on the existence of this solution concept for classes of games dealing with resource allocation problems.
Dynamic Coordination in Large Networks

M. Hoefer, A. Skopalik
funded by DFG

In this project we develop distributed protocols and analyze the resulting dynamics for coordination problems in large networks. The goal is to derive a general understanding of distributed algorithms and dynamics in problems with rational agents and locality of computation and information.

In the previous year we most prominently analyzed aspects of cooperation of rational agents and the resulting stability and convergence properties. For the prominent class of congestion games, which are frequently used to model routing and load balancing scenarios, we showed hardness of strong equilibria - states resilient to deviations of arbitrary coalitions of agents - and other less stringent coalitional equilibrium concepts. Our hardness results concern deciding existence of equilibrium in a given game, recognizing a state as equilibrium, and computing an equilibrium if it exists. Many of these results hold even in seemingly special classes of games with simple network structure. For classes of load balancing games, however, computation and recognition are easy, and even fast convergence of iterative coalitional improvement can be shown. In addition, we considered a variant of congestion games, in which players care about bottleneck resources. For such games existence of strong equilibria is known. We characterized the computational complexity in terms of a general strategy packing problem, for which we can provide efficient algorithms in special cases. In the general case, however, we were able to provide a number of complementary hardness results. Finally, we treated adjusted variants of the concept of strong equilibrium in several ways, e.g., pairwise equilibria in social network contribution games, or a novel concept of considerate equilibrium in load balancing games.

For the coming year, we presently plan to treat rationality aspects in models related to frequency assignment and power control in wireless networks. The main challenge here is the design of simple and reliable distributed algorithms, which cope with local information, asymmetric interference relations and dynamically changing request structure.

Lifetime Problems in Networks with Uncertain Battery Capacities

M. Ochel, K. Radke, B. Vöcking

Network lifetime problems address an inherent restriction of most modern wireless networks: the limited energy capacity of the mobile participants. If we assume each network node having a battery as an energy source, we can define the lifetime of the network as the time until the first node runs out of energy.
Designing and analyzing communication protocols under the goal of maximizing network lifetime has become increasingly popular and many classical problems like broadcast, data gathering, or scheduling have been examined in this model. However, previous theoretical analyses assume perfect knowledge about ideal batteries with linear charge/discharge properties. Real-world battery characteristics (like e.g. rate capacity and recovery effects) are not taken into account.

In our model we allow for a greater versatility in battery characteristics by assuming only very limited knowledge about battery capacities. Every battery has a given maximum capacity, but when discharging a battery by one unit of energy it loses a variable amount of its capacity. This amount is allowed to change in an online fashion every time the battery is used. We are only given a bound on the allowed interval.

This project aims to design efficient algorithms that achieve best possible competitive ratios against a worst-case opponent. Although competitiveness in this online setting can be severely bounded from below, algorithms with non-trivial competitive ratios compared to the optimal offline algorithm are possible.

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**Competitive Buffer Management for QoS Switches**

_K. Al-Bawani_

*joint work with A. Souza (Humboldt University of Berlin)*

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In this project, we design and analyze online algorithms for the problem of buffer management in QoS networks. In this kind of networks, each data packet is guaranteed a level of service corresponding to its class of service (CoS). This concept of quality of service (QoS) is abstracted by attributing each packet with a non-negative value that represents its CoS, such that a higher value means higher priority of transmission.

We consider a basic model of a network switch that consists of multiple buffers (queues) and one output port. Packets, each with a certain value, arrive at the input ports of the switch, are temporarily stored in the queues, and are eventually extracted from the queues and sent out of the switch. Queues are of limited capacity, and packets are sent in the order of their arrival (FIFO). Furthermore, at each time step, only one packet can be transmitted through the output port. Consequently, in cases of congestion, queues may overflow and thus some arriving packets are lost. Our problem arises from the need to decide which packets to insert into the queues and which ones to drop, so that the total value of the transmitted packets (i.e., the throughput) is maximized. Moreover, at times of transmission, we would also like to decide which queue to serve.

Recently, we studied a variant of the multi-queue model based on the concept of class segregation: Given \( m \) packet values, the switch consists of \( m \) queues, such that each queue stores packets of only one value. We analyzed a natural greedy algorithm that accepts packets as long queues are not full, and always serves the non-empty queue of the highest packet value. We showed an upper bound of \( 2 \) on the approximation ratio of this algorithm, i.e., for any sequence of packets, the optimum throughput is at most \( 2 \) times the throughput of the greedy algorithm.
In this project we consider algorithm design problems in wireless networks. In the previous year, we concentrated on different variants of request scheduling problems in several models of interference, including the realistic physical model of interference. We studied an online variant of request scheduling, in which communication requests between sender/receiver pairs arrive online in a metric space. Interference is modeled via the physical model with SINR ratio. The task is to schedule incoming requests in a feasible way by accepting or rejecting a request and assigning a power and a channel to each accepted request directly upon arrival. The goal is to make decisions in a way to maximize the number of successful requests. Our main results are optimal deterministic online algorithms that yield approximation ratios based on the structure of link lengths, duration, and sending powers of the requests.

In addition, we started to consider variants of wireless request scheduling, in which each request is submitted by an independent user. Users have different valuations for their request being successfully scheduled on different sets of channels. The problem is to maximize the total utility of all players, i.e., to schedule a set of requests on the channels such that the total valuation of all users is maximized. For this problem we derived a general way to design approximation algorithms in a large variety of models of interference. The main tool is a non-standard graph-theoretic parameter, the inductive independence number, which has not received treatment in the context of wireless interference models before. When valuations are private information of the users, our algorithms can be adjusted by payments to motivate users to report their valuations truthfully and prevent manipulation of the outcome.

In today's large-scale networks such as the Internet no authority is capable of enforcing a centralized data management. In such environments game theory comes into play. We concentrate on the well-known game-theoretic traffic model due to Wardrop, which has been studied in the 1950's in the context of road traffic systems. In this model, traffic is modeled as flow. Given a network equipped with load-dependent latency functions on the edges, fixed flow demands need to be routed between source-destination pairs.

From a game-theoretic perspective, this establishes a game with infinitely many agents, each carrying an infinitesimal amount of traffic from its source to its destination. As each agents acts selfishly, it aims at minimizing its personal cost, which is defined to be the sum of the edge latencies on a path connecting its source with its destination. The social cost is defined
to be the total latency incurred by the flow. In this environment the notion of Wardrop equilibrium captures the idea of rational agent behavior: all paths used between a given source-destination pair have equal latency.

Independent selfish behavior may cause a higher cost at equilibrium than in socially optimal solutions. Addressing this issue, Roughgarden and Tardos showed that the worst-possible inefficiency of equilibria, called the price of anarchy, can be unbounded even in two link networks.

In our work, we study two different ways to reduce the price of anarchy. The most well-studied approach is known as taxing. A central result states that imposing marginal cost taxes on every edge induces the social optimum. We consider the more general case in which only a given subset of edges may be taxed. For this case, we give positive and negative results on the computational complexity of finding optimal taxes for different classes of networks.

We also propose a novel approach to improve the performance of selfish flow in networks by additionally routing flow. In contrast to most well-established concepts designed to deal with negative effects of selfish behavior, optimal utilization of additional flow is neither detrimental from an agents' perspective nor does it require centralized control over the network infrastructure or the agents. Focusing on the computational complexity for the optimal utilization of auxiliary flow we present strong inapproximability results.

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Mathematical Analysis of Resource Allocation on Cognitive Radio Networks

A. Fanghänel, T. Kesselheim, B. Vöcking in cooperation with Prof. Dr. Petri Mähönen,
MobNets

funded by DFG, UMIC Research Cluster in the Excellence Initiative, Research Area A.

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For communication in a wireless network it is vital that concurrent transmissions do not interfere. To avoid collisions, one can assign multiple channels or different time intervals to the communication requests.

In research dealing with this problem of scheduling in wireless networks there is often a large gap between different approaches. On the one hand theoretical computer scientists analyze algorithms considering only simple interference models. This tends to oversimplify the physical aspect that for example result from different transmission powers used. On the other hand, there were engineers studying heuristics under complex, yet realistic models. However, they do not derive general performance guarantees.

The project aims at bridging this gap. We use the so-called physical interference model that is popular among engineers. Applying techniques from analysis of algorithms allows us to prove that our algorithms calculate near-optimal solutions in arbitrary network topologies (that is, not only random or regular ones). Also in this year, we could contribute to understanding and solving the fundamental problems.

In particular, we presented a measure called maximum average affectance allowing us to easily estimate the number of channels/time slots that any algorithm needs at least to schedule some set of communication requests for a given power assignment. This allowed us to
analyze distributed protocols for the scheduling problem similar to the ones applied in practice.

Furthermore, one of the main open problems in this model has been to solve the combined scheduling and power control problem with a non-trivial worst-case performance. Due to the non-convexity of the constraints, common optimization techniques fail. We gave the first constant-factor approximation algorithm for this problem.

Economical Caching: Online Learning for Buffering Problems

S. Geulen, B. Vöcking, M. Winkler
funded by AlgoSyn.

In recent years the development of systems combining the advantages of two or more power sources efficiently was motivated by economical, ecological, and political progress. The main challenge in these systems is to manage the interaction between the different power sources in such a way that the advantages of both can be exploited and their disadvantages compensate each other. One example of such a system is a hybrid car which has two engines, one combustion engine operated with petrol, and one electrical engine using a battery. The control unit of the hybrid car has to manage the battery, i.e., it has to decide at which time the battery should be recharged by the combustion engine, and the torque distribution between the two engines provided that the battery is charged sufficiently.

One way to model this problem abstractly is by considering the economical caching problem. An online algorithm is given a sequence of prices and demands for some commodity. Furthermore, it has a buffer of fixed capacity. The algorithm's goal is to fulfill the demands in such a way that it minimizes the accumulated cost. For this purpose, it can buy the units at the current price, take previously bought units from the storage, or buy more units than needed at the current price and put the remaining units into the storage. In the context of hybrid cars, prices correspond to the combustion efficiency which, e.g., depends on the rotational speed.

A new research direction was motivated by online learning. Given a set of strategies, called experts, an online learning algorithm has to choose in each time step an expert whose decision it wants to follow, under the objective of achieving an accumulated cost nearly as high as that of the best expert chosen in hindsight. This quantity is called the regret. For the case of a finite set of experts, algorithms like the Randomized Weighted Majority and Follow the Perturbed Leader can be modified to work in the economical caching setting. For the case of an infinite set of experts, further research has to be done. A possible approach is given by the idea of online convex programming. Zinkevich proposed a gradient descent algorithm which can be applied in the standard problem. It is an open question whether this algorithm can be used in this more general problem.

There are several ways of building experts. Experts can be based on simple heuristics, e.g., engine operating maps, or complex models like Markov Decision Processes. For this reason, a cooperation with the Hybrid Systems Group and the Institute for Control Engineering is intended with the purpose of the construction of appropriate experts and the implementation of these experts together with an online learning algorithm in the control unit of a hybrid car.
Besides the research in the area of complexity and efficient algorithms two interesting and new approaches in field of cryptographic methods were investigated.

The first one involves the construction of symmetric encryption algorithms. The typically used algorithms iterate a fixed order of operations to ease the construction of cryptographic hardware and to speed up computation. The new approach replaces this fixed order by a key-generated operation and operand order. Two systems are under consideration. One is based on a key generated random graph, the other uses key generated permutations.

Cryptographic protocols are developed for a wide range of applications. But in practical application only few are used. The second approach tries to overcome this problem by developing a configuration driven framework for as many protocols as possible. The advantage of such a system are as follows. A fast and easy construction, modification and test of communication protocols becomes possible. Also the possible improved security is a second important advantage.

Furthermore, efficient algorithms and complexity results within the class NP were investigated. I.e. special TSP based scheduling problems were considered. In this type of problems one or more agents have to schedule a list of tasks on a TSP based round trip. For special cases we did develop efficient algorithms or did prove NP-completeness.
Other Activities

Courses
Our group offered the following lectures and seminars:

Winter semester 2009/10
• Lecture on Computability and Complexity Theory
• Lecture on Algorithmic Graph Theory
• Seminar on Dynamics and Learning in Networks
• Seminar on Efficient Algorithms for Special Problems
• Proseminar on Randomized Algorithms

Summer semester 2010
• Lecture on Network Algorithms
• Lecture on Algorithmic Cryptography
• Lecture on Algorithmic Game Theory
• Seminar on Algorithms for Graphs
• Proseminar on Randomized Algorithms

Berthold Vöckings scientific activities
• Co-Chair of the Steering Committee of the Symposium on Theoretical Aspects of Computer Science (STACS)
• Speaker of GI Fachausschuss Theoretische Informatik
• Member of the editorial board of ACM Transactions on Computation Theory (TOCT)
• Member of the program committee of 11th ACM Conference on Electronic Commerce (EC), Harvard University, Massachusetts, USA, June 7-11, 2010
• Member of the program committee of 5th International Computer Science Symposium in Russia (CSR), Kazan, Russia, June 16-20, 2010
• Member of the program committee of 6th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS), Santa Barbara, California, USA, June 21-23, 2010
• Member of the program committee of 6th International Workshop on Algorithms for Sensor Systems, Wireless Ad Hoc Networks and Autonomous Mobile Entities (ALGOSENSORS), Bordeaux, France, July 5, 2010
• Member of the program committee of 37th International Colloquium on Automata, Languages and Programming (ICALP), Track C, Bordeaux, France, July 5-10, 2010
• Member of the program committee of 3rd International Symposium on Algorithmic Game Theory (SAGT), Athens, Greece, October 18-20, 2010
• Co-Organizer of a Dagstuhl-Seminar on Flexible Network Design, Schloss Dagstuhl, Wadern, Germany, May 24-28, 2010
• Co-Organizer of the SWAT Satellite Workshop on Realistic Models for Algorithms in Wireless Networks, Bergen, Norway, June 19-20, 2010
Talks and Publications

Talks


Martin Hoefer: Distributed Load Balancing in Wireless Networks. ITG Fachgruppensitzung Angewandte Informationstheorie, Aachen, Germany, October 2009.


Martin Hoefer: Competitive Routing over Time. 5th Workshop on Internet and Network Economics (WINE), Rome, Italy, December 2009.


Martin Hoefer: Contribution Games in Social Networks. 18th Annual European Symposium on Algorithms (ESA), Liverpool, UK, September 2010.


Thomas Kesselheim: Distributed Contention Resolution in Wireless Networks. 24th International Symposium on Distributed Computing (DISC), Cambridge, USA, September 2010.

Alexander Skopalik: Doing Good with Spam is Hard. 2nd International Symposium on Algorithmic Game Theory (SAGT), Paphos, Cyprus, October 2009.


Melanie Winkler: Regret Minimization for Online Buffering Problems Using the Weighted Majority Algorithm. University of Bonn and Fraunhofer IAIS, Knowledge Discovery Group, Bonn, Germany, August 2010.

Publications


Staff

- **Group head**
  Prof. Dr. Peter Rossmanith

- **Secretary**
  Birgit Willms

- **Research Assistants**
  Dr. rer. nat. Joachim Kneis
  Dipl.-Inform. Alexander Langer
  Dr. rer. nat. Daniel Meister (until April 2010)
  Somnath Sikdar, Ph.D.

- **Student Assistants**
  Michael Nett
  Felix Reidl
  Fernando Sanchez Villaamil
Overview

Our teaching and research profile mainly consists of

- Efficient Algorithms
- Parameterized Algorithms
- Moderately Exponential Time Algorithms
- Structural Graph Theory
- Complexity Theory
- Formalizing Mathematics
- Analysis of Algorithms

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.

Research in the field of exact algorithms aims to improve the running time required to solve NP-hard problems, whether be it in practical applications or in its computational complexity. One method to tackle hard problems is to exploit structural properties of the underlying input instances. For instance, Courcelle's Theorem states that all problems that are definable in Monadic Second-Order logic (MSO) can be solved in linear time when the input is of bounded treewidth, a structural parameter originating in Robertson and Seymour's work on the famous Graph Minor Theorem. The techniques that are used in the proof of this theorem are however not always feasible in practice. One of our research projects therefore aims to obtain practical relevant algorithms for problems on graphs of bounded treewidth.

Treewidth is a measure for undirected graphs and does not respect the direction of edges. The question whether similar results to that of Courcelle's Theorem can be shown for directed graphs has attracted a lot of attention in recent years. Many new width measures have been appeared, e.g., directed treewidth, entanglement, DAG-width, Kelly-width as well as directed generalizations of clique-width and rank-width, to name a few. All of these have in common that certain hard problems become easy when the respective measure is bounded. Yet, these width measures do not seem to be as successful as treewidth. Aiming to find an explanation, we found that a directed width measure that is substantially different from treewidth either cannot be as powerful as treewidth, i.e., unless P=NP there either can't be a similar result to Courcelle's Theorem, or the width measure lacks important structural properties.
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.

In 1990, Courcelle showed that all problems definable in Monadic Second-Order logic can be solved in linear time on graphs of bounded treewidth. His important theorem (and its extension to Extended MSO) is the foundation for many further results, where an algorithm for an (E)MSO-definable problem, which by Courcelle's Theorem is known to exist, is used as a black box. Surprisingly, there still is no implementation of this important theoretical result available, although such an implementation would be useful for a broad range of decision and optimization problems.
The major goal of this project is to close this gap and implement algorithms for Courcelle's Theorem that can compete with specific algorithms for the respective problems. Due to the hardness and complexity of the underlying model-checking problem with non-elementary lower-bounds, a naive and straight-forward implementation will most probably not be of any practical relevance. Therefore, this task includes inventing new advanced techniques to circumvent the arising difficulties and obstacles.

Structural Graph Theory and Parameterized Complexity

Somnath Sikdar, Joachim Kneis, Peter Rossmanith

Funded by the DFG-GACR Bilateral Project Program, grant RO 927/9

Many real-world algorithmic problems turn out to be intractable in their full generality. Parameterized complexity, however, provides a useful framework for a refined analysis of such hard problems, and a new concept in designing algorithms that can solve hard problems for real-world instances efficiently. In contrast to heuristics, this approach provides guaranteed runtime bounds.

Graphs are combinatorial structures suitable for modeling many discrete decision and optimization problems. Structural graph theory has already proven very useful in parameterized algorithmics. For instance, most of the traditional hard problems are efficiently solvable on graphs of bounded tree-width.

In this project, we plan to exploit further structural properties of graphs like branch-width, DAG-width, rank-width, or their topological properties. Our goal is to find new application areas of structural graph theory in parameterized algorithm design.

Parameterized Algorithms & Property Testing

Joachim Kneis, Alexander Langer, Peter Rossmanith

Funded by the DFG-NSC Bilateral Project Program

In real world applications, we often have to deal with huge data sets quickly and often we want to decide whether a given data set has a certain property. In practice, it is often sufficient to know whether the data set probably has a given property, or that the data set is at least close to having this property. For optimization problems, we could use approximation algorithms for a quick estimate of the solution. However, properties, such as ‘Is the data set sorted?’, either hold or do not hold, and hence they cannot be approximated, since there is no approximation to a ‘yes’ or ‘no’ answer.

This has lead to the concept of property testing: A property testing algorithm should be very fast and answer ‘yes’ if the property holds, and should answer ‘no’ if the input is ‘far away’ from having the property. Ideally, such property testers might test instances in sublinear time.
or even constant time, and it might make sense to allow even polynomial time for harder
problems.
In this project, we want to study whether and how the concepts of property testing and
parameterized complexity theory can be fruitfully combined.
Other Activities

Courses
Our group offered the following lectures and seminars:

Winter 2009/2010
• Lecture on ‘Analysis of Algorithms’
• Lab Course on ‘Graphalgorithmen’

Summer 2010
• Lecture on ‘Effiziente Algorithmen’
• Seminar on ‘Property Testing’

Seminar on ‘Medizinische Bildverarbeitung’ (with Deserno, Kobbelt, Ney, Seidl, Spitzer)
Talks and Publications

Talks


Somnath Sikdar: *Are there any good digraph width measures?* TACO workshop on Treewidth and Combinatorial Optimization, RWTH Aachen University, Aachen, Germany, June 2010.

Alexander Langer: *Courcelle's Theorem - A Game-Theoretic Approach*. Workshop on Graph Decomposition: Theoretical, Algorithmic and Logical Aspects, CIRM, Luminy, Marseille, France, October 2010.

Publications


**Technical Reports**

Software Modeling and Verification

Staff

• Professors
  Prof. Dr. Ir. Joost-Pieter Katoen
  Prof. em. Dr. Klaus Indermark
  Prof. Dr. Erika Ábrahám
  http://moves.rwth-aachen.de/

• Secretary
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• Lecturer
  AOR Priv.-Doz. Dr. Thomas Noll

• Researchers
  Dr. Henrik Bohnenkamp
  Xin Chen, M.Sc.
  Dr. Tingting Han
  Dipl.-Inform. Jonathan Heinen
  Dipl.-Inform. Christina Jansen
  Dipl.-Inform. Nils Jansen
  Dipl.-Inform. Daniel Klink (until Apr. 2010)
  Dipl.-Inform. Ulrich Loup
  Dr. Etienne Lozes
  Alexandru Mereacre, M.Sc.
  Dipl.-Inform. Johanna Nellen
  Dipl.-Inform. Martin Neuhäußer (until Jan. 2010)
  Viet Yen Nguyen, M.Sc.
  Dipl.-Inform. Maximilian R. Odenbrett
  Arpit Sharma, M.Sc.
  Falak Sher, M.Sc.
  Dipl.-Inform. Sabrina von Styp
  Dipl.-Inform. Haidi Yue

• Technical Staff
  Arnd Gehrmann

• Diploma/Bachelor/Master Students
  M. Bretsch
  S. de Carolis
  F. Corzilius
  C. Dehnert
  F. Fiedler
  F. Gretz
D. Guck
S. Herting
C. Jansen
M. Kampschulte
J. Nellen
M. R. Odenbrett
P. Richter
J. Scherer
F. Sher
L. von Büttner
S. von Styp
S. Wu

• **Student Researchers**
  B. Bruetsch
  C. Dehnert
  F. Dulat
  D. Guck
  S. Junges
  J. Katelaan
  M. Prümmer
  M. Scheffler
  M. Van de veire

• **Visiting Scientists**
  Dr. Alessandro Abate (TU Delft, NL)
  Benoit Barbot (ENS Cachan, F)
  Prof. Dr. Franck van Breugel (York University, CND)
  Prof. Dr. Stephane Demri (ENS Cachan, F)
  Muhammad Fadlisyah (University of Oslo, N)
  Dr. Colas Le Guernic (Verimag)
  Dr. Michael Huth (Imperial College, UK)
  Marijn Jongerden (Uni Twente, NL)
  Daniela Lepri (University of Oslo, N)
  Dr. Larissa Meinicke (Macquarie University, AUS)
  Prof. Dr. Peter Csaba Ölveczky (University of Oslo, N)
  Prof. Dr. Martin Steffen (University of Oslo, N)
  Mark Timmer (Uni Twente, NL)
  Dr. Olga Tveretina (Karlsruhe University, D)
  Ralf Wimmer (Universität Freiburg, D)
  Jun.-Prof. Dr. Verena Wolf (Saarland University, D)
  Dr. Ivan Zapreev (CWI, NL)
Overview

The year twenty-ten has been full of activities. The COMPASS project, a joint effort with FBK (Trento, I), and Thales Alenia Space (Cannes, F), funded by the European Space Agency (ESA), has been successfully brought to an end. In April, an advanced toolset was completed supporting a rich plethora of analysis facilities for AADL models, e.g. model checking, fault tree analysis, and performability evaluation. Based on our results, ESA offered a project extension as well as the financial support for a PhD student (in their NPI programme). At the moment, several successors to COMPASS are considered by the ESA, indicating the relevance of this project.

Other worthwhile successes this year: a paper in the Communications of the ACM, Carsten Kern (former Ph.D student) received the Borchers Plakette from the RWTH Aachen University for his excellent dissertation, while Tingting Han (currently post-doctoral researcher at the chair) received the prize for the best dissertation in 2009 of the University of Twente! Besides, we received a top-cited award (over 2005-2010) for a paper in the journal Theoretical Computer Science.

New projects include an FP7 project on stochastic hybrid systems (with ETH Zurich, TU Delft, OFFIS Oldenburg, and Politecnico Milano). The challenge will be to join control theory, hybrid and probabilistic aspects. Other new projects include the exploitation of multi-core architectures for (probabilistic) model checking (with the University of Eindhoven) in the context of an NWO project. Continuing projects include the DFG-NWO project ROCKS, our participation in the research training group AlgoSyn and the DFG Excellence Cluster UMIC.

We were actively involved in the organisation of a special session at the ISOLA Symposium in October 2010, and co-organised a Spring School on Quantitative Model Checking, together with Kim G. Larsen (Aalborg, DK) in Copenhagen. The school attracted about 85 participants, the maximal capacity.

On the personnel side, several changes took place. Martin Neuhäußer and Daniel Klink successfully defended their Ph.D dissertation, and both left to industry. Six new Ph.D students started: Falak Sher, Arpit Sharma (thanks to an India4EU grant), Hongfei Fu (thanks to a CSC scholarship), Maximilian R. Odenbrett (who works in a joint project with the University of Eindhoven, NL), Sabrina von Styp (AlgoSyn), and Christina Jansen. Taolue Chen joined us as a guest researcher since August.

The embedded junior professorship "Theory of Hybrid Systems", led by Erika Ábrahám, has expanded its research activities in the last year.

The research area of the group covers modeling and analysis of hybrid systems, probabilistic systems in general and - by participation in the research training group AlgoSyn - the application of SMT-solving for real algebra in the synthesis and verification of hybrid systems.

The projects HySmart and CEBug started this year, furthermore the group participates in the ROCKS project.

The quality of the work is reflected in several publications. Several both national and international cooperations led to new promising approaches, e.g., by recent work together with the external PhD students Muhammad Fadlisyah and Daniela Lepri from the University of Oslo, co-supervised by Prof. Ábrahám.
The group is happy to welcome Johanna Nellen as a new research assistant. She will work in an interdisciplinary area in cooperation with the engineering department.

In addition to research, the group was very successful in co-organizing several events that aim at the motivation of interested pupils for the studies of computer science (Schüleruniversität, Ringvorlesung für Schüler, Girls' Day, Helle Köpfe). Details can be found at the corresponding section of the annual report.

Joost-Pieter Katoen.
Research Projects

Formal Models of Microcontroller Systems

Th. Noll, B. Schlich (i11), J. Brauer (i11)

Embedded systems usually operate in uncertain environments, giving rise to a high degree of nondeterminism in the corresponding formal models. Moreover they generally handle data spaces whose sizes grow with the memory and the word length of the respective microcontroller architectures. This, together with other effects, leads to the well-known state-space explosion problem, meaning that the models of those systems grow exponentially in size as the number of components increases. Careful handling of both nondeterminism and large data spaces is therefore crucial for obtaining efficient methods and 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 abstraction techniques to tackle this problem. The first step was to set up a general automata-based model for microcontrollers, taking into account both the hardware, the software, and the environment of the system. During the period under report, this model was used to approach the state-space explosion problem as follows.

In the first activity, we developed static analysis methods for approximating the possible runtime values of data values. For this purpose, intervals have successfully been used for decades. Binary code on microcontroller platforms, however, is different from high-level code in that data is frequently altered using bit-wise operations and that the results of operations often depend on the hardware configuration. We therefore came up with a method that combines word- and bit-level interval analysis and integrates a hardware model by means of abstract interpretation in order to handle these peculiarities.

QUPES: Verification of Quantitative Properties of Embedded Software

T. Han, J.-P. Katoen, M. Neuhäußer

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 spaces with millions of states using dedicated tools. Opposed to, amongst others, the essential feature of model checking, where evidences will be provided on a property refutation, counterexample 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.

Verifying Pointer Programs with Unbounded Heap Structures


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.

After considering (possibly cyclic) singly-linked list data structures, the approach was extended to analyze programs that handle more complex dynamic data structures. We developed a novel abstraction framework that is based on 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.
Two central issues in this context are correctness and efficiency. The first essentially boils down to the requirement that a nonterminal can always be concretized to the data structure from which it was abstracted. To ensure this property, we defined a novel normal form for hyperedge replacement grammars that is inspired by the well-known Greibach normal form for string grammars. Moreover, we developed an algorithm for constructing a normalized grammar from a given hyperedge replacement grammar with bounded degree.

With regard to efficiency, two ideas were followed. The first concentrates on analyzing the (backward) confluence properties of graph grammars, which guarantees the uniqueness of abstractions and thus avoids the need to inspect several possible abstractions. The second is to adopt learning techniques to automatically derive abstraction grammars for the data structures occurring in the given program. This circumvents the complex and error-prone procedure of developing grammars manually. The techniques were successfully applied to dynamic data structures such as doubly-linked lists, binary and ternary trees (also with connected leaves). In particular, after implementing a prototype tool it was possible to establish the termination, correctness, and completeness of the well-known Deutsch-Schorr-Waite traversal algorithm in a fully automatic way.

Correctness, Modeling and Performance of Aerospace Systems (COMPASS)

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)

In this project 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, timed and hybrid behavior, (probabilistic) faults and their propagation, error recovery and degraded modes of operation. This language is based on the Architecture Analysis and Design Language (AADL) and its Error Model 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 which are defined by their type (interface) and implementation. Components interact via ports allowing for both message-oriented 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 specified 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 rigorous analysis methods. The precise character of these techniques together with the formal semantics of SLIM 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 support, among others: automated derivation of dynamic (i.e., randomly timed) fault trees, Failure Modes and Effects Analysis (FMEA) tables, assessment of Fault Detection, Isolation, and Recovery (FDIR) measures, and observability requirements for effective diagnosability by FDIR.

The prototype of an integrated platform on top of state-of-the-art tools with an accompanying graphical user interface is available, and has been evaluated by Thales Alenia Space using several case studies involving critical on-board computer-based systems from the satellite domain. Another outcome of the project is an extension of AADL's Error Model Annex and the corresponding semantics.

Current activities concentrate on improving the applicability and efficiency of the toolset when analyzing systems that exhibit complex characteristics in terms of non-determinism, timed and hybrid behavior, and discrete and continuous-time probabilistic errors, see the following project. More information on COMPASS is available at http://compass.informatik.rwth-aachen.de/.
The achievement of mission objectives and ultimate mission success relies on the safety and dependability of the space systems. During their operational lifetime, they have to overcome software and hardware failures autonomously, as communications to deep-space systems have long latencies. For this reason, it is imperative that these autonomous (and complex) systems operate correctly.

The aim of this project is to build upon the experiences from the previously described COMPOSS project and overcome several limitations of the current approaches to dependability and performance analysis. The first goal is to develop novel and advanced analysis techniques to enlarge the supported classes of system models by considering continuous-time (error) behaviour and non-determinism. The second goal is to enhance existing and develop new techniques that exploit the hierarchical and component-oriented structure of system descriptions. The plan is to provide prototypical realization of the developed techniques and apply them to small to moderately sized case studies and evaluate their feasibility.

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 this 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.

The MoDeST Tool Environment
H. Bohnenkamp, H. Yue, J.-P. Katoen

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) aims to provide the means to analyse and evaluate MoDeST specifications. It is written in the C++ programming language. The tool provides (i) interfacing capabilities for connection to existing tools for specific projected models, and (ii) also means for enhancement by native algorithms for analysis of (classes) of MoDeST specifications. In earlier work, MoToR has been connected to Möbius, a performance evaluation tool suite that has been developed at the University of Illinois at Urbana-Champaign, US. The MoDeST/Möbius tandem is currently used and constantly improved in the Quasimodo project case studies.

Ultra High Speed Mobile Information and Communication
H. Yue, H. Bohnenkamp, J.-P. Katoen

The evaluation of the quality-of-service of Wireless Sensor Networks is mostly done by simulation. In the context of the Quasimodo and UMIC projects, and in cooperation with the company CHESS, Haarlem, NL, we evaluated a gossiping MAC protocol (GMAC), a TDMA protocol for completely unconfigured wireless networks, which aims to improve message dissemination by collision avoidance between wireless nodes.

The GMAC protocol is designed with a specific radio model in mind, the Unit Disk Graph (UDG) model. Simulations, carried out with the MoDeST/Möbius tool set, show that GMAC has indeed a beneficial influence on the dissemination speed of a wireless network. Yet, the UDG model is very simple, and we investigated the possibility that it is perhaps too simple.
For this purpose, we evaluated GMAC using another radio model, the SINR model of Gupta/Kumar, which intuitively seems to be more realistic. The results show that indeed GMAC performs much worse under the SINR model, and in fact we were able to show that the simple slotted ALOHA protocol, without any collision avoidance, can in some circumstances perform even better.

Our current research aims at gathering evidence that the SINR model is in fact realistic enough to allow the derivation of reliable measures for wireless sensor networks using simulation. For that we try to explain measurement data from CHESS by means of the SINR model.

**Invariant Generation for Probabilistic Programs**

F. Gretz, J.-P. Katoen, A. McIver (Macquarie Univ, Sydney), L. Meinicke (Macquarie Univ, Sydney), C. Morgan (UNSW, Sydney)

Verification of sequential programs rests typically on the pioneering work of Floyd, Hoare and Dijkstra in which annotations are associated with control points in the program. For probabilistic programs, quantitative annotations are needed to reason about probabilistic program correctness. We generalise the method of Floyd, Hoare and Dijkstra to probabilistic programs by making the annotations real- rather than Boolean-valued expressions in the program variables. The crucial annotations are those used for loops, the loop invariants. Thus in particular we focus on real-valued, quantitative invariants: they are random variables whose expected value is not decreased by iterations of the loop.

One way of finding annotations is to place them speculatively on the program, as parametrised formula containing only first-order unknowns, and then to use a constraint solver to search for parameter instantiations that would make the associated “verification conditions” true. In this project, we aim to generalize and extend constraint-solving techniques for invariant generation to probabilistic programs. This allows for the verification of probabilistic programs that cannot be treated with currently available automated techniques such as abstraction refinement together with model checking. This work includes theory development as well as prototypical tool development to illustrate the feasibility.

**Verification of Stochastic Hybrid Systems**

J.-P. Katoen, A. Mereacre, F. Sher

In the context of the EU FP7-project "Modeling, verification and control of complex systems: From foundations to power network applications" (partners: ETH Zurich, TU Delft, University of Oldenburg, Politecnico Milano, and Honeywell), we propose novel methods for modelling, analysis and control of complex, large scale systems. Fundamental research is motivated by applied problems in power networks. We adopt the framework of stochastic
hybrid systems (SHS), which allows one to capture the interaction between continuous
dynamics, discrete dynamics and probabilistic uncertainty. In the context of power networks,
SHS arise naturally: continuous dynamics model the evolution of voltages, frequencies, etc.
Discrete dynamics reflect changes in network topology, and probability represents the
uncertainty about power demand and (with the advent of renewables) power supply. More
generally, because of their versatility, SHS are recognized as an ideal framework for capturing
the intricacies of complex, large scale systems.

Motivated by this, considerable research effort has been devoted to the development of
modelling, analysis and control methods for SHS, in both computer science (giving rise to
theorem proving and model checking methods) and in control engineering (giving rise to
optimal control and randomized methods). Despite several success stories, however, none of
the methods currently available is powerful enough to deal with real life large scale
applications. We feel that a key reason for this is that the methods have been developed by
different communities in relative isolation, motivated by different applications. As a
consequence, synergies between them have never been fully explored.

In this project, we systematically explore such synergies. Our multi-disciplinary team, which
brings together experts on all the state of the art SHS methods, will establish links between
model checking, theorem proving, optimal control and randomized methods. Leveraging on
their complementary strengths we will develop combined strategies and tools to enable novel
applications to complex, large scale systems. Common power networks case studies will
provide a testing ground for the fundamental developments, motivate them, and keep them
focused.

**SYRUP: SYmbolic RedUction of Probabilistic Models**

J.-P. Katoen, M. Timmer, M. Stoelinga, J. van de Pol (all three from University of Twente,
NL).

Efficient model-checking algorithms exist for qualitative and quantitative properties for a
range of probabilistic models. Their popularity is due to the presence of powerful software
tools, and their wide applicability; security, distributed algorithms, systems biology,
dependability and performance analysis, to mention a few. The main deficiencies of
probabilistic model checking are the state explosion problem and the restricted treatment of
data.

The state space grows exponentially in the size of system components and data domains. Whereas most abstraction techniques obtain smaller models by collapsing sets of concrete
states at the model level, this project takes a radically different approach. We will develop and
implement symbolic reduction techniques for probabilistic models. These techniques aim to
reduce models by model transformations at the language level in order to minimize state
spaces prior to their generation while preserving functional and quantitative properties. Our
symbolic reductions will support data as first-class citizens, i.e., we will develop techniques to
symbolically reduce formalisms for modeling probabilistic systems that are equipped with
rich data types, allowing, e.g., probabilistic choices parameterized with data.
Our approach is based on successful symbolic transformation techniques in the traditional and
timed setting, viz. linear process equations (LPEs). We will generalize and extend these
techniques to probabilistic automata (PA), a model akin to Markov Decision Processes that is
tailored to compositional modeling. The LPE technique is applicable to large or even infinite
systems, and will be equipped with symbolic transformations such as confluence reduction,
bisimulation minimization and static analysis for PA.

Computing maximum reachability probabilities in Markovian Timed Automata

T. Han, A. Mereacre, J.-P. Katoen

We investigate a stochastic extension of timed automata, called Markovian timed automata
(MTA). For this model, we study the problem of optimizing reachability probabilities. Two
variants are considered: time-bounded and unbounded reachability. For each case, we propose
Bellman equations to characterize the reachability probability. For the former, we provide two
approaches to solve the Bellman equations, namely, a discretization and a reduction to
Hamilton-Jacobi-Bellman partial differential equations, which can be solved by discretization.
For the latter, we show that in the single-clock case, the problem can be reduced to solving a
system of linear equations, whose coefficients are time-bounded reachability probabilities in
continuous-time Markov decision processes (CTMDPs).

Testing of Systems with Time and Data

S. von Styp, H. Bohnenkamp, J.-P. Katoen

Testing is one of the most important methods to verify the correctness of software. Nevertheless, testing manually is time consuming and expensive. Therefore model based
testing, which automatically generates test cases from a given formal model, has been
developed. In model based testing the specification is given by a transition system. A
conformance relation formally defines under which circumstances an implementation is
correct with respect to the specification. Based on this relation test-cases are derived
automatically and are used for testing the real implementation.

The goal of this project is to extend the existing test theory to allow real-time behaviour
together with data-dependent control flow. We start by giving a formal definition in form of a
transition system for representing systems that allow data-dependent control flow for inputs
and outputs and real-time behaviour. Afterwards a symbolic trace semantic is defined. This
semantic then is needed to define the conformance relation, which describes under which
conditions an implementation is correct with respect to a given specification. Future steps will
include to look at applications such as on the fly testing. This then shall be implemented in the
test tool JTorX.
In Process Control Engineering controllers for plants that are not correct with respect to their specification can cause fatal disasters, e.g. when tanks with acid run over, people get injured or high pressure can lead to explosions. Therefore an intensive testing of the controller is crucial but it consumes a lot of time and money. The specification of such controllers is usually formally given by sequential function charts.

This project is a cooperation with the Institute for Process Control Engineering and its aim is to apply the methods of model based testing on the plant controller in order to reduce costs, time and therefore to automate and systematise the testing process. The specifications are given as sequential function charts, which are translated to transition systems. We will start testing using simple controllers, e.g. a motor controller, which allows us to use already existing theories such as ioco and tioco including the testing tool JTorX. Data-dependent control flow is an important feature of the plant controllers, e.g. the next action depends on the current filling level of a tank. The same holds for real-time behaviour. It is crucial that certain actions are executed within a certain time. In order to be able to consider these characteristics it is planned to use the results from the project "Testing of Systems with Time and Data" and finally to test controllers for whole plants.

Hybrid systems are a powerful model describing a discrete controller in a continuous, real-world setting. Thus it often applies in the context of AlgoSyn where control and process engineering are involved. Formal verification of certain properties of hybrid systems is already an ambitious task, but going one step further, the work of AlgoSyn aims at synthesis of hybrid systems, i.e., synthesis of controllers for real-world settings.

In both synthesis and the more modest approach of verification, highly tuned solvers for systems of equations and inequations over the real numbers are needed in order to cope with practical problems. In case such systems involve nonlinear equations and inequations, the verification or synthesis problem quickly becomes undecidable and only very few solvers can deal with still decidable fragments by exact arithmetic. Such a decidable fragment is real algebra, i.e., polynomial arithmetic over the real numbers.

The goal of this research project is to adapt two procedures for solving systems of real algebraic equations and inequations, known from prominent results on decidability of the first order theory of real algebra, to work in a modern satisfiability-modulo-theories (SMT) solver: 1. the virtual substitution method (VS) and 2. the cylindrical algebraic decomposition method.
(CAD). We already succeeded in creating a prototypic implementation of an SMT-solver based on the first method. Since VS is restricted to low-degree polynomials we also want to integrate CAD which comes without degree restrictions. Since CAD is a very complex standalone procedure unaware of any features needed in the SMT-context, its modification is still a challenging aspect of this project. First little improvements on the theoretical basis were developed and are currently being implemented for testing.

### CEBug


For the correction of erroneous systems it is crucial to have counter examples at hand. Counterexamples are system runs which lead to erroneous behavior. Previous research on the analysis of stochastic systems concentrated on the computation of the probability with which runs of a stochastic system satisfy a given property. If this probability does not lie within the admissible bounds, the available model checking algorithms provide the probability value, but no counterexample. First steps towards counterexample generation for stochastic systems consider discrete-time Markov chains, a relatively simple class of stochastic systems. The goal of this project is, on the one hand, to improve the available technologies for counterexample generation and, on the other hand, to develop and implement algorithms for more expressive properties and for richer classes of systems. We are going to demonstrate the practical applicability of our algorithms on a set of benchmarks.

### HySmart

E. Ábrahám, J. Giesl, C. Fuhs, N. Jansen, P. Csaba Ölveczky, M. Steffen, M. Fadlisyah, D. Lepri (last four from University of Oslo)

The aim of this project is to bring together researchers from the field of rewriting techniques on the one hand, and hybrid systems on the other hand, to develop new rewriting-based techniques for the modeling and analysis of advanced real-time and hybrid systems beyond the reach of existing formal tools.

The functionality of many modern advanced computer systems – such as medical devices, control systems, embedded automotive and avionics systems, Internet protocols, etc. – is crucially dependent on the amount of time that passes during or between events. Such real-time systems are often critical systems that must be well understood before deployment. The use of formal methods in the early stages of the system development process has been advocated in order to arrive at a precise yet high-level mathematical model of the design of a complex system. The formal model can then be subjected to different kinds of mathematical analysis – preferably machine-assisted or entirely automated – to find errors in the design
and/or to prove the design correct. Advanced real-time computer systems pose a challenge to modeling formalisms, in that different aspects, such as, e.g., real-time and probabilistic behavior, advanced communication and interaction features, complex and unbounded data types, etc., must be captured. The most popular formal tools for real-time systems (UPPAAL, Kronos, and HyTech) are based on timed or hybrid automata. While the restrictive specification formalism of these tools ensures that interesting properties are decidable, they do not support well the specification of larger systems with different communication models and advanced object-oriented features.

In joint work with José Meseguer at the University of Illinois, Ölveczky has developed the Real-Time Maude formalism and analysis tool. Real-Time Maude can be seen as complementing timed automaton-based formal tools by emphasizing ease and generality of specification, including support for distributed real-time object-based systems. As mentioned below, Real-Time Maude has been successfully applied to a wide range of complex state-of-the-art systems that cannot be modeled using the standard formal real-time tools.

**Verification of hybrid systems based on reachability analysis**

*E. Ábrahám, X. Chen, S. Junges*

Since the reachability problem for hybrid systems is not decidable, we overapproximate the exact reachable sets in the property verification work. A significant task is to compare the current overapproximation representations. Since different representations are adapted at different cases, combining them in reasonable ways can handle a wide class of systems, and improvements can be derived from such comparison.

Controller synthesis for hybrid systems. Given a hybrid system, we compute or approximate the least restrictive controller for it such that the safety of the combined system (the hybrid system and its controller) is guaranteed. The task normally is carried out by a procedure of backward analysis with underapproximation methods, and we also need to consider the case that the hybrid system is partially observable.
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 FORMATS (Formal Methods and Analysis of Timed Systems)
- Member of the Steering Committee of QEST (Quantitative Evaluation of Systems).
- Member of the Steering Committee of ERCIM Working Group MQLA
- Board Member of the Dutch Society on Theoretical Computer Science (NVTI)
- Senior member of the Association of Computing Machinery (ACM)
- Member of the IFIP Working Group 1.8 on Concurrency Theory
- Member of the EPSRC Review College (Engineering and Physical Sciences Research Council), UK
- Co-organiser of the PhD School on Quantitative Model Checking, Copenhagen (DK)
- Member of several external PhD committees.

Member of the Program Committee of the following events:

- Messung, Modellierung und Bewertung (MMB)
- Tools and Algorithms for the Construction and Analysis of Systems (TACAS)
- Reachability Problems (RP)
- Quantitative Evaluation of Systems (QEST)
- Modeling and Verification of Parallel Processes (MOVEP)
- Numerical Solution of Markov Chains (NSMC)
- International Verification Workshop (Verify)
- Workshop on Quantitative Stochastic Models in the Verification and Design of Software Systems (QUOVADIS)
- Workshop on Tool Building in Formal Methods (TBFM)
- Symposium On Leveraging Applications of Formal Methods, Verification and Validation (ISOLA)

Invited speaker at:

- Verification, Model Checking, and Abstract Interpretation (VMCAI)
- IFIP WG 2.2 on Programming Concepts and Methodology
- Formal Methods for Components and Objects (FMCO)
- Formal Methods Week (FMWEEK)
- Modeling and Verification of Parallel Processes (MOVEP)
- 3rd Interaction and Concurrency Experience (ICE)
- Workshop on Modeling and Logics for Quantitative Analysis (MLQA)
Erika Ábrahám:
- Program committee member of the 1st International Workshop on Rewriting Techniques for Real-Time System (RTRTS)
- Program committee member of the 4th IEEE International Symposium on Theoretical Aspects of Software Engineering (TASE)
- Member of the CS Commission for School and Pupils
- Member of the CS Commission Honor Class
- Member of the CS Commission Bundeswettbewerb Informatik
- Speaker of the RWTH young scientists' group AixCYR
- Member of the Commission Gender Activities in the Graduate Research Schools

Co-organization of:
- Schüleruniversität
- Ringvorlesung Informatik
- Grünenthal Bionik Wettbewerb
- Die hellen Köpfe der Informatik
- Projekt Cybermentor
- Girls' Day

Thomas Noll:
- Program committee member of the 4th International Workshop on Harnessing Theories for Tool Support in Software (TTSS 2010)
- Program committee member of the 5th International Workshop on Systems Software Verification (SSV 2010)
- Program committee member of the 1st International Workshop on Rewriting Techniques for Real-Time System (RTRTS 2010)
- Program committee member of the 4th IEEE International Conference on Secure System Integration and Reliability Improvement (SSIRI 2010)
- Program committee member of the 8th International Workshop on Rewriting Logic and its Applications (ETAPS/WRLA 2010)
- Program committee member of the Software Engineering Track at the 25th Annual ACM Symposium on Applied Computing (SAC 2010)
- Member of the examination boards for CS Bachelor and Master (until April 2010)
- Student advisor for the following applied subjects within CS: Electrical Engineering, Civil Engineering, and Medicine
- Member of CS Commission for Teaching Service
Talks and Publications

Talks


Publications


Technical Reports


Programming Languages and Verification

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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 SAT solving, evaluation strategies, modularity aspects of programs, and formal specification languages.

In the winter term 2009/10, we held the lecture on *Functional Programming*, a seminar on *Verification Techniques*, and a seminar on *Satisfiability Checking* (together with the group of Prof. Dr. E. Ábrahám). In the summer term 2010, we gave the first-year course on *Formal Systems, Automata, Processes*, a seminar on *Automated Termination Analysis*, and a proseminar on *Advanced Programming Concepts in Java, Haskell, and Prolog*.

In March and April 2010, two new Ph.D. students joined our group: Thomas Ströder and Marc Brockschmidt. In November 2009, the Ph.D. thesis of Peter Schneider-Kamp was awarded with the *Friedrich-Wilhelm-Preis* for outstanding scientific contributions. He had completed his thesis in our group in December 2008 and since January 2009, he is assistant professor at the University of Southern Denmark.
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 techniques 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/
Termination Analysis for Logic and Functional Programs

J. Giesl, P. Schneider-Kamp, T. Ströder, R. Thiemann, A. Serebrenik, D. De Schreye, S. Swiderski, M. Raffelsieper, F. Emmes

This project is a cooperation with the TU Eindhoven (The Netherlands) and the KU Leuven (Belgium), funded by the DFG and the FWO. Techniques for automated termination analysis have mainly been developed for term rewriting and for definite logic programming. Our goal is to adapt these techniques such that they can be used for “real” logic and functional languages. This includes the handling of “non-logical” features such as cuts in languages like Prolog and the handling of lazy evaluation strategies and higher-order functions in languages like Haskell. To this end, we work on new approaches to transform logic and functional programs into term rewrite systems such that termination of the resulting term rewrite system implies termination of the original program. Then all existing techniques and systems for termination analysis of term rewriting can also be used to verify termination of logic and functional programs. At the same time, we also develop techniques and tools to incorporate ideas from term rewriting into techniques and termination tools that operate directly on logic and functional programs.

Satisfiability Checking for Termination Analysis and Program Synthesis

J. Giesl, C. Fuhs, M. Codish, P. Schneider-Kamp, Y. Fekete, R. Thiemann, A. Middeldorp, H. Zankl

This project is partially funded by the GIF and is a collaboration with the Ben-Gurion University (Israel), the University of Innsbruck (Austria), and the University of Southern Denmark. 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, polynomial orders, and the size-change principle. Moreover, we also investigate the use of our approaches to SAT encoding in order to synthesize and minimize Boolean programs in the form of digital circuits.
Termination Analysis for Imperative Programs

J. Giesl, C. Otto, M. Brockschmidt, M. Plücker, C. von Essen, T. Ströder, S. Falke

The goal of this project (funded by the DFG) is to use a similar approach as for logic and functional languages also for the termination analysis of imperative object-oriented languages like Java. In our approach, Java Bytecode programs are first transformed into so-called termination graphs by symbolic evaluation. These graphs take care of all aspects of the language that cannot easily be expressed by term rewriting (e.g., side effects due to aliasing, pointers, object-orientation, etc.). Afterwards, one generates term rewrite systems from the termination graphs whose termination can be analyzed by existing techniques and tools. To handle pre-defined data structures like integers, here we regard a special variant called integer term rewriting, where integers and their operations are pre-defined. Moreover, we also investigate how to use termination graphs for other program analyses besides termination analysis. Finally, in collaboration with the Karlsruhe Institute of Technology, we also work on an extension of our approach to languages like C which feature operations for direct heap manipulation and pointer arithmetic.

Strategies for Termination Analysis

J. Giesl, F. Emmes, C. Fuhs, M. Plücker, Y. Fekete, M. Codish

Typically, a termination prover offers a large number of different termination techniques. In order to increase its power and efficiency, the question is when to apply which of these techniques. While appropriate such strategies were developed manually up to now, in our project with the Ben-Gurion University, we examine the use of machine learning techniques in order to synthesize successful sophisticated strategies automatically.

Certified Termination Proofs

J. Giesl, C. Fuhs, A. Krauss, R. Thiemann, C. Sternagel

Complex systems like automated termination provers typically contain bugs. To increase the reliability of automatically generated proofs, it is desirable to certify them by a well-known theorem prover. In this project with the TU Munich and the University of Innsbruck, we try to couple existing termination provers like AProVE with the popular theorem prover Isabelle such that termination of Isabelle functions can be proved by AProVE and the obtained proofs are automatically certified by Isabelle afterwards.
Together with the TU Munich, our aim is to adapt the successful techniques developed for automated termination analysis in order to analyze the complexity of term rewrite systems automatically. This is a promising approach, since usually the termination proof allows us to draw conclusions on the maximal runtime of a program. While we will start with developing suitable analysis techniques for term rewrite systems, our aim is to extend automated complexity analysis to several different programming languages afterwards.
Other Activities

J. Giesl:
• Co-organizer and participant of the Dagstuhl-Seminar on *Interaction versus Automation: The two Faces of Deduction*, October 2009
• Research visit to the University of Réunion, France, October 2009
• Participant of the TeReSe Workshops in Utrecht (November 2009) and Aachen (May 2010)
• Participant of the *AlgoSyn Meeting*, Rolduc, The Netherlands, March 2010
• Invited speaker at the 9th *International Key Symposium*, Germsbach, Germany, May 2010
• Research visit to the Free University Amsterdam, The Netherlands, June 2010
• Chair of the *IFIP Working Group 1.6* on Term Rewriting and organizer of the WG 1.6 meeting, Edinburgh, UK, July 2010
• Participant of the 21st *International Conference on Rewriting Techniques and Applications (RTA '10)*, Edinburgh, UK, July 2010
• Participant of the 11th *International Workshop on Termination (WST '10)*, Edinburgh, UK, July 2010
• Program co-chair and participant of the 5th *International Joint Conference on Automated Reasoning (IJCAR '10)*, Edinburgh, UK, July 2010
• Research visit to the Max-Planck Institut für Informatik, Saarbrücken, Germany, July 2010
• PC-Member of the 16th *International Conference on Logic for Programming, Artificial Intelligence, and Reasoning (LPAR '10)*, Dakar, Senegal, 2010
• Member of the Steering Committee of the *Federated Logic Conference (FLoC)*
• Member of the Board of Trustees of the *International Conference on Automated Deduction (CADE)*
• Member of the Steering Committee of the *International School on Rewriting (ISR)*
• Member of the Steering Committee of the *Annual Termination Competition*
• Editor of a special issue of the KI journal on *Automated Deduction*, 2010
• Reviewer for the Ph.D. theses of Jörg Endrullis (Free University Amsterdam, The Netherlands) and Matthias Horbach (Max-Planck Institut für Informatik, Saarbrücken, Germany)
• Reviewer for the habilitation thesis of Étienne Payet (University of Réunion, France)
• Project reviewer for the DFG (several projects), the FWF, the ISF, and the Academy of Finland
• Reviewer for many international journals and conferences

M. Brockschmidt:
• Participant of the TeReSe Workshop, Aachen, May 2010
• Participant of the Workshop on Logics for Component Configuration (LoCoCo '10), Edinburgh, UK, July 2010
• Participant of the 21st International Conference on Rewriting Techniques and Applications (RTA '10), Edinburgh, UK, July 2010
• Participant of the 11th International Workshop on Termination (WST '10), Edinburgh, UK, July 2010
• Reviewer for international conferences

F. Emmes:
• Participant of the TeReSe Workshops in Utrecht (November 2009) and Aachen (May 2010)
• Reviewer for many international journals and conferences

C. Fuhs:
• Proceedings editor and participant of the Dagstuhl-Seminar on Interaction versus Automation: The two Faces of Deduction, October 2009
• Participant of the Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Jacobs University Bremen, Germany, October 2009
• Research visit at the University of Innsbruck, Austria, October-November 2009
• Participant of the TeReSe Workshop in Utrecht, The Netherlands, November 2009
• Research visit at the University of Southern Denmark, Odense, Denmark, February 2010
• Research visit (funded by GIF) at the Ben-Gurion University, Beer-Sheva, Israel, March 2010
• Organizer and participant of the TeReSe Workshop in Aachen (May 2010)
• Research visit at the University of Southern Denmark, Odense, Denmark, June 2010
• Participant of the Workshop on Pragmatics of SAT (POS '10), Edinburgh, UK, July 2010
• Participant of the 13th International Conference on Theory and Applications of Satisfiability Testing (SAT '10), Edinburgh, UK, July 2010
• Participant of the 11th International Workshop on Termination (WST '10), Edinburgh, UK, July 2010
• Participant of the 5th International Joint Conference on Automated Reasoning (IJCAR '10), Edinburgh, UK, July 2010
• Participant of the Workshop on Synthesis, Verification, and Analysis of Rich Models (SVARM '10), Edinburgh, UK, July 2010
• Participant of the Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Karlsruhe Institute of Technology, Germany, September 2010
• Editor of the Department of Computer Science Technical Reports of RWTH Aachen
• Reviewer for many international journals and conferences
C. Otto:
• Participant of the TeReSe Workshops in Utrecht (November 2009) and Aachen (May 2010)
• Participant of the 21st International Conference on Rewriting Techniques and Applications (RTA ’10), Edinburgh, UK, July 2010
• Participant of the 11th International Workshop on Termination (WST ’10), Edinburgh, UK, July 2010
• Reviewer for many international journals and conferences

M. Plücker:
• Participant of the TeReSe Workshops in Utrecht (Nov. 2009) and Aachen (May 2010)

T. Ströder:
• Research visit at the University of Southern Denmark, Odense, Denmark, November 2009
• Research visit at the University of Southern Denmark, Odense, Denmark, March 2010
• Participant of the AlgoSyn Meeting, Rolduc, The Netherlands, March 2010
• Organizer and participant of the TeReSe Workshop in Aachen, May 2010
• Research visit at the University of Southern Denmark, Odense, Denmark, June 2010
• Participant of the 6th International Workshop on Developments in Computational Models (DCM ’10), Edinburgh, UK, July 2010
• Participant of the 21st International Conference on Rewriting Techniques and Applications (RTA ’10), Edinburgh, UK, July 2010
• Participant of the 11th International Workshop on Termination (WST ’10), Edinburgh, UK, July 2010
• Participant of the 26th International Conference on Logic Programming (ICLP ’10), Edinburgh, UK, July 2010
• Participant of the 25th International Conference on Logic Programming (ICLP ’10), Edinburgh, UK, July 2010
• Participant of the 6th International Verification Workshop (VERIFY ’10), Edinburgh, UK, July 2010
• Participant of the 20th International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR ’10), Hagenberg, Austria, July 2010
• Research visit at the University of Innsbruck, Austria, July 2010
• Research visit at the Karlsruhe Institute of Technology, September 2010
• Participant of the Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Karlsruhe Institute of Technology, Germany, September 2010
• Reviewer for international conferences
Talks and Publications

Talks

C. Fuhs: *Inductive Theorem Proving meets Dependency Pairs*, Dagstuhl-Seminar on Interaction versus Automation: The two Faces of Deduction, Dagstuhl, Germany, October 2009

C. Fuhs: *SAT for Termination*, Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Jacobs University Bremen, Germany, October 2009

C. Otto: *Programmiersprachen und Verifikation*, RWTH Aachen, October 2009

T. Ströder: *Realizing Deterministic Behavior from Multiple Non-Deterministic Behaviors*, University of Southern Denmark, Odense, Denmark, November 2009

C. Fuhs: *Termination Analysis by Dependency Pairs and Inductive Theorem Proving*, TeReSe Workshop, Utrecht, The Netherlands, November 2009

C. Otto: *One Minute Madness*, Tag der Informatik, RWTH Aachen, December 2009


S. Weise: *Outermost-Terminierung von Termersetzungssystemen*, Lehrstuhlseminar, RWTH Aachen, März 2010

T. Ströder: *Towards Termination Analysis of Real Prolog Programs*, Lehrstuhlseminar, RWTH Aachen, April 2010

M. Brockschmidt: *The Finite Interpretation Graph: A Versatile Source for Automated Termination Analysis of Java Bytecode*, Lehrstuhlseminar, RWTH Aachen, April 2010

C. von Essen: *Automated Termination Analysis of Java Bytecode: From the Finite Interpretation Graph to Term Rewriting*, Lehrstuhlseminar, RWTH Aachen, April 2010

J. Giesl: *Programmiersprachen und Verifikation*, Ringvorlesung für Oberstufenschülerinnen und –schüler, RWTH Aachen, April 2010

J. Giesl: *Automated Termination Analysis of Java Bytecode by Term Rewriting*, 9th International KeY Symposium, Gernsbach, Germany, May 2010

A. Kelle-Emden: *Parallelizing Automated Termination Analysis*, Lehrstuhlseminar, RWTH Aachen, May 2010

L. Noschinski: *Automated Complexity Analysis of Term Rewrite Systems*, Lehrstuhlseminar, RWTH Aachen, May 2010

F. Emmes: *Dependency Pairs for Complexity Analysis Revisited*, TeReSe Workshop, Aachen, Germany, May 2010

J. Giesl: *Automated Termination Analysis of Java Bytecode by Term Rewriting*, Free University Amsterdam, The Netherlands, June 2010

C. Otto: *Automated Termination Analysis of Java Bytecode by Term Rewriting*, Lehrstuhlseminar, RWTH Aachen, July 2010
C. Fuhs: *Lazy Abstraction for Size-Change Termination*, Lehrstuhlseminar, RWTH Aachen, July 2010

T. Ströder: *Automated Termination Analysis for Logic Programs with Cut*, Lehrstuhlseminar, RWTH Aachen, July 2010

T. Ströder: *Dependency Triples for Improving Termination Analysis of Logic Programs with Cut*, Lehrstuhlseminar, RWTH Aachen, July 2010

C. Otto: *Automated Termination Analysis of Java Bytecode by Term Rewriting*, 21st International Conference on Rewriting Techniques and Applications (RTA ’10), Edinburgh, UK, July 2010

C. Fuhs: *Synthesizing Shortest Linear Straight-Line Programs over GF(2) using SAT*, 13th International Conference on Theory and Applications of Satisfiability Testing (SAT ’10), Edinburgh, UK, July 2010

T. Ströder: *Termination Analysis of Logic Programs with Cut using Dependency Triples*, 11th International Workshop on Termination (WST ’10), Edinburgh, UK, July 2010

C. Fuhs: *Lazy Abstraction for Size-Change Termination*, 11th International Workshop on Termination (WST ’10), Edinburgh, UK, July 2010

C. Fuhs: *Bit-Blasting for SMT-NIA with AProVE*, 8th International Workshop on Satisfiability Modulo Theories (SMT ’10), Edinburgh, UK, July 2010

T. Ströder: *Termination Analysis of Logic Programs with Cut*, 26th International Conference on Logic Programming (ICLP ’10), Edinburgh, UK, July 2010

T. Ströder: *Dependency Triples for Improving Termination Analysis of Logic Programs with Cut*, 20th International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR ’10), Hagenberg, Austria, July 2010

T. Ströder: *Termination Analysis of Logic Programs with Cut*, University of Innsbruck, Austria, July 2010

J. Giesl: *Automated Termination Analysis of Java Bytecode by Term Rewriting*, Max-Planck Institut für Informatik, Saarbrücken, Germany, July 2010

T. Ströder: *Program Synthesis for Termination Analysis*, AlgoSyn, RWTH Aachen, September 2010

C. Fuhs: *Synthesizing Shortest Linear Straight-Line Programs over GF(2) using SAT*, AlgoSyn, RWTH Aachen, September 2010

T. Ströder: *Realizing Deterministic Behavior from Multiple Non-Deterministic Behaviors*, Karlsruhe Institute of Technology, Germany, September 2010

T. Ströder: *Termination Graphs for Real Programming Languages*, Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Karlsruhe Institute of Technology, Germany, Sept. 2010

C. Fuhs: *Synthesizing Shortest Linear Straight-Line Programs over GF(2) using SAT*, Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, Karlsruhe Institute of Technology, Germany, September 2010

T. Enger: *Detecting Non-Termination of Non-Looping Term Rewrite Systems*, Lehrstuhlseminar, RWTH Aachen, September 2010

F. Kürten: *Automated Analysis of Side Effects in Java Bytecode*, Lehrstuhlseminar, RWTH Aachen, September 2010
Publications:

Journals and Conferences


**Workshops**


**Technical Reports**


**Theses**


Software Engineering

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  - Dipl.-Inform. T. Heer
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  - Dipl.-Inform. R. Hildebrandt (since August 2010)
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  - Dr. rer. nat. A.-T. Körtgen
  - Dipl.-Inform. T. Kurpick (BMBF funded)
  - Dipl.-Inform. M. Look (since May 2010)
  - Dipl.-Inform. C. Mengi (DFG funded)
  - Dipl.-Inform. A. Navarro Pérez
  - Dipl.-Inform. C. Pinkernell (BMBF funded)
  - Dipl.-Wirt.-Inform. H. Rendel
  - Dr. rer. nat. D. Retkowitz (until January 2010)
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  - Dipl.-Inform. M. Schindler (EU funded)
  - Dipl.-Inform. S. Völkel (EU funded)
  - Dipl.-Inform. I. Weisemöller (EU funded)
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  Dipl.-Wirt.-Inf. D. Reiss
  Dr. A. Schleicher
  Dipl.-Ing. F. Schroven
  Dipl.-Inform. M. Stein
  Dipl.-Inform. A. Zechner

• **Guest Researcher:**
  Dr. S. Maoz
  K. Chatterjee, MA of Sience

• **Technical Staff:**
  MATA M. Breuer (part time 50%)
  Dipl.-Math. (RUS) G. Volkova
  M. Tran, Trainee MATSE
  F. Leppers, Trainee MATSE
  M. Uzunov, Trainee MATSE

• **Student Researchers:**
Overview

In our second academic year with Bernhard Rumpe as Chair of the Software Engineering Group, we had been able to professionalize and systematize the organisational issues, such that much smoother, yet still lean processes could be established. On the one hand we where focussing on a good quality of our lessons, exercises and practicals. The Software Engineering Group has now established a number of lessons, such as Introduction to Software Engineering (undergraduate), Generative Software Engineering, Model Based Software Development, Software Architectures (Prof. Nagl), Programming-Language Ads 95 (Prof. Nagl) as well as some courses from our industrial partners, like Processes and Methods for Testing (Dr. Stefan Kriebel, BMW), which together with Software Engineering courses from our colleagues form a good body of knowledge for software development. Several related practicals and seminars with topics from Cloud Computing and Global Software Engineering complement these lessons.

On the organisational side, we are currently in the process of managing the “Tag der Informatik 2010” for the Informatics Department. Furthermore, we are involved in the newly started Commission for Teaching (“KfL”) that deals with strategic issues for the computer Science curricula and the Commission for Service Teaching (“KfSL”) that deals with lessons exported to other curricula. Both have the duty to ensure a good quality of the relatively new Bachelor/Masters programs, we are dealing with. Finally, because Prof. Spaniol resigned, we were elected to take over the speaker’s position for the Forum Informatik. On the industrial side, we have started a working group on Cloud Computing within REGINA and had already some fruitful meetings.

As our research can be divided into four major sections

- Modelling, model-based development,
- Energy management and monitoring in buildings,
- Automotive (Development Methods, Autonomy, Robotics), and
- Cloud Computing Services,

We have structured ourselves in the above groups. Four group leaders, Ingo Weisemöller, Claas Pinkernell, Tim Gülke and Dr. Anne-Therese Körtgen are managing these groups under the supervision of Anne-Therese Körtgen, who also manages the organisational and scientific routes of our Chair.

Our Software Engineering Laboratory (SE Lab) has started several projects, partly in combination with industry, partly on our own projects, to deliver industrial strength software. As a side effect of this effectiveness, our energy management group has started a company, called Synavision, together with energy experts from Braunschweig, to promote the use of an expert system for energy monitoring in buildings.

We also had quite a number of Ph.D.s being finished. Namely Christian Berger, Ibrahim Armaç, Hans Grönniger, Daniel Retkowitz, René Wörzberger and Holger Krahn finished their work and found good positions at Volkswagen Financial Services, Audi, HDI insurances, Nuance Communications Aachen, Generali Deutschland Informatik Services and Cirquent. We thank them, hope they have learned and explored the right things and wish them good luck. The Ph.D. theses are available under the newly created book series “Aachener Informatik-Berichte, Software Engineering” by Shaker publishing, Aachen.
Funding comes from various sources, including DFG, EU, BMBF and e.g. the following industrial partners Daimler, Bucyrus, Volkswagen, and Siemens.

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

Book series “Aachener Informatik-Berichte, Software Engineering”:
http://www.se-rwth.de/books/

Forum Informatik
http://www.fi.rwth-aachen.de/

Regina Working Group „CC“
http://www.se-rwth.de/ak-cloudcomputing/

Teaching
During the last year the group engaged in several teaching activities on undergraduate and graduate level for computer science students as well as students in electric engineering and information technology.

On undergraduate level several courses including lectures, proseminars, and practica have been offered. Furthermore, on graduate level the group offered specialised courses focusing on “Software Engineering” during the last year.

Namely, the following lectures were held:

- Software-Engineering (L3+E2), winter
- Model-Based Software Engineering (L3+E2), winter
- Software Architectures (L3+E2), winter
- Generative Software Development (L3+E2), summer
- Processes and Methods for Software Testing (L2), summer
- The SE Programming Language Ada 95 (L3+E2), summer,

Apart from that, several practicals and seminars were offered every semester including practicals in cooperation with other research groups.

- Graduate Lab Project in Software Engineering (E2), every semester
- Seminar on “New Topics of Software Engineering” (E2), every semester
- Working group for graduate and postgraduate students, during the whole year

Additionally, the group created the SE Lab to enable dedicated students to try and manage their own projects and ideas. It is also planned to establish a lab class in cooperation with other universities simulating global software engineering and the attached difficulties.

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

Algorithmic Synthesis of Reactive and Discrete-Continuous Systems

_J.O. Ringert and B. Rumpe_

DFG Graduiertenkolleg

The DFG Graduiertenkolleg 1298 AlgoSyn is an interdisciplinary research project aiming at the automated synthesis of software and hardware systems. We have joined AlgoSyn’s efforts in bridging the gap between engineering and theory as well as developing new methods in both fields. Working on bringing these two disciplines closer together and applying results from both areas has proven fruitful in AlgoSyn’s previous years.

We will assist with our modeling and software systems engineering experience in taming the complexity of the specification and development of distributed reactive systems. We plan to do so by developing languages and tools for specification, verification and synthesis. Focus of our work will be modeling languages for distributed components with asynchronous communication via message passing. Modeling the behavior of these systems as a specific type of automata allows high level specification and verifications as well as the synthesis to concrete implementations in certain cases.

Cloud Computing Services

_R. Hildebrandt, A. Körtgen, A. Navarro Perez, and B. Rumpe_

_M. Blume and M. Lüger_

Cloud Computing denotes a model for the provision and usage of IT resources. Such resources incorporate basic infrastructure like computation, storage and networking, as well as higher level runtime environments, services and applications. Clouds provide clients with network-based access to a virtually unlimited amount of such resources for a service-like managed, flexible on-demand and pay-per-use kind of usage. Internally, clouds manage a pool of physical resources, share these resources between clients in an abstracted way, account the usage and ensure performance, reliability and security.

Software running in a cloud faces several challenges. Technically, it runs on abstracted, heterogeneously realized platforms and is built of distributed, loosely coupled components. It must be scalable, self-managed, highly reliable, maintainable without downtime, secure and multi-tenant. Due to the interconnected nature of clouds, it has to integrate in a heterogeneous environment of software from other parties.

New architecture design concepts and programming paradigms for developing cloud computing applications are needed. In contrast to traditional software, they have to account for specific cloud computing characteristics such as the management of distributed
communication, the scheduling and instantiation of components and resources, or the handling the authentication and access rights. However, these additional aspects threaten to further complicate the development of software.

We address these challenges using model-based approaches. Employing appropriate models, specific aspects of cloud software such scaling, distribution and integration can be described in an abstracted, condensed and coherent way and kept separated from the actual business part of the software. The models are mapped upon concrete realizations using generative techniques. Code generators abstract from the technological heterogeneity of the cloud by generating different variants from the same models, generate proven management and security mechanisms and ensure meaningful default behavior based on defined conventions.

This approach is applied on different levels of a cloud’s typical anatomy and in the context of different scenarios:

**Passepartout** focuses on the a-posteriori integration of cloud-based services and applications by end-users in an easy to use manner. Integration is achieved by semi-autonomously sharing managed data and establishing collaborations (workflows) between services and applications. Data and workflows are specified using appropriate models. The models are used to configure a user-centric online service that manages the assets of one person in the cloud, in particular his online data and his desired automatable online workflows. This service acts as the central hub for data storage and provisioning as well as workflow orchestration.

The **Energie Navigator** serves as an exemplary scenario for an extension of existing software in order the use cloud facilities. An scheduling component estimates the computation needed for specific tasks and outsources large tasks to other instances of the software that are executed in the cloud and instantiated on demand.

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**Continuous Requirements Management**

*T. Gülke and B. Rumpe*

*In cooperation with VOLKSWAGEN AG*

Main tasks include analyzing the requirements-process during product development at VOLKSWAGEN AG in Wolfsburg and suggesting improvements. During three years, interviews with VW employees are held as well as tools evaluated and best practices in other industries and companies discovered. As a result, hidden processes, tools, and documents which contribute in some way to the discovery, engineering, and management of requirements are mapped out.

Since not only software-requirements are being included, a brief search throughout the whole product-development process is necessary to get together the whole picture. Marketing, product management as well as vehicle and prototype testing and many other departments and teams are being analyzed during this project. While trying to find similarities between documents and processes, abstract data models are constructed to prepare the introduction of a continuous requirements management tool. This allows for the explicit documentation of the results and knowledge extracted during the work.
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 and mobility aspects, the respective problems concerning configuration and service composition, the interaction of arbitrary devices, achieving personalization, 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. For this purpose, we have developed an approach for structural adaptation of the service composition at runtime based on mobility and dynamics in the eHome.

Furthermore, we have developed an approach for the semantic adaptation of eHome services to address incompatibility problems that arise when composing heterogeneous services from different vendors. An ontology-based approach allows for generating adaptor components automatically which are used to enable service composition by mediating incompatible services. We have also developed an interceptor-based approach for resolving conflicts between services regarding resource usage at runtime.

In addition, we have been working on supporting mobile users by personalizing multiple eHomes when moving from one eHome to another one (inter-eHome mobility). Our approach allows mobile users to personalize visited eHomes in two ways using a mobile device. First, a component called mobile user model enables flexible management of user data which can be easily made available to multiple eHomes. Second, personal eHome services can be executed on mobile devices interacting with appliances in visited eHomes. This way, habitual functionalities can be provided to mobile users even in eHomes which do not offer similar functionalities while the necessary appliances exist in these eHomes. This enables ubiquitous usage of personal functionalities.

Moreover, we have addressed problems regarding security and privacy due to inter-eHome mobility. On the one hand, the privacy of the users has to be protected while personalizing eHomes. For doing this, we developed an approach combining minimization and unlinkability
of personal data released to different eHomes. This is done by a negotiation-based identity management system combined with an authentication approach based on anonymous credentials. On the other hand, the eHomes and eHome services have to be protected against access by malicious users and services. To achieve this, we have implemented role- and credential-based access control.

To evaluate and demonstrate our tools, we developed several hardware and software demonstrator, the last one being based on Second Life. They allow simulating home environments with inhabitants and installed devices.

The eHome project has been finished by the middle of the year 2010. Summarized, four PhD and over 25 bachelor, master, and diploma theses have been accomplished in the context of this project.

**Energie Navigator – A software framework for optimizing energy efficiency of buildings**

* C. Herrmann, T. Kurpick, M. Look, C. Pinkernell, B. Rumpe, M. Tran

Nowadays new buildings are equipped with a lot of technical facilities, e.g. block-unit heating power plants or concrete core activation. These facilities are monitored by a multitude of sensors, which produce measured data. The measured data is typically used to control the facility itself (control circuit), but not for integrated monitoring and controlling.

The Energie Navigator project focuses on importing data from different types of buildings and facilities. After the data import quality of measured data has to be improved, e.g. by transforming them to equidistant timestamps or by filtering outliers. Based on the data that is stored in the backend, several tools (frontend) are implemented, e.g. a data visualization toolkit that displays data as line-, scatter- or carpet-plots. The Energie Navigator application addresses three groups of persons:

- energy experts and consultants
- building- and facility managers
- building occupants.
A main aspect of the expert tool is a rule- and metric-toolkit, which is used to define logical rules on sensors to define a target state of a facility or a building. These rules can automatically be checked by the framework. A rules- and metric-language is implemented as a domain specific language (DSL) according to the Object Constraint Language (OCL) of the Unified Modeling Language (UML) with the help of MontiCore, a framework for designing DSLs. The system is deployed locally as a common server application, but it optionally uses cloud infrastructure to optimize load balancing.

In addition to these expert functions the Energie Navigator also focuses on raising the energy awareness of end-users, e.g., by providing web based applications for current energy awareness.
consumption status. A prototype of this application is implemented at the Center for Computer Science at University of Technology Braunschweig.

The interdisciplinary workgroup of the project consists of members of Department of Software Engineering (CS3), RWTH Aachen University, Institute of Building Services and Energy Design TU Braunschweig, Ingenieurgesellschaft für energieeffiziente Gebäude mbH (energydesign-braunschweig) and Rumpe Information Technologies GmbH.

Some of the subprojects are promoted, e.g. by the Bundesministerium für Wirtschaft und Technologie (BMWi) and the European Commission (CIP ICT PSP).

Modelling and Configuration of Multi-Variant Software Documents in Automotive Software Engineering

C. Mengi, M. Nagl
Y. Arbach, Ö. Babur, M. Pogrebinski, and J. Pojer

Software engineering in the automotive domain has gained more and more importance. Today, about 80% of all innovations are software-based. Reasons for this are manifold: (a) Software supports the reduction of CO₂, (b) development of new functionality is cheaper compared to traditional hardware-driven development, (c) there are functionalities, which can only be implemented in software.

Although software brings advantages, there arise new problems which have to be solved. (1) The integration of software into a traditional hardware-driven process requires a large amount of time and effort. One reason is that software is tightly coupled to the hardware. (2) Furthermore, software components are not isolated but interact with further software components. These components do usually not run on the same Electronic Control Unit (ECU), but are distributed over several other ECUs. (3) The existence of different bus systems which connect the ECUs complicate the whole issue. (4) Moreover, the possibility to select optional fittings, e.g., parking assistant, rain sensor, intelligent light system etc., leads to the situation that an enormous number of software variants arise. So, automotive software engineering gets highly complex. It is a big challenge for both OEMs (Original Equipment Manufacturers) and suppliers to handle this complexity.

In Computer Science 3, we are analyzing three software documents which build the basis of an Electric/Electronic-Platform and provide new approaches for them to reduce the above mentioned complexity. These documents are (1) Function Nets, (2) Simulink-Models, and (3) Source Code.

Function Nets are conceptual models which formalize the functional requirements by modelling system functions together with their communication connections in a logical way. That is, Function Nets abstract from the underlying hardware platform, partitioning decisions, and any kind of real-time system realization (deployment, bus structure, protocols etc.). Therefore, Function Nets describe a first virtual realisation of the static system structure. By this, Function Nets form a clear model, which is more intuitive for a system architect. Furthermore, they provide a communication basis between developers for discussion, validation, simulation, and documentation. Thus, specification errors can be detected in time.
In order to use Function Nets to full capacity it is important to follow modelling principles such as abstraction of functions and connections, grouping of semantically equal functions and their connections, and establishing hierarchies. For this purpose, we are developing a checklist of *modelling guidelines* (or *method rules*) the aim of which is to support the system architect during design. To handle the variation, the first important step is to get a unified terminology about exiting variation points. Therefore, we construct a classification in order to distinguish between different types of variation. Second, to capture the points of variation we provide a so called *variability model*. Thereby, variation points and their variants are organized in a tree-based structure which is extended by a *constraint language* in order to express variability such as *mandatory*, *optional*, and *exclusive variation points*. Third, to express variability in Function Nets we integrate them with the variability model so that they can be used synchronously. Finally, to derive specific variants of Function Nets we provide a mechanism to *configure* the variability model and *derive* a variant out of the configuration.

Simulink-Models are *behavioural models* and part of the MATLAB® tool suite of The Mathworks™ company. With Simulink-Models it is possible to model graphically data-flow-oriented architectures such as automotive applications. While the main advantages of Simulink are that it can be used for simulation and code generation purposes, it still lacks of concepts to model and manage variability. Therefore, in our work we focused on existing variability mechanism/management concepts in Simulink and evaluate them by established *evaluation criteria*. The *evaluation* forms the basis for our approach to support variability concepts in Simulink. Particularly, we have identified different *types of variability*, structured them, and provide a *variability model* which is tailored for Simulink-Models. In the same way as for Function Nets, we provide a mechanism to *configure* the variability model and *derive* a variant out of the configuration.

Source code represents an *implementation model* which is either implemented manually or generated out of Simulink. In our work, we have focused on the programming language C/C++, because they are the most widely used languages in automotive software. Variation points are modelled implicitly by implementing C/C++ pre-processing directives. In this way, variable (conditional) compilation results in specific software variants. This approach allows fine-grained definition of variation points, but brings highly complex structures into the source code. The software gets more difficult to understand, to maintain and to integrate changes. The main reason for this is that a software engineer has no support on source code level beside the programming language itself. If a huge number of variation points exists, knowledge about a valid configuration gets difficult. Furthermore, a software developer has to find out the scattered code and the dependencies of one variant manually which is also very hard and time consuming. We have proposed an approach to support software developers in handling versatile source code and configuration of software variants. For this purpose, we have developed a concept to *capture and manage variability*. Furthermore, we support the possibility to *configure a software variant*. To represent the configuration result on source code, we introduced a *view-based approach* in order to display the current configuration and hide everything that do not belong to the configuration.
Global software engineering has become a common practice in many companies, as few can afford to produce software on their own and at a single location. But this leads to number of new challenges in software development projects. Quality management for example is much more difficult and schedule and budget overruns can be observed more frequently. Additionally global software engineering projects have to cope with different cultures, different languages, and different time zones – across companies, and across countries. The diversity of development locations on several levels seriously endangers an effective and goal-oriented progress of these projects.

Based on the identified challenges the partners of the GloSE project aim to produce technical, socio-technical and organizational improvements and solutions for distributed software development projects. Especially aspects of communication, information flow, and infrastructure in global projects as well as processes and methods are considered for all the tasks in software development: from requirements engineering to architecture design to implementation and testing. The developed methods, concepts and tools will be integrated in a GloSE platform and will be applied and validated in projects with the industrial partners and in student projects.

Usability of Models in Industry

F. Fieber and B. Rumpe

This project is a joint project of Siemens AG and the Software Engineering Group at RWTH Aachen. The objective is to investigate the conditions and challenges for a successful adoption of the model-driven development paradigm at Siemens by running a quantitative survey among a larger number of software projects. To our knowledge, typical research projects following the model-driven development paradigm only focus on single projects to gather data. By contrast, we want to take a high number of projects into account and assess them regarding to modeling and model-driven development. From the results of the survey and analysis of the projects we expect to get hints on the key factors for successful modeling in a large, software developing company. We want to derive possible improvements of the software development processes at Siemens.
So far we conducted several guided interviews with project managers from different organizational units of Siemens, located at different sites and concerned with different domains. The outcomes of these interviews are going to be used to detect the status quo in modeling and model-driven development at Siemens and to derive assumptions and hypotheses that will be deeper analyzed in the currently conducted survey.

ModelPlex – MODELing solution for comPLEX software systems
B. Rumpe, M. Schindler, and S. Völkel
In cooperation with 20 partners from 8 countries

Model-driven engineering (MDE) is an approach to Software Engineering that has proven benefits of cost reduction and quality improvement. Although models can indeed provide the necessary abstractions that enable human comprehension, communication, simulation and analysis, and synthesis of implementation artefacts which is the key for complex systems engineering, applicability still remains a challenge.

The EU-project ModelPlex defines and develops a coherent infrastructure specifically for the application of MDE to the development and subsequent management of complex systems within a variety of industrial domains. Therefore, ModelPlex uses established technologies developed in the preceding ModelWare-project as a basis for providing an enhanced MDE approach. In addition, new approaches, tools, and technologies are developed and form an integrated solution for handling complex systems.

ModelPlex is driven by Industrial use cases ensuring the applicability and the integration of the different technologies produced by the academics and industrial partners. In order to gain a solution which is usable in different domains and applicable for small and medium enterprises to global corporations, the ModelPlex-consortium consists of 20 partners with different backgrounds from 8 countries. Amongst them are SAP, IBM, Telefonica, several medium-sized companies as well as universities and research institutes from Germany, France, the United Kingdom, Russia, Belgium, Norway, Spain and Israel.

The main research areas of the Chair for Software Engineering are model composition, model based testing metrics, and the design of domain specific languages (DSLs).

Model composition is mainly concerned with handling models used to define complex software systems. We see the compositional style of development as the main instrument to handle complexity: huge systems should be defined by many small models which can be handled, understood, and evaluated separately instead of one huge model like it is the case in tools nowadays. Therefore we provide a semantic basis which clarifies how models can be defined separately, which interfaces exists between these models, and how these models interact.

Model based testing is like code testing one possibility to ensure the correctness of the system. Testing metrics help to evaluate which parts of the systems have (not) been tested. However, using many languages in order to define different aspects of the system complicates this approach: different languages have different kinds of metrics which have to be implemented separately. Therefore, we provide a language-independent framework which can be used to define metrics based on directed graphs (see Figure 1). This framework
automatically computes testing metrics, traces permit to interpret the result in terms of the original model.

A powerful technique for software development is the use of a specific notation for describing domain specific solutions. Domain specific languages (DSLs) allow the representation of information and models in a way that domain experts prefer over the use of general-purpose notations. DSLs make domain knowledge explicit and simplify the communication between domain and IT experts. The creation of a new language is a time consuming task, needs experience and is thus usually carried out by specialized language engineers. However, there exist a lot of tools which support the definition of new language even by non-IT experts and especially users with little experience in language design. Therefore, we developed a set of guidelines which help those users to define languages of high quality.

Figure 1: Idea behind the language-independent framework for testing metrics evaluation
Domain Specific Languages (DSLs) have recently become increasingly important for software developers and tool builders in several areas of application. Object oriented programming, which has been the most important programming paradigm since the 1990s, is supplemented by methods and languages that are tailored to a specific domain. The growing number and complexity of such languages is accompanied by the need to develop DSLs efficiently and to reuse artifacts from previous language development processes.

The MontiCore Framework allows for efficient, agile, modular, and compositional development of languages and tools as well as for the combination of DSLs and general purpose languages (GPLs) as shown in Figure 2. It supports an integrated definition of the concrete and the abstract syntax of languages and language modules, and the automatic generation of language processing infrastructure such as lexers and parsers. It also allows for efficient development model analysis and for development of code generators.

Figure 2: Compositional Development of Languages with MontiCore

Major improvements during the last term include the support of symbol table construction and support for the implementation of code generators. Moreover, we have applied substantial structural changes to the project as well as some technical improvements. The aforementioned features and compliance to the wide spread Eclipse Modeling Framework (EMF) are the most
important features of MontiCore’s upcoming version 2.0, which we plan to release by the end of the winter term 2010/2011 together with extensions and updates of our user documentation. As future work after this release we plan to extend MontiCore by a model transformation engine and to deliver a library of languages and languages components.

DSLs developed with MontiCore are used in a variety of projects at the department, e.g., the MODELPLEX project, rUML, UML/P, ENA, MontiArc and MontiWeb. At the time being, this set of languages developed with MontiCore contains modeling languages of general applicability such as UML, GPLs such as C++ and Java, and specific modeling or constraint languages, for instance languages used in automotive software engineering.

The precise definition of the meaning, i.e. semantics, of the Unified Modeling Language (UML) is highly relevant not only to the user of the language but also for tool builders. A common, unambiguous interpretation of the notational elements of the UML is a prerequisite for a reliable communication between people by means of models and their re-use in different modelling tools.

The semantics of UML has not been defined in the current UML standard. Accurately and precisely enough the main goal of the DFG project 1431/1-2 (rUML) therefore was the definition of a formal semantics for large parts of the UML. The current second phase of the project builds on results of the first phase in which a common semantic domain, the system model, has been defined. Moreover, semantics definitions for several UML sublanguages have been defined, using a predicative, denotational approach.

The second phase of the projects aimed to complete the semantics definition, building on reasonable syntactic and semantics adaptations of the UML version as defined by the OMG. Semantics for class diagrams, object diagrams, Statecharts, sequence diagrams, and simple versions of an action language and the OCL (object constraint language) have been defined or completed.

UML has introduced semantic variation points to integrate different views on the semantics of certain constructs but also to allow different technological spaces. The definition of semantic variation points and other variability of UML are not very well defined in the current standard. We developed a general classification of variability mechanisms in modeling languages. We then showed how to capture and configure language variants with the help of feature diagrams know from software product line engineering.
A tool infrastructure (see Figure 1) has been developed to define a modeling language completely, including syntax, semantics and its variability. The framework MontiCore is used to define the syntax of a language while the theorem prover Isabelle/HOL is used to define the semantic mapping and semantic domain of the language under consideration. The approach has been used to obtain a machine-readable, yet flexible semantics for class diagrams, object diagrams, Statecharts, sequence diagrams, and simple versions of an action language and the OCL.

**MontiWeb**

*A. Navarro Perez, D. Reiss, B. Rumpe, and M. Stein*

This project tackles the question: “Can we increase efficiency by applying the model driven approach to the development of web information systems?”

In order to investigate this question a generator for web information systems has been developed. This generator produces a running web system from class diagrams and activity diagrams, both based on the UML/P diagram family, and from a class view language.

In 2010, activity diagrams were integrated into the overall context of MontiWeb, to allow for the modeling of navigation structures and workflows within web systems. Further approaches have been made regarding user-based access control for web systems and the ability to distribute the entire system into reusable model units (Modlets).
In the different phases of software engineering projects several tools are used that enable the engineers to accomplish their tasks. But usually these tools are only rudimentarily or not at all integrated and therefore do not support the developers in their work in an optimal way. To facilitate an ideal support of the developers the tools need to be integrated on different levels.

The aim of this research project is to analyze how heterogeneous tools that were not developed with integration in mind can be integrated. The tools that are considered in this project are software engineering tools that are utilized in the development of complex software systems. The result of this project is on the one hand a definition of an integration methodology and on the other hand a software engineering tool environment as well as a reference architecture for the integration of heterogeneous software components.
This project evaluates methods and techniques for developing software for a steering system at VOLKSWAGEN AG. The current steering system is shipped with the products VW Tiguan (see picture) and VW Passat. More systems for other vehicles are in development and need their own hardware and especially software.

Different software implementations for different steering systems have to fulfill different requirements. The aim is to capture common properties and differences of these implementations to reuse them in new products. To support these activities several tools and processes should be developed. This method is known as software product line engineering which allows to develop new software systems in shorter time and more cost-and resource-efficient.

Some approaches for product lines already exist. They should be evolved by the Chair for Software Engineering with actual research results in this area. Auxiliary conditions are existing processes which are defined to meet the requirements of the SPICE-certification. Furthermore the developed software is used in a safety-critical system. This means that other requirements like the IEC61508 or Misra coding conventions also have to be fulfilled.
Main task is the development of a strategy and tool support for the migration of requirements data from a legacy requirements system at VOLKSWAGEN AG in Wolfsburg. The project is split into two phases. In the first phase the legacy requirements system will be inspected to gather a detailed insight into the system, its data and data-model. In addition transformation strategies are developed to migrate data with a possibly heterogeneous data-model to a system with a fixed data-model without losing information. Also strategies for the transformation of possibly incompatible concepts have to be designed.

Task in the second phase is the development of a software tool that implements the developed strategies as well as the documentation of the developed migration methodology.

The number of traditionally engineered websites is constantly decreasing, being replaced by complex web applications which are capable of bringing a whole new experience of interactivity to the user. The Google Web Toolkit (GWT) enables developers to abstract from plain JavaScript and HTML to standard JAVA, making development significantly easier and hence to apply more complex, state of the art architectures. VIRE is a framework based on GWT which is specifically designed to support the development of web-based editors, reducing development time by supplying infrastructure like a command-based Undo/Redo-mechanism or the integration of the MVC-pattern. The framework’s domain is the transformation of usually non-formal documents (like Microsoft PowerPoint or Word) being used by a large number of people in a process into a formal web-application which allows editing the same document layout they are used to.

One specific web-editor being built upon VIRE is ProcEd, a process editor developed for and used by the VOLKSWAGEN AG. ProcEd replaces a large set of PowerPoint slides representing a specific process which is currently being updated and therefore needs constant work on by different groups of people.
Other Activities

The Software Engineering Lab was founded in 2009 by Prof. Rumpe to cultivate the link of research and industry around Software Engineering topics. It aims to connect by contents and by people. The SE Lab creates a great network of industrial partners and of high potentials which consist of associates of the chair of software engineering as well as excellent, highly motivated students. They perform joint projects, talks, lectures, and workshops. In that way, industry initiates research and receives up-to-date and innovative technology know how and custom made solutions. Simultaneously, research keeps in touch with present industrial needs and gets realistic application scenarios. In SE Lab projects, our excellent students can work in the context of their thesis, student jobs, or practical courses on practical tasks and solutions.

The official opening of the SE Lab was in October 2009, where interested students, research assistants, and industry partners have been informed about the topics and aims of the SE Lab. Dr. Allmann from Audi had a talk which was a great first contribution for the idea of the SE Lab to connect people and knowledge. In the opening, people got to know each other in a congenial atmosphere, a kicker tournament took place consisting of mixed teams.

In 2010, the SE performed projects with Volkswagen AG which are still ongoing. In these projects, tools and methods are developed to support the development of software product lines, requirements management, as well as requirements tool integration. With Daimler AG there is a project ongoing dealing with Simulink variant management and at Siemens we introduce model-based techniques and tools to their software development. Besides the complex tasks of the projects themselves, they all face the challenge to provide solutions which integrate in the existing software development processes and tool landscapes.

There are three innovative long-term in house development projects at the SE Lab which gain more and more attention in industry. The MontiCore framework and the SSE Lab provide basic software solutions for efficient and fast development of high-quality software. These tools are already used by software developing organizations at different universities and
demanded by several software houses. The Energie Navigator is a tool to monitor and optimize energy consumption of large buildings and plants and is elaborated in various industrial projects. To learn more about the projects at SE Lab, please see the dedicated project reports below.

In 2010, the SE Lab initiated the Technology Forum. Here, members of the SE Lab network, industry partners, students, and members of the chair, talk about innovative technologies and trends and exchange knowledge. We welcomed talks from industry partners, such as Thales, SAP, DSA, Ericsson, EMIC, Audi, Daimler, and BMW. Research assistants and their students presented new technologies in developing android and iPhone applications as well as web applications with Google Web Toolkit. Also Cloud Computing technologies were introduced here.

The connection to industry could be tightened by gaining lecturers from BMW AG and DSA GmbH. In summer, Dr. Stefan Kriebel gave a lecture about “Processes and Methods of Software Tests” where the students also got insights in industrial software development. In next winter, Dr. Ansgar Schleicher will give a lecture about “Applied Software Engineering within the life cycle of Automotive Electronics”. This concept of interaction is very promising and will be followed up. In reverse, we plan to give advanced and special trainings to software developers in enterprises.

Besides lectures, we enabled students in the SE Research Camp and also in practical courses to learn how to build smart phone applications and web services first and to apply them in the following by realizing software in a team. Here, several nice software came out such as the building information system GISELA with an Android and iPhone interface and car remote control apps in the context of the AURIGA project.

Astonished by the demand of all SE Lab activities, projects, Technology Forum, lectures and SE Research Camp, in 2011 we will extend our offerings.

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Software and Systems Modeling (SoSyM) Journal

Since 2001, Software and Systems Modeling (SoSyM) is an international journal that focuses on theoretical and practical issues pertaining to the development and application of software and system modeling languages and techniques. The aim of the journal is to publish high-quality works of further understanding about theoretical underpinnings of modeling languages and techniques, to present rigorous analyses of modeling experiences, and to present scalable
modeling techniques and processes that facilitate rigorous and economical development of software.

The journal is unique in its emphasis on theoretical foundations of modeling languages and techniques and on rigorous analyses of "real-world" modeling experiences. The balance of theoretical works and works based on in-depth analyses of experiences provides researchers with insights that can lead to better modeling languages and techniques and provides modeling practitioners with a deeper understanding of modeling languages and techniques that can lead to more effective application.

The journal targets researchers, practitioners, and students that have a vested interest in results generated by high-quality modeling research and by rigorously analyzing modeling experiences.

**GI-QFAM: Joint Interest Groups on Modeling**

The Joint Interest Groups on Modeling (Querschnittsfachausschuss Modellierung, QFAM) of the German Informatics Society (Gesellschaft für Informatik, GI), which was founded in 1998, is an association of developers and users of model based software development approaches. It serves as a platform for the exchange of experiences and discussion of new ideas. As such, it hosts the annual convention *Modellierung*, which takes place either as a workshop or as a conference.

QFAM is unique as it brings people together from various disciplines of computer science that are related to modeling. Currently, there are 12 other groupings of the GI clustered in QFAM, which cover a wide area of topics such as formal methods, knowledge representation and management, or business information systems. The members of QFAM come from almost all areas of the German-speaking countries.

In March 2010, Prof. Dr. Bernhard Rumpe took over the chairmanship of the QFAM from Prof. Dr. Ulrich Reimer from the University of Applied Sciences St. Gallen. In addition, he is going to host the 2011 edition of the workshop *Modellierung* in Aachen, for which we expect 40 of the most renowned experts on modeling as our guests.
Since with Cloud Computing emerging and promising technologies come up and REGINA industry members are potentially affected as users and suppliers of such technologies, the new Arbeitskreis “Cloud Computing” was initiated in 2010 by Prof. Rumpe. The aim of the Arbeitskreis is to enable the industry members from REGINA to make decisions, if, how, and where they could switch to Cloud Computing technologies and find new business models. That is why concrete applications, challenges, and limitations of Cloud Computing are focussed in the panel.

The group will meet gather every two months and talk about topics of all areas, infrastructures, platforms, and software from the user as well as the supplier point of view. Referees from industry as well as from university present their experience, solutions, and open questions.

In 2010, the Arbeitskreis met for three times where the subject in general was presented by Prof. Rumpe and the scope and aims of the Arbeitskreis were defined. We had two referees from EMIC and Ericsson who presented a platform solution for e-Science and an infrastructure solution, Telecom Clouds, for providing networks as a service.

Web sites
http://www.se-rwth.de/ak-cloudcomputing

Mailing list
ak-cloudcomputing@lists.rwth-aachen.de

Conference Activities and Academic Administration
M. Nagl:
• Vice Chair of the Accreditation Committee of EQANIE (European Quality Assurance Network for Informatics Education)
• Vice Chairman of German Informatics Faculties Conference (Fakultätentag Informatik)
• Member of the Board of 4ING (Union of the German Faculties Conferences of Mechanical Engineering, Electrical Engineering, Civil Engineering and Informatics)
• Accreditation Expert, Member of the Accreditation Committee, and Vice Chairman of the Accreditation Committee of EQUANIE (European Quality Assurance Network for Informatics Education)
• Reviewer's Board of the Innovation Alliance SPES of the German Minister for Research
• Member of the Finding Commissions for the Professorships "Institut für Kunststoffverarbeitung" and "Bausstatik und Baudynamik"
• David-Kopf-Preis 2009, Member of the Evaluation Committee
• ICGT 2010 International Conference on Graph Transformation, Enschede NL 28. 9. - 1. 10. 2010 (Member of the Program Committee)
• Colloquium of Graph and Model Transformation Berlin 2010, Member of the Program Committee
• David-Kopf-Preis 2010, Member of the Evaluation Committee
• AGTIVE 2011 (Application of Graph Transformation with Industrial Relevance), Budapest, Hungary, Member of the Program Committee

B. Rumpe:
• Organizer of QFAM-Meeting, Klagenfurt, March 2010
• Speaker of „Querschnittsfachausschuss Modellierung“ of Gesellschaft für Informatik
• “Software im Fahrzeug”, Organizer of Conference at VW- Auto Uni, May 5, 2010
• Member of the Program Committee: International Conference on Model Driven Engineering Languages and Systems, October 4-9, 2009, Denver, Colorado, USA
• Member of the Program Committee: 7th ACIS International Conference on Software Engineering Research, Management and Applications, December 2-4, 2009, Haikou, Hainan Island, China
• Member of the Program Committee: Conference on Embedded real time software and systems, May 19-21, 2010, Toulouse, France
• Member of the Program Committee: International Conference on Software Engineering, May 2-8, 2010, Cape Town, South Africa
• Member of the Program Committee: Workshop on Model-Based Development of Embedded Systems, February 3-5, 2010, Braunschweig, Germany
• Member of the Program Committee: Conference on Model-based Engineering of Software-reliant Systems with AADL, May,2010, Pittsburgh, USA
• Member of the Program Committee: Workshop on Model Based Architecting and Construction of Embedded Systems, October 6, 2009, Denver, Colorado, USA
• Member of the Program Committee: 22nd International Conference on Advanced Information Systems Engineering, June 8, 2010, Hammamet, Tunisia
• Member of the Program Committee: Workshop on Domain Engineering, June 8, 2010, Hammamet, Tunisia
• Member of the Program Committee: European Conference on Modelling Foundations and Applications, June 15-18, 2010, Paris, France
• Member of the Program Committee: International Conference on Engineering of Complex Computer Systems, March 22, 2010, Oxford, UK
• Member of the Program Committee: International Conference on model Transformation, June 28- July 2, 2010, Malaga, Spain
• Member of the Program Committee: Model-Based Engineering of Real-time and Embedded Systems, May 4, 2010, Carmona, Spain
• Member of the Program Committee: Symposium on Automotive/Avionics Systems Engineering, October 13-14, 2009, San Diego, USA
• Member of the Program Committee: Multi-Conference Wirtschaftsinformatik, February 23-25, 2010, Göttingen, Germany
• Member of the Program Committee: Third Workshop on Transforming and Weaving OWL Ontologies in MDE/MDA, June 30, 2010, Malaga, Spain

• Member of the Program Committee: Modellierung 2010, March 24-26, 2010, Klagenfurt, Germany

• Chair of the Program Committee Workshop on Formal Methods and Agile Methods, September 17, 2010, Pisa, Italy

• Track chair & organizer SOFSEM, January, 2010, Prague, Czech Republic

• Organizer of REGINA-Arbeitskreis Cloud Computing
Talks and Publications

Talks
Gülke, T.: Software steuert sich durch die Stadt…. Autonomes Fahren, April 2010, Aachen, Germany
Nagl, M., Weihe, K.: Weiterbildung in der Informatik- die Rolle der Universitäten, Plenarversammlung Fakultätentag Informatik, November 2009, KIT Karlsruhe, Germany
Nagl, M.: Grußwort des Fakultätentags Informatik zur Ehrenpromotion von Prof. Vollmar, January 2010, Braunschweig, Germany
Nagl, M.: Software- Werkzeuge für komplexe Entwicklungsprozesse, Kolloquium, June 2010, Halle, Germany
Nagl, M.: Software Architecture - The Essence of a Software System, Tongji University, September 2010, Shanghai, China


Rumpe, B.: Generative Software-Entwicklung zur Optimierung der Konstruktion eingebetteter Systeme, AAET, November 2009, Braunschweig, Germany.


Books
Publications


Software Construction

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  (until Jan. 2010, third-party funds position)
  Dipl.-Inform. Matthias Vianden
  (third-party funds position)

• Student Researchers:
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  Bora Kiliclar
  Frederic Evers
Overview

Our research focuses on the development of new and advanced methods, tools, and techniques in the broad area of software construction. Since software engineering is done in software developing organizations, we always try to develop and deliver software engineering support that is applicable under industrial software development conditions. Hence, most of our research projects are performed in close cooperation with industrial partners. Details on the projects can be found in the corresponding section of this report.

Currently we are actively working in the following areas:

• **Metric-based process evaluation and improvement.** Like in other engineering disciplines, measuring is a prerequisite to determine the performance of processes and products. We have started a new project the aims to develop an integrated highly customizable measurement infrastructure.

• **Simulation-based quality assurance of business processes and workflows.** Business processes as well as workflows become more and more an important means to specify and integrate software services and applications. An appropriate validation and verification approach of those models is an open issue but crucial for gaining all the benefits.

• **Advanced use case modeling.** Use case modeling is applied in industry for years to specify functional requirements. But the potentials of this requirements engineering technique are not utilized so far. An advanced modeling approach is needed enabling improved use case based requirements validation as well as use case based automated system testing.

Since appropriate tools are often the door opener to transfer research ideas to practice we are developing dedicated tool support for those areas. Currently we offer the following tools:

• ViPER (Visual Tooling Platform for Model-Based Engineering, www.viper.sc)
• QMetric and BugzillaMetrics (www.qmetric.org)
• NaUTiluS (Narrative Use Case Description Toolkit for Evaluation and Simulation)
• MeDIC (Measure Documentation - Integration and Calculation)

Teaching

In addition to undergraduate courses on Programming and Software Development the group offers on the graduate level the following set of courses focusing on Software Construction and Software Quality Assurance:

• Lecture Software Quality Assurance
• Lecture Object-Oriented Software Construction
• Lecture Software Project Management
• Seminars and Practical Labs

Furthermore we are responsible for the Software Engineering course of the master program Software Systems Engineering at the Thai German Graduate School of Engineering, Bangkok, Thailand.
Research Projects

Evaluating Business Process Models
A. Ganser, H. Lichter
External cooperation: Osthus GmbH, Aachen

Research in constructing software, in other terms software engineering, already exists for decades and over the years several approaches emerged. Ranging from procedural, functional until object oriented approaches, creating a model of the system to be build is a cornerstone of every approach. But, all software systems, which are modeled and developed with these approaches, deal with single pieces of software or software systems for narrow scopes (metaphor: e.g. for departments in companies). Consequently, one step in abstraction deals with connecting these software systems to workflows. This adds a goal oriented perspective and links several systems together to (e.g.) support departments working together in a static, but automated way. What remains is the importance of models in a sense of abstractions from the real world. The next step in abstraction adds business goals as a motivation and concerns the whole company or even several companies.

Hence, business process modeling enlarges the perspective with business goals and mainly adds the aspects of agile business processes and business goals. This sounds like documentation at first but committing to business processes actually burden engineers with severe architectural constrains. Moreover, demands emerged which want to have these business processes automated. As a consequence, business processes are required to be flawless in many different ways.

On the one side, a lot of research has been undertaken in the field of metrics for business process models. On the other side, a lot of quality models exist on a very high level of abstraction. But, only very few researchers ventured to establish a link between metrics and models. This is due to the gap perceived small but actually it is immense.

So, the initial questions are: What can we do with the metrics invent so far? What do the numbers mean with respect to a given quality model? Which metrics are missing? And, combined with simulations on business process models - which information we can glean? And, finally, is there interesting information derivable from historical information of models?

These simple questions turn out to be challenging since lot of the foundations are still missing.

Methodical and Tool Support for Advanced Use Case Modelling
V. Hoffmann, H. Lichter

Use cases are a widely accepted technique for the elicitation and specification of functional requirements. Nowadays Use Cases are addressed by many modern software development
processes and are a major driver for requirements engineering and several other downstream modelling activities like testing or the development of user documentation. Nonetheless all current use case modelling approaches lack a concise quality assurance infrastructure.

Therefore we have devised several mechanisms for the assessment of the quality of narrative use cases, a formalism for textual use case descriptions based on a formal meta-model.

First we have created a quality model for use case based specifications alongside several metrics for the analysis of specific quality aspects of this model. E.g. readability, consistency or granularity. All those metrics are either based on the formalized structure of the description, on their textual content or on a combination of both.

Moreover we have experienced that practitioners complain about difficulties in use case reviews. They report, that especially domain experts have difficulties to evaluate correctness and completeness of use case based descriptions because they have difficulties to follow the scenarios that form the behaviour of a system, since they are often scattered about several use cases. Therefore we have created a simulation framework for the enaction of use case based descriptions that should help to experience the behaviour in a simple intuitive fashion. Moreover we have enriched this simulation means with user interfaces. Thus the use case description simulation infrastructure can be used for very early prototyping and as basis for feasibility studies.

During the last year we enriched our existing tool support ViPER-NaUTiluS - an integrated tool support for specifying, editing and analysing of enriched use case descriptions based on the ViPER-IDE- with an infrastructure for the description and calculation of use case metrics. Furthermore the NaUTiluS framework now includes a use case simulator for the specified behaviour descriptions and an extension for GUI-prototypes. Thus NaUTiluS enables prototyping of the system behaviour very early in the development process.
Automatic Test Case Generation based on Rich Use Case Models
M. Obaid, H. Lichter

Although UML notational diagrams are a good means 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. Various current tools are available that support attaching more details into use case models and allow behaviour specifications of use cases with natural language descriptions. While some research work has been done to form high quality use case models that capture such descriptions (which are less readable or less practical for later phases use), other approaches were based on using limited semantically processed natural language phrases, but they still have usability problems and did not manage to reach the needed level of the practical use. Having such a usable high quality use case model is beneficial to represent what the future system will do and how it will behave, it 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 such enhanced use case models.

The research focus is of two main phases, the first is the usage of flows of events based modelling of use cases, which forms a base and a higher quality future test scenarios in addition to a potential range of UC scenarios to choose the desired functionalities to be test and form the fore mentioned test scenarios. The second phase is an approach to allow the addition and manipulation of test data within the test scenarios chosen, which should be supported within a proper visualization to ensure flexible and usable test scenarios handling. Moreover, other areas must therefore be supported such as the coverage criteria, which is the mechanism to choose the functionalities that are wanted to be tested from the range of the use case scenarios and quality assurance for the final test cases and their possible usage lateron.

During the last year, a meta-models based approach was created to support the generation of test cases from already existing and slightly modified (possible to add more test data) flow-oriented narrative use case models. This approach covers the mechanism of the research idea, with near future additional GUI visualization and proper more flexible criteria coverage to be implemented.

Process Assessment based on Software Repository Data
H. Schackmann, H. Lichter
External cooperation: Kisters AG, Aachen

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. Moreover the core of BugzillaMetrics is a generic metric evaluation algorithm that is adaptable to different change request management and version control systems. Currently adapters for Mantis, CVS, and Subversion are available. These tools have been made available open source in the QMetric tool suite. Further on the QMetric tool suite was extended by support for the definition of quality assessment models, and their automatic evaluation. Quality assessment models leverage the evaluation results of the software metric to the level of the quality characteristics of interest for the user. The tools had been evaluated in case studies targeted at the evaluation of quality characteristics within a project portfolio of open source projects, as well as in an industrial context.

<table>
<thead>
<tr>
<th>Metric-Based Project and Process Management</th>
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<tr>
<td><em>M. Vianden, H. Lichter</em></td>
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<tr>
<td>External cooperation: Generali Informatik Services, Aachen</td>
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Solid and well engineered processes are the basement of successful software development projects. However the process may need to be changed due to outer or inner influences. The need for change raises two key questions: What parts in the process need to be changed and how do they need to be changed?

To answer the first question, processes and their application need to be transparent. One way of achieving transparency is to use metrics. Hence it is important to know what metrics to use when and where. Our idea is to provide an integrated metric environment together with supporting metric processes and metrics over metrics as a mean to ease the selection of the right metrics.

To answer the second question the Research Group Software Construction is developing a metric based quality model for software developing processes in close cooperation with Generali Deutschland Informatik Services. Applying this model should allow to assess and to improve the underlying processes. Using this knowledge another goal is to incrementally build a repository of process-adjustments that are in accordance with established models such as CMMI or SixSigma. This repository can then be mined using dedicated metrics and other input parameters to support the optimization of the processes.
Organizations have to improve their processes continuously. There is a variety of collections of best practices known as maturity-, process- and quality-models as well as standards, norms, etc. that can be used. We call them reference models. Organizations have to decide which of these models they want to use. Should an organization select CMMI or SPICE? Is COBIT perhaps the right reference model? CMMI-SVC or ITIL?

The aim of our research is to provide a method for an objective selection of reference models that best fit to an organization. An objective selection requires transparency of the reference models and other factors that influences the selection decision. Our approach is to use dedicated models to achieve this transparency.

Transparency of reference models means understanding the reference models: On one hand identify the redundancies and compatibilities between reference models and on the other hand avoid misinterpretations by selection and later by their implementation in the organization. An integrated model is build to achieve such a transparency. A common structure is used to normalize the reference models regarding their structure. An additional model is used to interconnect and semantically normalize the reference models. The fine granularity of the integrated model allows an automatic comparison of the reference models and helps answering the redundancies and compatibility questions of the organizations.

Transparency of other factors for the selection means understanding which elements are relevant and need to be considered for making a decision selection. A model of organizations goals and characteristics is used to identify these elements and their relationships.

A mapping between the integrated model and the model of organizations goals and characteristics of an organization allow an objective selection for reference models that best suit to an organization.
Other Activities

• Member of the international program committee, International Workshop on Formal Methods plus Agile Methods in Software Engineering, Rio de Janeiro, December 8 -11, 2009, H. Lichter

• Member of the international program committee, FM+AM’ 2010, 2nd International Workshop on Formal Methods and Agile Methods, Pisa, September 17. 2010, H. Lichter

• Member of the program committee, Modellierung 2010, Klagenfurth, March 24-26, 2010, H. Lichter

• Member of the international program committee, 25th Annual ACM Symposium on Applied Computing, Software Engineering Track, Sierre, Switzerland, March 22-26, 2010, H. Lichter

• Member of the international program committee, 4th IEEE International Conference on Secure Software Integration and Reliability Engineering, Singapore, June 9-11, 2010 H. Lichter

• Member of the program committee, Software Engineering 2010, Paderborn, February 22-26, 2010, H. Lichter

• Member of the international program committee, SOFSEM 2010, 36th International Conference on Current Trends in Theory and Practice of Computer Science, Špindlerův Mlýn, Czech Republic, January 23-29, 2010, 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 Lehre and Service-Lehre, H. Lichter

• Member of the examination board of Bachelor Computer Science, H. Lichter

• Member of workgroup “Zusammenarbeit Hochschule und Industrie”, GFFT, Gesellschaft zur Förderung des Forschungstransfers, H. Lichter

• Reviewer of PhD thesis A. Grimm, LMU Munich, H. Lichter

• Organization and member of workgroup “Messen und Bewerten”, REGINA e.V., H. Lichter, M. Vianden, S. Pricope, A. Ganser

• Organization of Software Engineering Research Camp 2009 and 2010 in cooperation with Department of Computer Science 3, H. Lichter, A. Ganser, M. Vianden

• Organization of the Beginner’s Course in Computer Science 2010, H. Lichter, A. Ganser, S. Pricope

• Member of Beginner’s Course Task Force in context of “Studieren im Focus der Exzellenz”, 2010, A.Ganser
Talks and Publications

Talks


C. Piyabunditkul: Combining CMMI and Agile Approaches Based on a SPI Advisory Tool, SEPoW 2009, First Software Engineering Postgraduates Workshop (In conjunction with APSEC 2009), Universiti Sains Malaysia (USM), Penang, Malaysia, November 30, 2009.


S. Pricope: Model Based Selection of Organization Specific Improvement Instruments 36th Euromicro Conference on Software Engineering and Advanced Applications SEAA 2010, Lille, France, September 3, 2010

V. Hoffmann: A Model Based Narrative Use Case Simulation Environment, 5th International Conference on Software and Data Technologies (ICSOFT 2010), Athens.


Publications


Staff

- **Faculty**
  Prof. Dr.-Ing. Klaus Wehrle
  Prof. Dr. rer.nat. Dr. h.c. Otto Spaniol

- **Secretariat**
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- **Research Staff**
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  Dipl.-Inform. Jó Ágila Bitsch Link
  Dipl.-Inform. Uta Christoph
  Dr. Juan Miguel Espinosa Carlin (until July 2010)
  Dipl.-Inform. Stefan Götz
  Dipl.-Inform. Tobias Heer
  Dipl.-Inform. René Hummen
  Dr. Martin Krebs (until August 2010)
  Dr. Karl-Heinz Krempels (until July 2010)
  Dr. Jan Kritzner (until July 2010)
  Dipl.-Inform. Georg Kunz
  Dr. Olaf Landsiedel (until February 2010)
  Mónica Alejandra Lora, MSc
  Dipl.-Inform. Sadeq Makram
  Dipl.-Inform. Ulrich Meis (until April 2010)
  Oscar Garcia Morchon, M.Eng.
  Dr. Andriy Panchenko (until May 2010)
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  Fahad Samad, MSc
  Dipl.-Inform. Raimondas Sasnauskas
  Dipl.-Inform. Benjamin Schleinzer
  Dipl.-Inform. Florian Schmidt
  Dipl.-Inform. Tim Seipold
  Dr. Thitinan Tantidham (until September 2010)
  Dr. Dirk Thißen
  Dipl.-Inform. Nicolai Viol
  Dipl.-Inform. Elias Weingärtner
Dipl.-Inform. Hanno Wirtz
Dipl.-Inform. Alexander Zimmermann

- **Technical Staff**
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  Kai Jakobs
  Rainer Krogull
Overview

In 2010 the former Chair Informatik 4 and its associated Research Group on Distributed Systems merged to form the new Chair of Communication and Distributed Systems. This merger followed the appointment of Klaus Wehrle, former Head of the Distributed Systems Group, as new Chairholder. The two entities merged on 1 August 2010.

The research focus of the former Chair Informatik 4 was on the 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 included:

- Mobile and Wireless Networks (Security Management, Traffic Models, Mobile Intemetting, 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

The vision of the Distributed Systems Group was the development of flexible, scalable & resilient communication systems and the required models, methods, and tools to design, analyze, realize, and evaluate these systems.

The range of systems considered covered complex and massively distributed Peer-to-Peer systems, traditional Internet-based communication systems, 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, they identified three important research areas:

- 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
The research activities of the new ComSys Chair will pretty much be a superset of the above, with the likely exception of the field of Mobile and Intelligent Agents.

For further information please see:
http://comsys.informatik.rwth-aachen.de
Wireless Mesh Network (WMN) is unquestionably an interesting technology addition in wireless communication networks because of its self-organizing, self-healing and reliability dimensions. However, possible misuse or hijacking of these networks by adversaries makes them highly vulnerable. While many security issues that exist in these networks have already been discussed, a few of the severe attacks that still lack sufficient investigation are channel assignment (CA) attacks and other brutal attacks such as jellyfish attacks and gray hole attacks. These attacks can easily lead to network partition or even unavailability.

While the quondam CA schemes have mostly used dynamic CA (DCA) methods, these schemes do not consider the security threats that exist to assign these channels to the available wireless links. We provide a lightweight solution to secure DCA in WMNs.

Moreover, most of the defensive mechanisms are not able to detect a set of protocol compliant attacks called jellyfish (JF) attacks that target protocols used by closed-loop flows such as transmission control protocol (TCP). A framework to render protection against jellyfish attacks has been presented. To mitigate vulnerability, another aim is to come up with an effective solution for the scenario of malicious colluding nodes (mesh routers) in a WMN.

Due to the very nature of wireless networks being mobile, grievous security issues may arise, for which some homogeneous solutions have already been proposed. However, each node may have its own security requirements depending on the available resources and the services or applications it uses. We propose a requirement and resource friendly security framework established on Merkle trees and then we also present an adaptive security service-level association (ASSA) for mobile wireless networks such as WMNs and wireless ad hoc networks.

RatPack: Analysis of Animal Ecological and Social Networks With Programmable Sensor Nodes

Jó Ágila Bitsch Link, 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. Our current research focuses on enhancing the sensor hardware, providing energy efficient schemes for detecting communication opportunities and data forwarding. The reconstruction of subterranean burrow systems and improved classification of ultrasound vocalizations and step detection mechanisms are additional areas where we made contributions.

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**Standardising the Internet of Things**

*Kai Jakobs, Kai Reimers (Research Group Electronic Business), Thomas Wagner (Research Group Electronic Business)*

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.

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.

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

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

As a result, the following initial recommendations have been made:
• Establish ISO as lead organisation to co-ordinate the IoT standardisation process.
• No regional standards should be passed prior to their international counterparts.
• Introduce ‘quotas’ for all stakeholders.
• Provide funding to have small users and consumers be represented throughout the process by dedicated, knowledgeable champions.
• Educational initiatives specifically targeting the Third Estate should be initiated.
• Enable a ‘hierarchical’ representation of (small) indirect stakeholders.

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

FP7 – China-EU-Standards
Kai Jakobs

This project brought 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. It developed a knowledge network of leading players in the field, within Europe, China and beyond. Moreover, the project has examined the new ICT standardisation activity emerging in China, apparently linked to its goals to promote indigenous technology. It compared these emerging standardisation processes with those that have emerged and are being currently pursued by European players.

Based on these studies, a number of policy recommendations have been developed, including, for example:

• European policy actions on standardisation for innovation must make explicit engagements with China. This needs to include continued support to allow European firms to gain expertise and experience in Chinese standardisation processes.
• The EU must support the development of standards processes for future Internet platforms and services that further European goals. This will include opening them up internationally and ensuring that they are attractive to China-based industrial players and Chinese policy makers.
• Attempts are being made in China to develop ‘China-friendly’ patent pools, and European policy makers must engage with this process.
• Europe must develop a better understanding of how developing countries could become engaged in global standardisation processes and help them move up ‘the standardisation ladder’. China could be an exemplar and a leader in the developing world, for example by e.g. supporting low cost standards.

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
The proliferation of broadband Internet connections has led to an almost pervasive coverage of densely populated areas with private and commercial wireless access points. 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 untrusted 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. 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.

Municipal Wi-Fi networks aim at providing broad Internet access and selected network services to citizens, travelers, and civil servants. Such services can range from web sites to interactive tourist guides to remote meter read-outs and traffic monitoring. While establishing such networks is financially challenging for municipalities, Wi-Fi-sharing communities accomplish good coverage and ubiquitous access by capitalizing on the dense deployment of private access points in urban areas. However, lack of trust, security, and openness make community models unsuitable for municipal Wi-Fi projects.

The project Mobile ACcess is a collaboration of the LuFG i4, Informatik 8, and 7 partners including the cities of Aachen and Monschau. It is a joint effort to show the feasibility and practicability of a city-wide network consisting of individual access networks united by a

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Management. The project is co-funded by the European Commission under the FP7 ‘Social Sciences and Humanities’ programme.

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

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**PISA: The Peer-to-Peer Wi-Fi Internet Sharing Architecture**  
*Tobias Heer, Klaus Wehrle*

**Mobile ACcess: Mobile and City-wide Communication Environment for Secure Internet Services**  
*Tobias Heer, René Hummen, Nicolai Viol, Hanno Wirtz, Klaus Wehrle*
novel concept for Wi-Fi sharing communities. Mobile Access spans a number of problem domains ranging from networking and network security to application design and paradigms for disruption-tolerant mobile applications. The heart of Mobile ACcess' security and network components is the PISA Internet sharing architecture (see above).

Mobile ACcess: Authentication of Mobile Devices and infrastructure and Mobility Management

René Hummen, Tobias Heer, Klaus Wehrle

Device mobility plays an important role in the Mobile Access scenario. A user’s mobile device should be able to connect to the community network once and stay connected while moving as long as network coverage permits. Furthermore, the community-driven aspects of Mobile Access are based on the provisioning of authenticated access to the Internet through trusted entities within the community network in a decentralized fashion. In order to enable both node mobility and node authentication, we maintain an implementation of the Host Identity Protocol (HIP) called HIP for Linux (HIPL). Our research focuses on achieving fast handovers and on developing protocol extensions that allow for efficient in-network establishment of authenticity of the communicating peers and their generated data streams.

Mobile ACcess: User-provided Services for Mobile Devices

Hanno Wirtz, Tobias Heer, Klaus Wehrle

The proliferation of powerful mobile devices turns users that previously only acted as clients in a network into potential service providers. For example, cameras, GPS-modules and powerful CPUs provide input sources as well as computational resources on mobile devices. In our research, we investigate whether mobile users with such devices can act as service providers to other users in a municipal Wi-Fi network such as Mobile ACcess. Furthermore, the appropriate infrastructure and security and privacy concerns are the focus of our work.

Mobile Access: Wi-Fi based user localization

Nicolai Viol, Klaus Wehrle

The ability to dynamically adapt information and contend of applications respectively to the users position is the key feature of novel, so called location aware services. However,
accuracy and availability of common localization technologies like for example GPS are limited in municipal areas and indoor scenarios. Providing a dense and further growing infrastructure collaborative municipal Wi-Fi network forms a technological basis to build a city-wide user localization service. We aim to provide both, an accurate and easy to maintain Wi-Fi based localization service to enable fast and seamless city-wide indoor and outdoor location aware services.

Probabilistic Addressing in Wireless Networks
Muhammad Hamad Alizai, Klaus Wehrle

Unreliable connectivity and rapidly changing link qualities make it challenging to establish stable addressing in wireless networks. This is especially difficult in communication scenarios where nodes determine their own addresses based on the underlying connectivity in the network. In this project, we present Probabilistic ADdressing (PAD), a virtual coordinate based addressing mechanism that efficiently deals with dynamic communication links in wireless networks. It assigns probabilistic addresses to nodes without needing to pessimistically estimate links over longer periods of time. Our prototype implementation over real testbeds compares PAD with the state-of-the-art addressing and point-to-point routing approaches in sensornets, such as S4 and BVR. Our results from three widely used testbeds indicate that PAD achieves 3-7 times more stable addressing even under challenging network conditions, reduces the magnitude of change in addresses by 3-12 times, and minimizes the hop distance and number of transmissions in the network by 10-20%.

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.

TinyOS Meets Wireless Mesh Networks
Muhammad Hamad Alizai, Klaus Wehrle

We introduce TinyWifi, a TinyOS platform supporting Linux driven devices. It allows direct execution of protocol libraries originally developed for a different networking domain. Applications from highly resource constrained sensornets can easily be compiled for resource rich Wi-Fi based networks, thereby making the very rich and mature protocol repository of TinyOS available for broader wireless research. Using TinyWifi as a TinyOS platform, we expand the applicability and means of evaluation of wireless protocols originally designed for sensornets towards inherently similar Linux driven ad hoc and mesh networks.

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, bit errors on a wireless link are detected by CRC on the physical layer and erroneous packets are discarded. However, many voice and video coding schemes make use of error concealment, and therefore prefer the reception of partially corrupted data to no data at all. Being able to receive partially corrupted data therefore is a vital point in enhancing the quality of VoIP communication, especially over wireless links, where bit errors are much more common.
However, if errors occur, the application needs to be made aware of these. Depending on whether it accepts partially corrupted data, it will receive the packet, or the packet will be dropped. An important problem here is the occurrence of errors in packet headers, because these contain management information vital for identifying the correct receiver. These errors therefore have to be corrected while the packet is processed in the network stack.

One important building block is the use of soft information, that is, the confidence that the physical layer placed in its decision whether a bit decoded from the received analogue signal is a 0 or 1. This approach has been used for some time already in turbo coding schemes, and is also used for specialized voice codecs. In a packet-switched network, however, the two decoders would reside in the APP and PHY layer, respectively, and therefore be separated. Cross-layer signalling must be used to restore a direct communication path between the two. In addition, the soft information that these decoders work with can be used to improve on error correction in protocol headers, by identifying which errors coincide with low confidence in the correct bit value. Finally, correct or reconstructed headers can be used in the same way as pilot bits, boosting the perceived speech quality of a VoIP stream after decoding with an iterative decoder.

Distributed filesystems for Wireless Mesh Networks

Benjamin Schleinzer

In my project, I am exploring how multiple users can share information and collaborate while connected to a wireless mesh-network. Solutions that work well for participants from different institutes and disciplines are distributed file systems. They don’t impose a new way of working with files and client-side administration is kept to a minimum. Today’s distributed file systems can be classified into two different approaches: Firstly we have clients accessing resources on a server and secondly we have peers in a Peer-to-Peer network that are used to store our files. My work concentrates on Peer-to-Peer based file systems, as topology changes in mesh-networks due to the fluctuation of network users calls for a flexible solution. Client-server based approaches do not offer this kind of flexibility. The goal of the project is to show that unique requirements exists for a distributed file system for wireless mesh-networks. In my thesis I will present these requirements and evaluate them based on an implementation of such a file system developed during the project.

Peer-to-Peer techniques can be used in different ways which results in certain advantages, e.g. shared workload, redundant data storage, but also present new challenges, e.g. confidentiality and availability of data. Also the increased network load created by the communicating peers has to be considered. This means, during every step of the development the produced data volume needs to be kept low while data availability must be guaranteed. To streamline the development process we defined two data types: so called containers store metadata about the file system, directories or files and each container uses a unique cell tree (a data structure organized as a tree consisting of single cells) as a data backend.

While communication protocols are researched in another group, my work focuses on the security of the file system. A critical aspect of our file system is that the content of the cell trees must be secured against unauthorized access or manipulation while sharing the content with multiple trusted users must still be possible. To satisfy this assumption and maintain the
ability to store containers and cell trees on untrusted nodes strong encryption is needed. At the same time some data like the containers holding file system descriptors must be readable by everyone while still be resilient against manipulation.

From a security standpoint we face different problems. Besides the described security concerns we need to reliably identify threats against our assets (cell trees and containers) during every phase of development. In a next step mechanisms to negate these threats must be identified. Eventually these mechanisms need to be evaluated in regards to generated network load, classified according to evaluation and finally implemented. To help with this complex process we are looking at security patterns, but finding the security patterns most suitable to our unique problem remains a challenge. Currently there exists no global database or tool to search for security patterns in a structured.

CAIRO - context aware intermodal routing

Uta Christoph, Karl-Hinz Krempels

Goal of the CAIRO project is to offer a navigation and assistance system for the public transport on mobile devices (mobile or smart phones), which links static data (e.g. railway stations, time schedules) with dynamic data (train delays, route changes for busses) into an intermodal routing service.

With the help of this system users can be provided with individual information depending on their current situation. For example, in case of delays on long distance travels alternative routes can be determined. CAIRO achieves this by considering intermodal offers (e.g. trains, busses, car or bycicle sharing possibilities) and traffic information of the public transport. Thus for the first time an intermodal, dynamic routing is realized which takes into account the current location of the user and real time data of the public transport system.

CAIRO is a joint project of Deutsche Bahn AG (DB Vertrieb GmbH), HaCon GmbH, InnoZ GmbH, RWTH Aachen University, and VBB Verkehrssverbindung Berlin-Brandenburg GmbH.

The Impacts of Next Generation Wireless Networks on Transport Protocols

Alexander Zimmermann

Future Mobile Web Services and Applications develop an ever-increasing demand for reliable high-speed communication. In recent years, a new class of networks that aim to meet these requirements have evolved: Wireless Mesh Networks (WMN). Since they provide a flexible technology WMNs are easy to deploy in areas where the installation of a (wired) infrastructure is impossible or too costly. Although their redundant, hierarchical and layered architecture promise a self-organizing, -healing, and -configuring network the advantages cannot be fully utilized due to protocol constrains. While efforts exists to improve the general
performance on the wireless link layer (e.g., cognitive radios, dynamic spectrum access, beam forming etc.), the idiosyncrasies of those next generation networks pose new challenges to protocols on almost every layer of the OSI Reference Model. Especially the transport layer constitutes an unexplored area for this kind of networks since only little work exists in this area. For instance, the performance of today's most popular reliable transport protocol, the Transmission Control Protocol (TCP), not only depends on the access technology, but also on the frequency in use, interference level, the bandwidth available, and the employed routing techniques. To eliminate the adverse effects of non-congestion events caused by emerging technologies on underlying layers existing transport protocols need to be redesigned. Moreover, the unique characteristics of WMNs provide opportunities to improve performance and reliability in such networks.

SliceTime: Hybrid Evaluation of Distributed Systems
Elias Weingärtner, Klaus Wehrle

The goal of SliceTime aims at making the concept of network emulation accessible for the analysis of large-scale distributed systems. SliceTime relies on the integration of real-world prototypes, which are typically constituted by a software program, and a simulation, which models the context of the prototype. For example, the prototype may be the implementation of a network protocol, and the network simulation would model any arbitrary computer network in this case, for example, a corporate network or potentially a internet backbone which consists of a set of routers and network links. But why to 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 available at any point in time. However, while network simulation 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. Hence network emulation spans the gap between these worlds, compensating the weaknesses of each other.

Over the past year, we were able to transform an early proof-of-concept implementation into usable system. More specifically, the following contributions have been achieved lately:

- A first experiment has shown that SliceTime is applicable to large-scale scenarios with more than 10000 hosts in the simulation. In the experiment, we investigated a emulation scenario with 15000 nodes exchanging data in a P2P fashion.
- By porting the simulation engine to the ns-3 simulator, we are now able to leverage any ns-3 simulation set-up for investigations using our hybrid emulation framework.
- SliceTime has been extended for the analysis of 802.11 networks

Besides these contributions, we have also demonstrated the applicability of this methodology to the domain of embedded systems. We are also currently preparing the framework for benchmarking different BitTorrent implementations.
Discrete event-based simulation is a commonly used evaluation methodology throughout the development process of networked systems. However, it currently faces at least two significant challenges: First, recent advances in wireless communication technology demand highly accurate simulation models, resulting in a steep increase in model complexity and runtime requirements. Second, multi-processor computers constitute the de-facto default hardware platform even for desktop systems, thus providing cheap yet powerful “private computing clusters”. As a result, the parallelization of discrete event simulations significantly gained importance and is therefore (again) in the focus of active research.

Model Complexity: Simulation models of wireless networks typically require a considerably more detailed modeling of the lower network layers than models of wired networks. In particular, the wireless channel and the physical layer demand precise models to capture the subtle effects and interactions of advanced wireless communication technologies such as MIMO transmissions or successive interference cancelation. Consequently, simulation runtimes increase drastically which in turn hampers the development process and in-depth evaluations.

Parallel Discrete Event Simulation: Being an active field of research for more than two decades, parallel discrete event simulation is supported by a wide range of network simulation frameworks. Despite this tool support, creating a parallel simulation model is still challenging and running simulations on a distributed simulation cluster is complex. At the same time, the increasing number and speed of processing cores in today’s commodity hardware makes a higher degree of parallelization very attractive and cost-effective for speeding up network simulation. Nevertheless, a key challenge in parallel simulations, in particular of wireless networks, is the efficient utilization of the available processing power.

In this project we address these challenges by developing a novel parallelization architecture that specifically focuses on the efficient simulation of wireless network simulation models on state-of-the-art multi-core computers. We primarily investigate means of extracting a maximum degree of parallelism from a given simulation model and schemes to achieve a balanced work load across computing cores.
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.

High-coverage Testing of Communication Protocols Before Deployment
Raimondas Sasnauskas, Klaus Wehrle

High-coverage testing of sensornet applications is vital for pre-deployment bug cleansing, but has previously been difficult due to the limited set of available tools. The main challenge is to detect bugs that occur due to low-probability events, such as node reboots and packet losses. These events, due to their non-deterministic nature, have the potential to drive the distributed execution into corner-case situations hard to detect using existing testing and debugging techniques.

In our project, we designed and implemented KleeNet, a debugging environment that aims to effectively discover such situations before deployment. By running unmodified
communication protocols on symbolic input and automatically injecting non-deterministic failures, KleeNet automatically generates distributed execution paths at high-coverage. Moreover, we integrated the KleeNet symbolic execution engine with the COOJA sensor network simulator to allow for straight-forward and intuitive high-coverage testing initiated from a simulation environment. A tight coupling of simulation and testing helps detect, narrow down, and fix complex interaction bugs in an early development phase.

The main challenge in this project remains to be the scalability and the detection of redundant execution states. We plan to apply state mining techniques for both state equivalency and new bug detection.

A Quality of Experience Architecture for Wireless Metropolitan Area Sharing Networks.

Mónica Alejandra Lora

Nowadays the mobile wireless users are in constant demand of connectivity, and so the same, different applications require more bandwidth or they have strict Quality of Service (QoS) requirements. The challenge that presents itself to these trends is to ensure the accessibility and good performance of these services to the user, because it is the only way to promote the use and inclusion of ubiquitous services to the society.

The Cooperative Wireless Networks (CWN) are becoming an inexpensive alternative for these new trends. In CWN, the Access Points (APs) belong to different domains and cooperate in such a way that allow stations (STAs) to access services such as Internet, without a centralized management entity of the whole infrastructure.

Currently, the STAs select the AP based on the Received Signal Strength Indication (RSSI) related to each AP link. It is advisable do not use the default AP-selection mechanism defined in IEEE 802.11e, because it does not always lead to an association with the best AP. If several STAs choose the same AP based on the RSSI, this AP will be overloaded and probably its neighbor AP will be under-utilized.

In this way, a key issue with the use of CWN is how to distribute in a more efficient and fair way the resources between STAs and APs into the CWN, taking into account that every AP has different capabilities, load and coverage; and in the same way, the requirements and features of every mobile STA are different, but are looking for a good service level / quality of user experience (QoE).

In order to provide bandwidth balancing in the decentralized CWN, as well as QoE for the selfish users, it is necessary to design a service model based on metrics (like availability, speed, cost, trust) from the user’s domain and using Quality of Service (QoS) indicators, which will allow proper management of resources in the CWN, and therefore beneficial for the users. Relative to the user’s domain it is important to model the user’s goals and expectations, in the same way, the current context of the user.
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.
Other Activities

Klaus Wehrle

Programme Committee member of (excerpt)

- The 3rd International Workshop on OMNeT++
- The 2nd International Workshop on Information Quality and Quality of Service for Pervasive Computing (IQ2S'10)
- The 10th IEEE International Conference on Peer-to-Peer Computing (P2P'10)
- The 35th IEEE Conference on Local Computer Networks (LCN)

Reviewer for

- Transactions on Industrial Informatics
- ACM Transactions on Sensor Networks
- Information Technology
- ACM/IEEE Second International Conference on Cyber-Physical Systems
- IEEE International Conference on Cluster Computing 2010
- 5th ACM International Workshop on Mobility in the Evolving Internet Architecture

He also served as external expert for Eidgenössische Kommunikationskommission

Dirk Thißen

Programme Committee member of

- 6th Int. Conf. on International Conference on Web Information Systems 2010,
- 9th Int. Conf. on WWW/Internet 2010,

During Summer Term, Dirk also held a temporary professorship at the Computer Science Department of the University of Bonn.

Tobias Heer

Co-organizer of

- the ‘Mobile Collaboration Systems’ Workshop, held in conjunction with the 9th International Conference on the Design of Cooperative Systems
- a Workshop on ‘Collaborative mobile networking’ at Lake. This workshop was a joint workshop between the Helsinki Institute for Information Technology and Comsys.

Panelist on ‘Advances and Future of Wireless Converged Networks, at the CON-WIRE Workshop @ ICCCN 2010 in Zurich.

Kai Jakobs

Editor-in-Chief

- International Journal of IT Standards & Standardization Research,
• ‘Advances in IT Standards & Standardization Research’ book series,
• ‘EURAS Contribution to Standardisation Research’ book series.

Editorial Boards
• ‘Advances in Information Resources Management’ book series,
• Business Process Management Journal,
• Information Resources Management Journal,
• Informing Science.

Programme Committee member of
• 6th Int. Conf. on International Conference on Web Information Systems 2010,
• 14 Int. Conf. on Internet and Multimedia Systems and Applications 2010,
• 9th Int. Conf. on WWW/Internet 2010,
• 3rd ITU Kaleidoscope conference 2010,
• 15th Int. Conf. of the European Academy for Standardisation

Reviewer for
• IT & People,
• Technological Forecasting & Social Change,
• Organization Studies,
• Policy & Internet,
• Oxford University Press,
• MIT Press.
Publications


UMIC Mobile Network
Performance Group

Staff

• Faculty
  Prof. Dr. James Gross

• Research Assistants
  Oscar Puñal
  Christian Dombrowski
  Donald Parruca
  Di Li

• Guests
  Peter Pisarcik
Overview

The Mobile Network Performance Group is a junior research group that is associated with the DFG Excellence cluster UMIC – Ultra-high Mobile Information and Communication – as well as with the chair computer science 4 Communication and Distributed Systems (Prof. Wehrle). The Mobile Network Performance group deals with research questions at the intersection of computer science and electrical engineering with a special focus on adaptation in wireless networks. Our current research fields include:

- Design & performance of 80 MHz future wireless local area networks
- Energy-efficient adaptation in LTE cellular networks
- Parallel network simulation for wireless systems and networks
- Ultra-high reliability in wireless local area networks for industrial applications
- Clustering and routing in cognitive ad-hoc wireless networks

In our research we rely on a set of different methodologies, namely mathematical analysis, simulations and prototyping. Our research lab consists of a large server for parallel network simulation of LTE networks as well as of a FPGA-based prototyping environment for lower layer wireless network development and research.
Research Projects

Ultra-robust Wireless Transmission

This project covers aspects of highly reliable communication over wireless channels. An application scenario is real-time sensitive message exchange, e.g. in industrial automation. This exchange is carried out as a wired connection in traditional systems. However, using cables not only reduces flexibility but also causes installation and maintenance costs. Developments of wireless transmission systems over the last decades have shown an immense progress. Hence, it is reasonable to think about employing wireless transmission systems instead of using cables.

In this context, a multitude of challenges arise: Beside the problem of radio channel volatility, there is also the task of deterministic medium access in a multi-station scenario. In previous work, these problems were either tackled on a very abstract theoretical level, or by suggesting algorithms dealing with particular scenarios.

That is why we follow an integrated cross-layer approach. Our intention is, on the one hand, to gain insights into theoretical boundaries of reliability over wireless channels, and on the other hand, to develop algorithms which base on these theoretical boundaries and their implications. The next - and most important - step is to realize these algorithms in a practical system, and see how the reliability can be improved under real world conditions.

The Wireless-OpenAccess-Research Platform developed at Rice University, Houston - TX/USA, serves as the basis for our implementations. We have already developed a medium access protocol using a token passing scheme to achieve a decentralized deterministic medium access. This protocol supports differentiated traffic classes, and is flexible and failure tolerant.

UMIC Simulation Framework

(joint project together with Georg Kunz and Klaus Wehrle)

Discrete event-based simulation is a commonly used evaluation methodology throughout the development process of networked systems. However, it currently faces at least two significant challenges: First, recent advances in wireless communication technology demand highly accurate simulation models, resulting in a steep increase in model complexity and runtime requirements. Second, multi-processor computers constitute the de-facto default hardware platform even for desktop systems, thus providing cheap yet powerful “private computing clusters”. As a result, the parallelization of discrete event simulations significantly gained importance and is therefore (again) in the focus of active research.

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wireless channel and the physical layer demand precise models to capture the subtle effects and interactions of advanced wireless communication technologies such as MIMO transmissions or successive interference cancelation. Consequently, simulation runtimes increase drastically which in turn hampers the development process and in-depth evaluations.

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In this project we address these challenges by developing a novel parallelization architecture that specifically focuses on the efficient simulation of wireless network simulation models on state-of-the-art multi-core computers. We primarily investigate means of extracting a maximum degree of parallelism from a given simulation model and schemes to achieve a balanced work load across computing cores.
Talks and Publications

Talks


Publications


M. Bohge, J. Gross, and A. Wolisz, "Optimal Soft Frequency Reuse and Dynamic Sub-carrier Assignments in Cellular OFDMA Networks", European Transactions on Telecommunications, (accepted for publication).


We are very proud that the group was also able to compile together with several other groups from UMIC and together with the COMSYS group of Prof. Wehrle the following book publication:

Staff

- **Professors:**
  - Prof. Dr. rer. pol. Matthias Jarke
  - Prof. Gerhard Lakemeyer, Ph.D.
  - Prof. Dr. rer. nat. Thomas Berlage
  - Prof. Wolfgang Prinz, Ph.D.
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- **Researchers:**
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  - Mohamed Amine Chatti (until 31.08.2010)
  - Olga Domanova
  - Vito Evola (since 28.10.2009)
  - Sandra Geisler
  - Sukeshini Grandhi Ph.D.
  - Anna Hannemann
  - Matthias Häusler
  - Jessica Huster
  - Fisnik Kastrati (since 05.07.2010)
  - David Kensche
  - Dr. Ralf Klamma
  - Dejan Kovachev
  - Dr. Milos Kravcik (since 01.02.2010)
  - Dr. Karl-Heinz Krempeels (since 1.08.2010)
  - Stefan Kreutter (until 31.12.2009)
  - Xiang Li
  - Dr. Andreas Lorenz (since 01.02.2010)
  - Dominik Lübers (until 28.02.2010)
  - Jan Robert Menzel (since 01.04.2010 until 31.10.2010)
  - Zinayida Petrushyna
  - Manh Cuong Pham
  - Dr. Christoph Quix
  - Dr. Jürgen Rapp
  - Khaled Rashed
  - Dominik Renzel
Dominik Schmitz
Christoph Terwelp (since 01.06.2010)
Yao Wang
Dietlind Zühlke

• **Visiting Lecturers:**
  Chief Social Scientist Marc Smith, Ph.D.

• **Technical Staff:**
  Tatiana Liberzon
  Reinhard Linde
  Daniel Plötzer (until 02.09.2010)

• **Student Researchers:**

• **Cooperation Partners:**
Overview

Today, the field of Information Systems includes not just structured databases, but at least equally important the semi-structured and unstructured data in the World Wide Web. The Chair Informatik 5 addresses both domains, with the management of so-called metadata (data about data) in the kernel of its research interests. Current major themes include mobile web services and applications, metadata model management, and technology enhanced learning.

In the academic year 2009-2010, the group enjoyed once again a significant growth of third-party funding. The total grew to well above 2 m€ for 2009 and is expected close to 3 m€ in 2010. The largest growth in additional projects was in the sector of technology-enhanced learning where several new EU-funded projects and networks of excellence started, but also new projects in cooperation systems and life science informatics with BMBF funding were added; the application domain for mobile communication pursued in our Excellence Cluster UMIC was extended to the field of Car-to-X communication. Prof. Jarke was invited to present an overview talk on UMIC at the German national computer conference, Informatik 2010, which drew over 1.100 participants to Leipzig in September 2010.

Members of the group took leading roles in the organization and program chairing of international conferences, including the IEEE UbiMedia 2010 Conference in Shanghai and the 12th International Conference on Electronic Commerce (ICEC 2010) in Honolulu, several workshops on multimedia metadata and storytelling/ educational gaming, and once again the Joint European Summer School on Technology-Enhanced Learning.

The total personnel at Informatik 5 grew to over 40 researchers and administrative personnel, plus over 25 student assistants. The team represents by now almost 20 different nationalities. In personnel development, a major step was the habilitation of Dr. Ralf Klamma which was completed in July 2010 and formally approved by the Faculty of Mathematics, Informatics, and Natural Sciences after the summer break. In addition, doctoral theses were defended by Andreas Lorenz, Dominik Lübbers, Amine Chatti, and David Kensche. To assist guidance of the growing number of doctoral student and management of the many projects, several new postdocs were hired, including Dr. Sukeshini Grandhi (from NJIT, USA), Dr. Milos Kravcik (Open University Netherlands), Dr. Andreas Lorenz (Fraunhofer FIT), and Dr. Karl-Heinz Krempels (until summer 2010 member of Informatik 4). Dr. Amine Chatti joined the CiLeLearning Center of RWTH Aachen University after completing his doctorate in our group, whereas Dr. Dominik Lübbers joined the HaCon train research center in Hannover.

The cooperation with the Fraunhofer Institute for Applied Information Technology FIT continued in 2010, in research through an increasing number of joint projects and personnel exchanges, in teaching through the Bonn-Aachen International Center for Information Technology (B-IT) and the new B-IT Research School for Doctoral Training. In B-IT, a major effort was preparing and conducting the materials and audit for the re-accreditation of our international master programs in Media Informatics and Life Science Informatics, also for the RWTH master degree on Software Systems Engineering. For the first time, the new European accreditation agency EQANIE was active in Germany as part of this process, so that these programs will be the first computer science programs in Germany accredited both nationally and Europe-wide. In the B-IT Research School, again a huge number of applications for doctoral scholarships were received, making it a hard work to select the last of our now 27 scholarships. A former RWTH library is currently remodeled to improve the B-IT research training facilities.
Research Projects

Research projects at Informatik 5 are organized according to the groups of mobile applications and services, technology enhanced learning and communities, model and data management.

Excellence Cluster UMIC Mobile Applications and Services:
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. UMIC was 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 groups 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 institutes of electrical engineering, mechanical engineering, architecture, and computer science in two subprojects in the research area of “Mobile Applications and Services”.

UMIC group at Informatik 5
Virtual Campfire aims to provide professional communities such as researchers’ communities for cultural heritage management an advanced framework to create, search, and share multimedia artifacts with context awareness easily and fast. Advanced multimedia storytelling approaches are conceptualized and developed based on metadata standards and Community of Practice concept. Requirements from professional communities are analyzed based on real research scenarios in cultural heritage management in Afghanistan together with researchers from Aachen Center for Documentation and Conservation. Research based on those requirements deals with problems and challenges of mobile multimedia management for professional communities.

In 2010, Mobile Campfire, the mobile version of Virtual Campfire, has been launched on iTunes App Store. Mobile Campfire enables user communities to create, annotate, search, and share photos and share multimedia stories on iPhone, iPod and iPad. The prototype of SeViAnno extends the semantic-enhanced video annotation service for Virtual Campfire to enable collaborative tagging of video frames based on the metadata standard MPEG-7. Research results and prototypes have been presented and demonstrated at several international conferences, including MDM 2010. Upon request of Culture Section of German Foreign Office, an evaluation of the historic city walls of Ghazni in Afghanistan, the future Islamic Culture Capital in 2013, has been conducted using our technology by cultural heritage experts from RWTH Aachen Center of Documentation and Conservation.

Several academic events were organized to discuss research questions for mobile multimedia management. The UMIC Workshop on Future Mobile Applications (UMICWS’10,
http://dbis.rwth-aachen.de/cms/events/umic-workshop-on-future-mobile-applications), jointly organized with Fraunhofer FIT, was held on February 26th, 2010, at UMIC Research Center. Over 40 PhD students and researchers from UMIC and other institutions participated in the workshop. A successive workshop proposal of the First IEEE PerCom Workshop on Pervasive Communities and Service Clouds (PerCoSC 2011) was accepted by the IEEE International Conference on Pervasive Computing and Communication, together with Prof. Christian S. Jensen from Aarhus University, Denmark. The Third International Workshop on Story-Telling and Educational Games (STEG 2010), to be held in conjunction with ICWL 2010 in Shanghai (December 2010) continues with the success of the first two workshops and explores advanced research results and questions with the research communities.

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), Informatik 9 (Data Management and Exploration) and the UMIC research group IT Security. The aim is to develop a P2P network in which patients, doctors, nursing staff, and emergency services have full and protected access to information and services in their mobile work environment. Data about the health status of a patient is collected by a network of sensors integrated in the textile clothes. The data can be reviewed by doctors to consult the patients online, or by the emergency service to improve the diagnosis in an emergency situation.

The initial prototype includes a body sensor shirt for measuring vital parameters and a mobile device for data integration and analysis. The data collected on the mobile device can be sent to other peers in the network for further analysis. This prototype is now applied in a sports context: a mobile monitoring system for runners. Runners often overestimate their physical condition and overstrain themselves during practice or competitions. Therefore, a mobile monitoring system which measures crucial vital parameters can help to avoid critical situations. It is planned to apply the system in the Lousberglauf 2011, an annual running event in Aachen with more than 2000 participants.

The work of Informatik 5 focuses on the development of the mobile software for data integration, data exchange and data visualization. Requirements for the sports application were collected by several interviews with runners and coaches from the university teams. The software will be developed on the Android platform.

Cooperative Cars – CoCar

M. Jarke, C. Quix, S. Geisler, S. Schiffer, Guido G. Gehlen (Ericsson GmbH Eurolab), Gordian Jodlauk (Ericsson GmbH Eurolab), P. Roy, S. Weber

The Cooperative Cars (CoCar) project, supported by the German Federal Ministry for Research and Education and Ericsson EuroLabs, will test the suitability of UMTS technologies and their foreseeable extensions (such as LTE) for direct, targeted transmission of traffic data arising from both stationary and vehicle-based sensors. The CoCar project is a
part of the research initiative Adaptive and Cooperative Technologies for the Intelligent Traffic (AKTIV) led by the German automotive industry. Several partners from telecommunications and automobile industry will identify which traffic management and driver assistance applications are suitable for use of this technology. A first phase of the project was finished in 2009; the project is now continued in the Cooperative Cars Extended (CoCarX) project.

Informatik 5 cooperates in this project with Ericsson in Aachen and Fraunhofer FIT and develops data models, algorithms and systems for the data processing of CoCar applications. One focus is the research on a data quality model to simulate and estimate the effect of various parameters in data acquisition and processing for the traffic state estimation and forecasting. Furthermore, we investigate data stream management systems as the core component for the data processing, and we study data mining algorithms for the traffic state estimation. Based on a quality - and priority-based traffic information fusion architecture, Informatik 5 has developed a simulation test bed to identify the properties of roadway networks and system design parameters which have a significant impact on the quality of the traffic state estimation. For example, the simulation framework has been applied to the queue-end detection problem: based on messages which are sent by CoCars (e.g., emergency braking or warning flashers) the system has to identify the location of the end of a traffic jam. This is an important application as many accidents are caused by drivers not realizing a queue-end in front of them.

![The queue-end detection scenario](image)

![Screenshot from the traffic simulation showing real and forecasted queue end](image)
CAIRO - context aware intermodal routing
O. Spaniol, K.-H. Krempels, U. Christoph, C. Terwelp

Goal of the CAIRO project is to offer a navigation and assistance system for the public transport on mobile devices (mobile or smart phones), which links static data (e.g. railway stations, time schedules) with dynamic data (train delays, route changes for busses) into an intermodal routing service. With help of this system an user can get individual information depending on her current situation. For example, in case of missed connecting trains on long distance travels alternative routes can be determined. CAIRO achieves this by considering intermodal offers (e.g. trains, busses, car or bicycle sharing) and real time information of the public transport systems. Thus for the first time an intermodal, dynamic routing is realized which takes into account the current location of the user and real time data of the public transport system. CAIRO is a joint project in cooperation with Deutsche Bahn AG, HaCon GmbH, InnoZ GmbH, and VBB Verkehrsverbund Berlin-Brandenburg GmbH.

Research Group Metadata in Community Information Systems

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 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. The group started three new research projects OBIP, TELMAP and GALA in 2010. We have strong funding in technology enhanced learning and cultural heritage management with a “Web Science” research approach. We combine analytic methods for the Web like social network analysis, community/multimedia/text & data analysis with advanced Web engineering methods (single-login, variable and fine-granular access control, mobility support, multimedia management, multimedia annotation, interoperable search and retrieval, matching) for the support of professional communities in domains with ever changing and demanding requirements.

We organized two workshops in the Multimedia Metadata Community (http://www.multimedia-metadata.info) in Barcelona (WISMA’10) and in Saarbrücken (SeMuDaTe’10) as well as workshops about about storytelling and educational gaming (ETEL WS, STEG’10) in Barcelona and Shanghai. Highlights of the year were our strong participation in the organization of the IEEE Ubi-Media in Jinhua, China, in July 2010 and the JTEL Summer School 2010 in Ohrid, Macedonia.
The aim of this DFG-funded cluster project of four NRW universities is development and research of context adaptive systems for knowledge processes. The main goal of the Informatik 5 subproject “Traceable Cooperative Requirements Engineering for Communities-of-practice” is the extension of earlier context, process or cooperation models by comprehensible evolution histories, this leading towards a cycle of comprehensible information collection, processing and employment for learning and re-engineering.

In 2009-2010, three new community-oriented requirements engineering tools were developed. The Bubble Annotation Tool (BAT) allows enjoyable collaborative requirements elicitation by multimedia annotation with speech bubbles. The core service of BAT combined with different social community analysis measurements served as basis for the CONTici Dashboard (DABA). Community-awareness within DABA fosters participation of community members in the requirements engineering process. The third system captures agent-oriented scenarios of processes or systems in a story-telling approach: “MIST-M” presents a mobile story-telling platform, allowing requirements sharing within community anywhere at any time while Similarity Search (SiSe) provides conflict and similarity identification between different scenario stories.

This project is supported by Graduiertenkolleg (GK) “Software for mobile communication systems”. The aim of the project is to represent and analyze scientific knowledge in the field of Computer Science and develop recommendation techniques that support researchers to find conferences and journals to submit papers, to search for interesting research communities and potential collaborators. Social Network Analysis (SNA) is applied to discover the pattern of interaction between researchers, especially in Web 2.0 environment. Visualization techniques are used to represent and identify research communities and their evolution in term of knowledge diffusion and research collaboration.

In 2009-2010, we integrated data from two large digital libraries - DBLP and CiteSeer. Based on this data, we built a so-called map of computer science knowledge to understand how the knowledge in computer science is organized. Clustering is performed on the knowledge network to identify the similar venues (conferences, journals, workshops) and to understand the relations between research domains. Venues are ranked using some SNA measures such as betweenness, PageRank and HITS scores, to identify interdisciplinary, high prestige and top knowledge consumers and producers. The visualization and ranking were integrated in our system called AERCS (An Academic Event Recommender system for Computer Scientist). Furthermore, we evaluated our clustering approach for recommender system in digital libraries using social network. The evaluation on venue recommendation shows that clustering approach outperforms traditional collaborative filtering.
This work was supported in part by NRW State within the B-IT Research School. The goal of the project is to investigate possibilities to augment the capabilities of weak mobile devices and develop middleware that can seamlessly offload the computing and storage of mobile applications into the Cloud. Cloud computing technologies have been emerging recently as a solution to scalable on-demand computing storage resources that can be accessed via the Internet. The never ending strife for increasing mobile processing power and more data, Clouds can be the best possible solution to augment the mobile execution platform. Furthermore, due to changing conditions in the mobile environments, context-awareness can play crucial role in delivering mobile services with best performance.

ROLE Architecture

ROLE is an EU-funded large-scale integrating project within the 7th Framework Program in the domain of technology enhanced learning (TEL). The project aims at delivering and testing prototypes of highly responsive TEL environments, offering breakthrough levels of effectiveness, flexibility, user-control and mass-individualization, thereby advancing the
state-of-the-art in human resource management, self-regulated and social learning, psychopedagogical theories of adaptive education and educational psychology, service composition and orchestration, and finally the use of ICT in lifelong learning. ROLE offers adaptivity and personalization in terms of content respectively navigation and the entire learning environment and its functionalities. This approach permits individualization of the components, tools, and functionalities of a learning environment, and their adjustment or replacement by existing web-based software tools. Learning environment elements can be combined to generate (or mashup) new components and functionalities, which can be adapted by collaborating learners to meet their needs and to enhance the effectiveness of their learning. Informatik 5 is the vice-coordinator of the project, acting as technical leader and community facilitator.

Already in early phases of the project, a project-within-project culture was established in order to drive the development of various stages of ROLE software prototypes, starting with the ROLE Christmas Project resulting in first prototypes for ROLE-enabled Widget PLE, and continued with the ROLE Easter Project, where prototypes were directly developed for the application and evaluation in the five ROLE test-beds. The cooperation of I5 with ZLW/IMA and Fraunhofer FIT resulted in an enhanced version of a Web 2.0 Knowledge Map for the RWTH test-bed, which was designed to support mechanical engineering students during their introductory programming lecture and lab course at RWTH Aachen University. The outcomes of both projects also resulted in publications in TEL journal special issues. Currently, the I5 team is responsible for the management of the subproject Stonehenge kicked-off during the first ROLE Developer Camp held in August 2010 in Lausanne, Switzerland. The expected outcome of Stonehenge is a showcase platform to be publicly presented at fairs, conferences, etc. A further highlight was the first dissemination trophy won by the I5 team for numerous publications, presentations, and community facilitation activities in the context of ROLE. In the second dissemination trophy the I5 team was runner-up.

**EU Support Action TELMAP: Future gazing Technology Enhanced Learning - The Roadmap for the unknown Learning Landscape**

*M. Jarke, R. Klamma, M. Kravcik*

TELMAP focuses on ‘exploratory/Roadmapping activities for fundamentally new forms of learning’ to support take-up of those new forms, via ‘awareness building and knowledge management on the results of EU RTD projects in TEL’ and ‘socio-economic evaluations in education and for SMEs’. We gather information on the current, desired and emerging position of TEL, and on awareness and appropriation (by educators and SMEs) of RTD results in TEL. We codify that information using state-of-the-art knowledge management methods, at three levels of scale: 1) macro (political, economic, social, technological, legal, and environmental), 2) meso (organisation of education and training systems and institutions), and 3) micro (enacted paradigms of learning and teaching). Cutting across these levels of scale is the categorisation of changes as exogenous or endogenous relative to forms of learning and to the TEL community. This provides direct input to TEL-relevant decisions at all three levels, including economic, political, and research discussions.

With a 10-year horizon, we co-develop a portfolio of stakeholder-specific roadmaps and influence maps, to gain insights into fundamentally new forms of Learning, Education and Training activities (LET) and into what makes for effective transfer and scalability. Our collaborative development approach leads to a Multi-perspective Dynamic Roadmap to track, anticipate and manage knowledge about new forms of LET and their impact on TEL. This
extends established TEL Roadmapping methods in novel, powerful and cost-effective ways, with high potential for sustainability and for targeting each stakeholder’s goals. Outcomes include well-grounded recommendations on TEL and LET innovations, plus a platform and a sustainable dynamic process that will foster collaboration and consensus-building across specialized communities and stakeholder groups.

EU Network of Excellence GALA: Gaming and Learning Alliance

M. Jarke, R. Klamma, M. Kravcik

GaLA gathers the cutting-the-edge European Research & Development organizations on Serious Games, involving 31 partners from 14 countries. Partnership involves universities, research centers, and developer and education industries. The GaLA motivation stems from the acknowledgment of the potentiality of Serious Games (SGs) for education and training and the need to address the challenges of the main stakeholders of the SGs European landscape (users, researchers, developers/industry, educators). GaLA aims to shape the scientific community and build a European Virtual Research Centre aimed at gathering, integrating, harmonizing and coordinating research on SGs and disseminating knowledge, best practices and tools as a reference point at an international level. The other key focuses of the project are: the support to deployment in the actual educational and training settings; the fostering of innovation and knowledge transfer through research-business dialogue; the development high-quality didactics on SG by promoting and supporting courses at Master and PhD level.

EU Life Long Learning Program TeLLNet: Teachers’ Lifelong Learning Networks

M. Jarke, R. Klamma, Y. Cao, Z. Petrushyna, M. C. Pham, R. Vuorikari (European Schoolnet)

The new EU Life Long Learning Project TeLLNet supports the European Schoolnet in cooperation with the European Schoolnet, Open University the Netherlands, and Institute for Prospective Technological Studies (IPTS) as one of European Commission Joint Research Centers. Within the project we are going to apply network analysis methodologies and approaches on social networks to analyze patterns of human communication, cooperation, and other kinds of interaction taking place in business, organizations and the World Wide Web. Social Network Analysis (SNA) provides a useful approach to identifying social capital and social structure in Schoolnet communities. Small world effect and scale-free networks are observed and analyzed. This research work is based on both theoretical research and practices. In 2010, we applied SNA as a meta-competence to describe, represent and evaluate social and professional competence for teachers’ lifelong learning. Thus, a competence model is developed for dynamic competence management based on SNA. This new approach brings new methodologies, perspectives and information services of competence management in research areas of lifelong learning and technology enhanced learning. It can be applied in competence management and development within organizations and enterprises. The experiments and evaluation are conducted on the continuously growing data set of the European school network with over 72,000 schools, 130,000 registered teachers, 17,000 projects and a large number of emails and blogs. First evaluation result proves the power law distribution of the teachers’ networks.
DAAD IKYDA: Non-linear Digital Storytelling for the Battleship “G. Averof”

M. Jarke, R. Klamma, Y. Cao, A. Hannemann, D. Kovachev, E. Stefanakis (Harokopio University, Greece), G. Kritikos (Harokopio University, Greece), E. Gadolou (Harokopio University, Greece), H. Papadaki (Harokopio University, Greece)

Non-linear digital storytelling for the battleship “G. Averof” is an interdisciplinary research project with Harokopio University, Athens, starting in 2009 within the IKYDA program. The IKYDA program is an integrated action program between German Academic Exchange Service (DAAD) and the Greek State Scholarship Foundation (I.K.Y) since 2000 to promote academic research cooperation between German and Greek researchers. The battleship “G. Averof” is the world's only surviving heavily armored cruiser of the early 20th century and serves as a museum operated by the Greek Navy today. This research project aims at the promotion and enrichment of the museum archives for cultural heritage management. We seek to share knowledge on advanced storytelling platforms and services for the battleship "G. Averof" with advanced 3D scanners, helicopter cameras to capture objects on the battleship. It provides communities more opportunities to create, access, share, and even reuse the large valuable multimedia collection about the battleship “G. Averof” with Web 2.0 community based storytelling technologies. It will contribute to advanced research on social software, storytelling, multimedia metadata, GIS, and cultural heritage management together with the project Virtual Campfire.

IKYDA project meeting at Harokopio University, Greece, 19-11-2009

Researchers from Harokopio University have paid two visits in January and September 2010 to exchange knowledge with the colleagues at Informatik 5. A group of research assistants and students for Informatik 5 have visited Harokopio University in November, 2009. During the exchange stay, the battleship “G. Averof” was scanned with the Riegl LMS-Z390i 3D scanner with over 20 scans from different viewpoints. Y. Cao, A. Hannemann and D.
Kovachev presented research on multimedia storytelling and 3D scanner technologies to the master students with good discussions. The visits from both partners to each other have fostered research cooperation and knowledge sharing well. Two joint papers have been presented in GIS conferences and workshops.

**DAAD Dissertation Project: Closing the Semantic Gap of Image and Video Retrieval for Faked Multimedia**

*M. Jarke, R. Klamma, K.A.N. Rashed, M. Lux (U. Klagenfurt), H. Kosch (U. Passau)*

The project is supported by German Academic Exchange Service (DAAD). The goal of the project is the integration of content-based multimedia search and retrieval techniques with respect to low-level semantics of multimedia and high-level semantics (generated from social networks like Flickr) to detect and classify faked multimedia. Main objectives of the project are: analyzing visual features of suspected multimedia, investigating the impact of community involvement in detection of faked multimedia, and developing methodologies to combine low-level and high-level semantic techniques to detect faked multimedia. In 2009-2010, besides to extension faked image dataset, we concentrated on exploiting the Web 2.0 and community of practice advantages for the collaborative fake multimedia detection, considering the trust and quality of community members’ contributions.

**Overcoming barriers in the innovation process**

*M. Jarke, R. Klamma, D. Schmitz, F. Piller (TIM), M. Brettel (WIN), I. Koch (Lehrstuhl f. Psychologie), K. Henning (IMA)*

The IMP Boost project “Overcoming Barriers in the Innovation Process” investigates “effectuation”, a new approach to explain the success or failure of entrepreneurs. In contrast to traditional “causation” approaches the entrepreneur is not considered to be driven by a concrete goal and to choose between different alternatives in regard to how well they help to achieve this goal. Instead the entrepreneur evaluates the alternatives, in particular the choice of strategic partners, in regard to their potential for future success. The goals are adapted to the choices and in particular the needs of the strategic partners. The aim of the IMP Boost project is to compare the two approaches, “effectuation” and “causation” by running simulations. Based on theoretical research neither of these two approaches is to be favoured in general. Accordingly, we need to identify the settings, conditions, and constraints that put either of these approaches in front. From first modelling experiences and basic considerations, agent-based approaches towards simulation seem well suited as a means for investigation. Due to the high importance of networking, approaches from social network analysis as well as actor-network theory are expected to become relevant as well. The work is carried out in tight collaboration with our partners from the economics.

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

*M. Jarke, R. Klamma, R. Linde*

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 3 TB of open source software. Typically, the SunSITE enjoys around 23 million ftp and http accesses per month.

**HumTec Project “Natural Media and Engineering”**

*M. Jarke, V. Evola, S. Grandhi, I. Mittelberg (HumTec)*

This interdisciplinary project on natural human media (multimodal interaction) between linguistics (Prof. Jäger), informatics (Prof. Jarke), psychology (Prof. Koch, Prof. Willmes, Prof. Huber) and psychiatry (Prof. Schneider, Prof. Mathiak) is funded within the Human Technology (HumTec) initiative of the Future Concept RWTH-2020, under coordination of Profs. Jäger and Koch. A team of three newly hired international Junior Professors and Postdocs has been formed under the direction of Prof. Irene Mittelberg; the main research attention is directed to the analysis of gestures in conjunction with other “natural media” of the human. The intended long-term practical impact is improved human-machine interaction design based on a deeper understanding of the media. Dr. Sukeshini Grandhi (formerly New Jersey Institute) represents computer science and information systems in this project, focusing on the different roles of computer games in the Natural Media context. She brings to this work extensive experience in mobile technology design, especially from her Ph.D. thesis work on Interruption Management in Mobile Telephony at the New Jersey Institute of Technology.

In the reporting period, a Natural Media Lab allowing for very detailed gesture recognition was set up, and first experiments have been conducted. Moreover, the group organized the four Conference of the International Society for Gesture Studies (ISGS).

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

*M. Jarke, G. Lakemeyer, R. Klamma, D. Schmitz, D. Renzel*

Since September 2005, Informatik 5 is hosting the i* Wiki, a platform for researchers and users to foster investigation, collaboration, and evaluation in the context of the i* modeling language.
Research Area Model Management

M. Jarke, C. Quix, M.A. Chatti, S. Geisler, F. Kastrati, D. Kensche, X. Li, L. Guo, M. Khelgati, J. Li, P. Roy, N. Sonjampa

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.

In 2010, the group worked on methods for schema merging and schema matching. A method was developed which allows merging schemas using logical correspondences. The schema matching framework has been extended with methods for semantic matching and new algorithms for more efficient string matching. As in the previous years, GeRoMeSuite participated in OAEI, a competition of ontology alignment systems.

Furthermore, the group started developing a dataspace framework. Dataspaces aim at integrating structured as well as unstructured data in an incremental way. First results are an algorithm for the discovery schemas from unstructured data and an architecture for processing structured queries over unstructured data.

Conceptual Design of a Metamodel for Industry Automation

M. Jarke, C. Quix, D. Schmitz, M. Zhang

The control of production plants employs the research for decades. Due to a large variety in production processes, machine types, factory layouts, and many component suppliers, a large quantity of device controls, communication systems, production control software, engineering and visualization software, production planning systems and further control systems in hardware and software have been developed at the market. The grown heterogeneity makes interoperability and thus the flexibility in component selection more difficult. This is because for the operation of a production plant, all components must be interconnected using interfaces and protocols such that an integrated automation architecture is formed.

Most important aids for the control of the complexity of such automation architectures are models. They formally describe both control components and production processes, and thereby support planning, control and regulation of production processes. The diversity of the component suppliers and of the involved communities implies heterogeneity in the models and used modeling languages: they are proprietary, domain specific, and often incompatible. This applies also to production plants, which combine both discrete and continuous manufacturing processes.

The result of this project is an analysis of the relationships between the existing metamodels in industry automation. These relationships have been formalized in a metamodel which links models from discrete manufacturing and from process engineering.

In this project, Informatik 5 cooperates with the Laboratory for Machine Tools and Production Engineering (WZL, Prof. Brecher) and the Chair of Process Control Engineering (PLT, Prof. Epple) of RWTH Aachen University. The project is funded as a Pathfinder project in the context of the Exploratory Research Space at RWTH Aachen.
Models for Quality Management in Schema Matching with Applications to Medicine
M. Jarke, C. Quix, S. Geisler, D. Kensche, X. Li, A. Gal, T. Sagi (Technion Haifa)

Schema matching is the task of providing correspondences between concepts describing the meaning of data in various heterogeneous, distributed data sources. Schema matching is recognized to be one of the basic operations required by the process of data and schema integration and thus has a great impact on its outcome. As such, schema matching has impact on numerous modern applications. Somewhat surprisingly, up until recently there was little fundamental research that can lead to a theoretically rigorous infrastructure for further development of algorithmic solutions to the problem of schema matching. Having a theoretical basis in place, one could start and design a set of algorithms to support the design of schema matching, enhancing user effectiveness. In this pilot project, which is funded by the Umbrella Cooperation Program, Informatik 5 cooperates with Avigdor Gal (Technion Haifa, Israel) to investigate the following open fundamental research question: What qualifies as a good schema matcher? Most research work offer empirical, explanatory analysis, testing their proposed schema matchers using common a posteriori metrics such as recall and precision. An interesting question is whether one can suggest a priori measures to identify a good schema matcher for a specific problem instance. A positive answer to this question would allow the use of schema matching and data integration even if the outcome is somewhat uncertain.

During the project, the matching frameworks GeRoMeSuite (from RWTH Aachen University) and SMB (from Technion) have been integrated. The integration can be done in three modes, namely enhance mode, recommendation mode, and learning mode. The enhance mode takes a similarity matrix as input and enhances the clarity of the similarity values, i.e. good values should be increased and bad values should be decreased. The recommendation mode uses a-priori features such as the size of the schemas and number of matching attributes to select the best matchers for a matcher ensemble. A-priori features are recorded by GeRoMeSuite and passes, together with similarity matrices that were generated from different base configurations, to SMB. These are then used by SMB to recommended weighted ensemble of matcher configurations.

In a learning mode, user feedback or reference alignments are used to enhance SMB decision making. The user validates attribute correspondences, which are fed to SMB to induce a learning process and improve future matcher ensemble decisions.

ConceptBase - A deductive object manager for meta databases
M. Jarke, C. Quix, D. Kensche, S. Geisler, X. Li, M.A. Jeusfeld (Uni Tilburg, NL)

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. Since summer 2009, ConceptBase is available as an open-source system under FreeBSD license on SourceForge. In the academic year 2009/10, the group focused on continuous improvement of the system and removed several bugs.
The developments concentrated on the identification of pathological structures in breast cancer probes. We first started with a supervised machine learning approach based on annotations by pathological experts. Reliability tests showed that isolated annotations of regions within the digitalized images are an inappropriate starting point. There were significant disagreements between various coders. Therefore we switched to unsupervised image classifications and clustering procedures applying self organizing map (SOM) algorithms. The results were then validated and corrected by human experts. In these cases the contributions of the pathologists were better oriented and therefore stable. Based on these validated classifications of tissue regions further analytical steps were introduced in order to specify the structural heterogeneity of various distribution patterns of tumors. Additionally distribution patterns of hormone receptors (ER, PR) within tumor regions have been analyzed. The results will be merged with clinical data of the patient and via machine learning analysis with respect to the prognostic capacity of the pertinent constellations.

The project in collaboration with the University Hospital Hamburg Eppendorf, Carl Zeiss MicroImaging and Qiagen is funded by the Federal Ministry of Education and Research (BMBF).

Transporter protein topology influences numerous cellular processes. Internalization of transporter proteins into the cells or their directed placement into the cellular membrane regulates flow of substances and, if altered, causes diseases. As a part of the Clinical Research Group 217 "Hepatobiliary Transport and Liver Diseases (Speaker: Prof. Dr. D. Häussinger, University of Düsseldorf) a workflow for an automatic data analysis was developed. The slow and subjective evaluation of microscopic images by human experts is now automated. A machine learning algorithm is applied for the membrane detection, and protein location profiles are automatically extracted at all valid positions. Numerical descriptors were developed and evaluated for the detection of translocation. The automatic analysis evaluates more data points and is sufficiently reliable compared to the manual method.

SurgeryTube develops web-based multimedia training modules for surgery training. Compressed geometrical models and pre-computed visualizations are focussed on laparoscopic liver surgery and the usage of novel e.g. navigation-based support systems Integrated web-based communication among teachers and learners is supported by Web 2.0 mechanisms such as for a and blogs as well as automatic tools for content presentation in various data formats as well as anonymization of patient data. Under the coordination of long-term partner Dr. Raimund Mildner, Lübeck, Informatik 5 cooperates with medical and visualization partners from Magdeburg, the Universities of Lübeck and Gießen, and industry partners.
Other Activities

Services

Prof. Jarke was elected Chairman of the Fraunhofer Information and Communication Technology group, comprising 17 institutes with a total of over 2000 full-time researchers and a budget close to 200 m€. In this role, he also became a member of the Fraunhofer Presidential Board.

Prof. Jarke’s other major administrative and service activities in 2009-2010 included:

- Deputy coordinator, UMIC Excellence Cluster on Mobile Information and Communication, RWTH Aachen University
- Executive Director, Fraunhofer FIT, Birlinghoven
- Founding Director, Bonn-Aachen International Center for Information Technology (B-IT), a joint institute of RWTH Aachen and Bonn University offering international master programs in applied IT
- Coordinator, B-IT Research School, a joint doctoral training school in applied informatics between RWTH Aachen University and Bonn University co-funded by NRW State
- Inaugural Dean, Applied Information Technology, German University of Technology in Oman (GUtech)
- Past President, GI German Informatics Society; also Chair, GI Fellow selection commission and Jury Chair, GI Innovationspreis
- Vice President, European Research Consortium for Informatics and Mathematics (ERCIM) running e.g. the European part of the World Wide Web Consortium W3C
- Scientific advisory board, Faculty of Informatics, University of Vienna, Austria
- Scientific advisory board, Learning Lab Lower Saxony (L3S), Hannover
- Chair, Scientific advisory board, OFFIS e.V., Oldenburg
- Research commission, Free University of Bozen, Italy (until June 2010)
- Advisory board, Large Scale Complex IT Systems Initiative (LSCITS), UK
- Hochschulrat, FH Köln
- Member of Program Board, LOEWE Excellence Initiative Hessia
- Curatory board and scientific advisory board, IBFI, Schloss Dagstuhl
- Jury, Wissenschaftspris Stifterverband der Deutschen Wirtschaft
- Chair/member of several faculty search committees at RWTH Aachen University, GUtech, University of Hamburg, Fraunhofer
- Jury, ACM/AIS Best Dissertation in Information Systems Award 2009
- Reviewer, DFG, NSF, NSERC Canada

Within the RWTH Excellence Initiative “RWTH-2020”, Prof. Jarke is responsible for the activity “International Recruiting”. In cooperation with Prof. Hornke (Psychology), Z. Petrushyna, V. Busch (International Office), A. Schulz (RWTH International Academy), and representatives of four pilot departments, the team analyzed future strategies for the recruiting of more top international faculty and top international graduate students. A number of measures were piloted in both areas, and the roll-out of some successful ones is planned for the coming year. Since the start of RWTH-2020, the share of international hires at the professorial levels has increased by 40%, doctoral students 65%, and significant quality improvements in international master student recruiting can be observed.

R. Klamma is technical leader & community facilitator of the EU IP ROLE, senior researcher in the EU projects TELLNET, TELMAP, and the Network of Excellence in Serious Gaming
GALA as well in the DFG project CONTICI. He is standing expert of the W3C in the Media Annotations Working Group.

Dominik Schmitz is a manager of the i* Wiki.

Yiwei Cao is member of DIN NI-32 “Data Management and Data Exchange”.

Thomas Rose is evaluation expert for EU Project Proposals on "ICT for Energy and Water Efficiency in Public Housing" 21.-23.6.2010. He is the program committee member of the workshop for "IT-support of rescue forces", GI conference 2010, Leipzig.

Editorial Boards

Yiwei Cao was reviewer for International Journal on Multimedia Tools and Applications.


Ralf Klamma serves as associate editor for IEEE Transactions on Learning Technologies (TLT), Springer Journal on Social Network Analysis and Mining (SNAM) IJASS, IJTEL, and IJHSC. He is editor-in-chief for the SunSITE CEUR and several community information systems like the PROLEARN Academy (www.prolearn-academy.org), the Multimedia Metadata Community (www.multimedia-metadata.info) and the Bamiyan Development Community (www.bamiyan-development.org). In the moment he is editing special issues of the World Wide Web Journal (WWWJ) for the IEEE Ubi-Media 2010 conference and of i-com journal for the Digital Networks workshop at Informatik 2010. He also served as reviewer for IEEE Transactions on the Management of Information Systems (TMIS), IEEE Transactions on Learning Technologies (TLT), IEEE Multimedia, VLDB Journal, Multimedia Tools and Applications (MTAP), and Journal of Networks and Applications (JNCA).


Wolfgang Prinz is member of the Editorial Boards of the CSCW Journal and of i-com: Zeitschrift für interactive und cooperative Medien.

Christoph Quix served as a reviewer for the journal on Data & Knowledge Engineering, IEEE Internet Computing, the Journal of Web Semantics, and the VLDB journal track (PVLDB).

Conference Organization

Yiwei Cao was co-chair of Third International Workshop on Story-Telling and Educational Games (STEG’10), and the UMIC Workshop on Future Mobile Applications (UMICWS’10). She was program committee member of 6th International Workshop on MOBILE and NETWORKing Technologies for social applications (MONET’10), 11th and 12th Workshop of the Multimedia Metadata Community (WISMA’10 & SMDT’10), The 3rd IEEE International Conference on Ubi-media Computing (U-Media 2010), Mobile Learning’10 (ML’10), Workshop UMICWS’10, Workshop WIMA’10 at USAB’10, Workshop SIRTEL’10 at EC-
Matthias Jarke served as General Co-Chair of the 12th International Conference on Electronic Commerce (ICEC 2010) in Honolulu, Hawaii, August 2-4, 2010. He is also Theme Track Chair “Gateway to the Future” at the International Conference on Information Systems (ICIS 2010) in St. Louis, Missouri, Dec. 13-14, and program committee member of the following conferences: Software Engineering 2010 (SE 2010, Paderborn, February 2010), Modellierung 2010 (Klagenfurt, March 2010), 22nd CAiSE 2010 and First Intl. Workshop on Empirical Research in Process-Oriented Information Systems (Hammamet, Tunisia, June 2010), 16th REFSQ ’10 (Essen, June 2010, Group Decision and Negotiation (GDN ’10, Delft, June 2010), and MobileHCI 2010 (Lisbon, September 2010). He also serves on the Advisory Board of the CIO Colloquium, a network of the Chief Information Officers in German industry.

Nils Jeners served on the program committee of Workshop “Anforderungen und Lösungen für die Nutzung interaktiver Displays im Kontext kollaborativer Arbeit” at Mensch & Computer 2010 in Duisburg, Germany, September 2010.

Ralf Klamma was program co-chair of the 3rd IEEE International Conference on Ubiquitous Media Computing (Ubi-Media 2010), Jinhua, China, 5-7 July, 2010. He was also co-chair of the following events: 6. JTEL Summer School in Technology Enhanced Learning, Ohrid, Macedonia, July 2010, Doctoral Consortium at EC-TEL 2010, Barcelona, Spain, September 2010, UMIC Workshop on Future Mobile Applications (UMICWS’10), Aachen, Germany, February 2010, 11th Workshop of the MPEG-7 Community on Multimedia Metadata (WISMA’10), Barcelona, Spain, March, 2010, 12th Workshop of the MPEG-7 Community on Semantic Multimedia Databases (SeMuDaTe’10), Saarbrücken, Germany, December, 2010, IFIP PRO’VE’10 Special Track on Collaborative Networks, St. Etienne, France, Oktober 2010, and PerCOSC’11 at the IEEE PerCom, Seattle, USA, March 2011. He was area editor for the ICIS’10, St. Louis, USA, December 2010, special track organisator on competence management in personal learning environments at the Professional Training Facts 2010, Stuttgart, Germany, October 2010, and senior reviewer for the PLE’10, Barcelona, Spain, July 2010. He served as program committee member / reviewer for the following conferences: ACM CHI’10, ACM Group’10, ACM SAC’11, ACM Multimedia’10 Workshop P2P Networks, ACM Multimedia’10 Workshop MTDL’10, ACM Group’10, ACM CSCW’11, ACM Workshop RecSysTel’10, IEEE ICAL’10, IEEE DEST’10, IEEE EDUCON’10, IEEE EDUCON’11, IEEE EUROCON’11, IEEE MUE’10, IEEE MUE’11, WMM’10, Wirtschaftsinformatik’11, International Symposium on Collaborative Technologies and Systems (CTS’10), Communities & Technologies’11, ICWL’10, EC-TEL’10, GI-Workshop Digital Social Networks (GI-DSN’10), Workshop Business Process Management and Social Software (BPMS2’10), Interactive Computer Aided Learning (ICL’10), I-KNOW’10, STEG’10, Workshop Computer-based Knowledge & Skill Assessment and Feedback in Learning Settings (CAF’10), WeKnow’10, Workshop on Text Information Retrieval (TIR’10), MMedia’10, BASNA’10, STEG’10.


Zina Petrushyna co-organized the Joint European Summer School on Technology Enhanced Learning 2010. She was a program committee of the IADIS E-learning conference 2010.

Manh Cuong Pham was reviewer of the First and Second International Conference on Complexity, Informatics and Cybernetics (IMCIC 2010, IMCIC 2011), and the IEEE International Conference on Ubimedia Computing (U-Media) 2010.

Wolfgang Prinz was Technical Paper Co-Chair of the ACM GROUP Conference 2010. Moreover, he served on the program committees of the conferences Mensch & Computer 2010, ECSCW 2009, and CRWIG 2010.

Dominik Renzel was technical program chair of the ROLE Developer Camp 2010 and co-organizer of the workshop "Storytelling and Educational Games in the Learning Flow" at ECTEL 2010. He was member of the program committee for Workshops on Semantic Multimedia Database Technologies (SeMuDaTe 2009) and Interoperable Social Multimedia Applications (WISMA 2010). He was also reviewer for Multimedia Tools and Applications (MTAP), ACM GROUP’10, a special issue in the Journal on Distant Education Technologies (JDET), and the IEEE International Conference on Ubimedia Computing (U-Media) 2010.

Dietlind Zühlke chaired a Workshop on Computational Intelligence in Siegburg, March 2010.

Software Demonstrations

Virtual Campfire, STEG Workshop at ECTEL’10, September 29, 2010, Barcelona, Spain
Virtual Campfire, 11th International Workshop of the Multimedia Metadata Community (WISMA 2010), May 19-20, 2010, Barcelona, Spain
Virtual Campfire, UMIC Workshop on Future Mobile Applications, Aachen, Germany, February 26, 2010, Aachen, Germany
Virtual Campfire, SeMuDaTe Workshop at SAMT 2009, December 2, 2009, Graz, Austria
Virtual Campfire, UMIC Day 2009, October 20, 2009, Aachen Germany
MobSOS Application/XMPP Server, Workshop on Semantic Multimedia Database Technologies (SeMuDaTe2009), December 2, 2009, Graz, Austria
ROLE X-Mas Project Prototype, ROLE Christmas Project Meeting, December 17, 2009, Aachen, Germany
ROLE Easter Project Prototype - RWTH Test-bed "Web 2.0 Knowledge Map" in cooperation with ZLW/IMA, ROLE 1st Annual Review, April 20, 2010, St. Augustin, Germany
PALADIN II and Mediabase commander, ROLE Development Strategy meeting, September 07, 2009, Aachen, Germany
CoCarX - Data Stream Management zur Verkehrsdatenanalyse, aktiv Final Presentation, Mendig, June 23-24, 2010
Interdisciplinary HealthNet Project, UMIC Open Day, April 21, 2010

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Talks and Publications

Talks

Y. Cao: Mobile Multimedia Management for Virtual Campfire - The German Excellence Research Cluster UMIC. Joint Lab of Next Generation Internet Interactive Computing, Shanghai University, Shanghai, China, July 9, 2010 (invited).


Y. Cao and X. Chen: Virtual Campfire iNMV -Storytelling on the iPhone. UMIC Workshop on Future Mobile Applications, Aachen, Germany, February 26, 2010.


S. Geisler: Einführung in SQL Server Spatial, PASS (Professional Association for SQL Server) Regionalgruppe Ruhrgebiet, August 12, 2010

S. Geisler: Dynamische Erstellung von SSIS-Paketen, PASS (Professional Association for SQL Server) Regionalgruppe Ruhrgebiet, February 11, 2010

M. Jarke: Information Technology for Engineering and Management. DAAD Review of GUtech, Muscat, Oman, 2.11.2009.


D. Kensche: Solving ORM by MAGIC: MApping Generation and Composition. Third International Conference on Objects and Databases (ICOODB), Frankfurt/Main, Germany, September 30, 2010.


R. Klamma: Reflection Support for Communities on the Web, ROLE WP Meeting, Aachen, Germany, April, 2010.


D. Kovachev: Context-aware Mobile Multimedia Services in the Cloud, the 10th International Workshop of the Multimedia Metadata Community in Semantic Multimedia Database Technologies (SeMuDaTe’09), Graz, Austria, December, 2009.


X. Li: *Towards a Unified Framework for Schema Merging*. PhD Workshop, 36th Intl. Conference on Very Large Databases (VLDB), Singapore, 13.9.2010


Manh Cuong Pham: *The Structure of the Computer Science Knowledge Network*. The IEEE International Conference on Advances in Social Networks Analysis and Mining (ASONAM 2010), Odense, Denmark, 9-11 August, 2010.

Manh Cuong Pham: *Clustering Technique for Collaborative Filtering and the Application to Venue Recommendation*. The 10th International Conference on Knowledge Management and Knowledge Technologies (I-KNOW 2010), Graz, Austria, 1-3 September, 2010.

W. Prinz: *Innovation Trends in IT*, European Leadership Committee, Bayer AG, Leverkusen, 27.4.2010

W. Prinz: *PMO Maturity Studie 09: Status Quo & Entwicklungsstrends*, Keynote PMO Symposium 09, Düsseldorf, 30.4.2009


W. Prinz: *Supporting the change of cooperation patterns by integrated collaboration tools*, Thessaloniki, October 2009

W. Prinz: *Developing Collaborative Working Environments – what can we learn from Web 2.0?* Keynote, CoopIS 2009, Villamoura, Portugal, November 2009

D. Renzel: *Virtual Campfire: Collaborative Multimedia Semantization with Mobile Social Software*. Workshop on Semantic Multimedia Database Technologies (SeMuDaTe2009), December 2, 2010, Graz, Austria.


D. Schmitz: *Agent Instantiation in i*, University of Toronto, Canada, May 10, 2010.

D. Schmitz: *Analyzing Agent-Based Simulations of Inter-Organizational Networks*, 6th Int. Workshop on Agents and Data Mining Interaction, ADMI 2010, Toronto, Canada, 11.5.2010.

D. Schmitz: *Applications of ConceptBase in the ZAMOMO Project*, RWTH Aachen University, May 25, 2010.


D. Zühlke: *Learning vector quantization for heterogeneous structured data*. 18th European Symposium On Artificial Neural Networks, Computational Intelligence and Machine Learning (ESANN 2010), Bruges, Belgium, 28.4.2010.

D. Zühlke: *Unsupervised learning for heterogeneous structured data*. Mittweidaer Workshop for Computational Intelligence, 30.6.2010

D. Zühlke: *Neural Computation in industrial applications of life science informatics*. Invited Talk, Colloquium Informatica, Johann Bernoulli Institute for Mathematics and Computer Science, University of Groningen, 8.8.2010

D. Zühlke: *Machine learning in life science informatics - industrial applications*. Invited Talk, ICOLE-2010, German–Polish Workshop on Computational Biology, Scheduling and Machine Learning, Lessach, Austria, 26.09.2010

**Publications**

**Books and Edited Volumes**


Ralf Klamma, R. W. H. Lau, Shu-Ching Chen, Q. Li, Ishfaq Ahmad, Jianmin Zhao: Proceedings of the 3rd IEEE International Conference on Ubi-Media Computing (U-Media), 5-7 July 2010, Jinhua, China


**Journal Articles**


S. Hansen, K. Lyytinen, Matthias Jarke: Interview with Fred Brooks on "Building Effective Large-Scale Requirements". BISE 2, 3 (2010): 191-194 (German version "Erhebung effektiver Anforderungen im großen Zusammenhang" in Wirtschaftsinformatik 52, 3 (2010))


Conference, Book Contributions, Patents


Sandra Geisler, Yuan Chen, Christoph Quix, G. G. Gehlen: Accuracy Assessment for Traffic Information Derived from Floating Phone Data. Proc. 17th Intelligent Transportation Systems and Services World Congress, Busan, Korea, 2010
Sandra Geisler, Christoph Quix, A. Schmeink, David Kensche: **Ontology-based Data Integration: A Case Study in Clinical Trials.** To appear in: Database Technology for Life Sciences and Medicine

Sandra Geisler, Christoph Quix, Stefan Schiffer: **A Data Stream-based Evaluation Framework for Traffic Information Systems.** Proc. 1st ACM SIGSPATIAL International Workshop on GeoStreaming (IWGS) 2010, November 2, 2010, San Jose, USA

W. Graether, N. Jeners: Neuartige Interaktionsformen beim Kartenspielen mit iPhones und MS Surface. Workshop Anforderungen und Lösungen für die Nutzung interaktiver Displays im Kontext kollaborativer Arbeit an Mensch & Computer 2010, Duisburg, Germany

S.A. Grandhi, G. Joue, I. Mittelberg: *There is more than what meets the hand: using semiotic principles to understand the use of communicative hand gestures in interaction design.* Proceedings Workshop on Whole Body Interaction, at SIGCHI, Atlanta, Ga, July 2010

S.A. Grandhi, R. Schuler, Q. Jones: **Telling calls – making informed call handling decisions.** Proc. 8th ACM Conf. on Designing Interactive Systems, Aarhus, Denmark, 2010


Matthias Jarke, Markus Klann, Wolfgang Prinz: **Serious Gaming -- The Impact of Pervasive Gaming in Business and Engineering.** In C.M. Schlick (ed.): Industrial Engineering and Ergonomics - Visions, Concepts, Methods and Tools, Springer 2009, pp. 281-292


Matthias Jarke, Hans W. Nissen, Thomas Rose, Dominik Schmitz: **Goal-Based domain modeling as a basis for cross-disciplinary systems engineering.** In S. Nurcan, C. Salinesi, C. Souveyet, J. Ralyté (eds.): Intentional Perspectives on Information Systems Engineering. Springer 2010, 83-100

Ludwig Jäger, Matthias Jarke, Ralf Klamma, Marc Spaniol: **Transkriptivität -- operative Medientheorien als Grundlage von Informationssystemen in den Kulturwissenschaften.** In H. Bublitz, R. Marek, C.L. Steinmann, H. Winkler (Hrsg.): Automatismen, pp. 299-314. Wilhelm Fink Verlag 2010


Dejan Kovachev, Ralf Klamma: Context-aware Mobile Multimedia Services in the Cloud. Published in Ralf Klamma, Harald Kosch, Matthias Lux and Florian Stegmaier (Eds.): Proceedings 10th International Workshop of the Multimedia Metadata Community on Semantic Multimedia Database Technologies (SeMuDaTe'09), CEUR Workshop Proceedings, Vol. 539, Graz, Austria, December, 2009

David Kensche, Christoph Quix, Xiang Li, Sandra Geisler: Solving ORM by MAGIC: MApping Generation and Composition. Proceedings of the 3rd International Conference on Objects and Databases (ICOODB 2010), Frankfurt am Main Germany, September, 2010.

Xiang Li, Christoph Quix, David Kensche, Sandra Geisler: Automatic Schema Merging Using Mapping Constraints Among Incomplete Sources. Proc. 19th ACM international conference on Information and knowledge management (CIKM’10), October 2010, Toronto, Canada


Oleksandr Lobunets, Nils Jeners: Designing an iPad prototype for collaborative brainstorming. Workshop Anforderungen und Lösungen für die Nutzung interaktiver Displays im Kontext kollaborativer Arbeit at Mensch & Computer 2010, Duisburg, Germany


Andreas Lorenz, Marc Jentsch, Cyril Concolato, Enrico Rukzio: A Formative Analysis of Mobile Devices and Gestures to Control a Multimedia Application from the Distance. 15th IEEE Mediterranean Electrotechnical Conference, pages 796–801. IEEE Xplore, 2010


Haroula Papadaki, Eleni Gadolou, Emmanuel Stefanakis, Georgios Kritikos, Yiwei Cao, Anna Hannemann, Dejan Kovachev, Ralf Klamma: The role of CMS in the education of GIS using storytelling. Seventh European GIS Education Seminar (EUGISES 2010), September 2010, Serres, Greece


Manh Cuong Pham, Ralf Klamma: The Structure of the Computer Science Knowledge Network. In Proceeding 2010 IEEE International Conference on Advances in Social Networks Analysis and Mining (ASONAM 2010), August, 2010, Odense, Denmark

Manh Cuong Pham, Yiwei Cao, Ralf Klamma: Clustering Technique for Collaborative Filtering and the Application to Venue Recommendation. Proc. 10th Intl. Conf. Knowledge Management and Knowledge Technologies (I-KNOW 2010), September 2010, Graz, Austria


A. Schmeink, Sandra Geisler, A. Brauers, Christoph Quix: A Method and Module for Linking Data of a Data Source to a Target Database. Patent Application, No. PCT/IB2009/055537


Martin Wolpers, Martin Friedrich, Ruimin Shen, Carsten Ullrich, Ralf Klamma, Dominik Renzel: *Early Experiences with Responsive Open Learning Environments*. In Proceedings 10th International Conference on Knowledge Management and Knowledge Technologies (I-KNOW 2010), 1-3 September, 2010, Graz, Austria


**Position Papers and Interviews (Selection)**


Matthias Jarke: *Multimedia(macht) für alle*. Editorial, InnoVisions 2, Fall 2010, p. 3.


Knowledge-Based Systems & Cognitive Robotics Group

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• Student Researchers
  Masrur Doostdar, Bahram Maleki-Fard, Tim Niemüller,
  Christoph Schwering, Niklas Hoppe

• Visiting Researchers
  Thomas Meyer, Ph. D., Meraka Institute, South Africa
  (August 2010)
  Prof. Hector Levesque, Ph. D., University of Toronto,
  Canada, (September – December 2010)
  Radhakrishnan Delhibabu, Anna University, (September
  2010 – July 2011)
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.

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).

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, 2009 and 2010).

The scope of the RoboCup initiative has gotten much broader in recent years. It now also covers the design of robots to rescue people from urban disaster areas in the RoboCup Rescue leagues or the development of service robots in the RoboCup@Home league. The task of robots in the latter domain is to help people in a home-like environment with fulfilling tasks of everyday life.

The “AllemaniACs” RoboCup Team 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 (cf. Fig. 1). 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.

In 2009, we started over by moving large parts of our control software to our newly developed robot control software fawkes. Furthermore, we were the first team in the competition to show robot-robot communication and coordination when we made two of our robots team up to serve multiple guests in a party-like scenario. We were also actively involved in research on how service robots can be benchmarked and what results from benchmarking activities such as RoboCup@Home have been obtained so far. In 2010, we took a break from the competitions to elicit possible further extensions of our robotic system and to consolidate the existing features. For one, we extended our research in making use of fuzzy representations and control in a domestic setting. For another, we worked towards integrating self-maintenance into the robotic system. That is to say, we studied ways to enable the robot to autonomously take care of issues coming up at run-time that would normally lead to a failure.

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 an omni-directional drive system and an omni-vision camera system. Such 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 re-construction 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, named Fawkes. 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.

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, axioms, and plan constraints and preferences, and which virtually constitutes a standard in the field of planning.

This soon to be completed, DFG-funded project started in 2005 and has been conducted in cooperation with the Research Group on the Foundations of Artificial Intelligence lead by 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 have worked on establishing a common semantic basis for both GOLOG and PDDL within the situation calculus. This has been achieved first for the ADL fragment of PDDL, and was subsequently extended by the language’s further features. The situation calculus semantics for PDDL now covers roughly the full scope of PDDL, thus providing the foundation for embedding state-of-the-art planning systems like FF in Golog. Expressiveness was further studied formally by means of compilation schemes between corresponding fragments of both formalisms, and experimental evaluations have shown that
combining a GOLOG system with a PDDL-based planner is indeed beneficial in terms of savings in the computation time needed by the overall system.

In the second project phase three of the obvious shortcomings and problems that arise even with a GOLOG system with an embedded PDDL planner were tackled. First, available GOLOG systems as well as planners currently lack an efficient and expressive way of representing incomplete world knowledge. For the sake of efficiency, they usually rely on the closed-world and domain closure assumptions, which are not realistic in practice, and constitute a drastic loss of expressiveness. Full first-order logic on the other hand is unsuitable because of its undecidability. Based on results by Liu, Lakemeyer and Levesque we developed a variant of GOLOG that retains a significant part of first-order expressiveness using so-called proper+ knowledge bases, yet allows for a reasoning method that is not only guaranteed to terminate, but, given certain limitations, even tractable. The method relies on a limited form of reasoning that is sound with respect to first-order logic, but only complete for a certain, relevant class of entailments.

Second, the assumption behind PDDL and the associated planning competition is that planners are domain-independent. That is, when faced with a new planning problem, it is assumed that such a planner does not possess any prior knowledge about that particular planning domain. While this assumption is justified when it comes to an unbiased comparison of different planning algorithms, it is also well known that in practice, special domain knowledge that is provided by the human domain designer can often help in reducing the search space enormously, and thus speeding up planning significantly. Planners such as TLPlan and TALplanner utilize domain knowledge in the form of formulas in some temporal logic in order to identify branches of the search tree that can be pruned. Furthermore, a GOLOG program by itself already constitutes a form of domain-dependent knowledge in the sense that it is restricts the space of all action sequences to only those adhering to the program, and therefore the domain-independence assumption is untrue in the context of a GOLOG system. For this reason, in order to be able to exploit multiple forms of domain-dependent knowledge together, another objective of this project phase was to embed domain-dependent planners into GOLOG in a similar manner as for the domain-independent ones. To this end, sublanguages of the situation calculus had to be identified that correspond to those planners’ underlying input logics. Within the report period this was achieved for a certain, relevant subset of TALplanner’s Temporal Action Logic, and evaluations showed a significant improvement in the combined system’s runtime behaviour.

Third, before deploying a GOLOG program to an actual agent such as a mobile robot, it is often desirable to verify that it meets certain requirements such as safety, liveness and fairness conditions. While such verification problems have been widely studied in the area of model checking, there has been little research within the situation calculus community, in particular regarding the verification of GOLOG programs that are non-terminating. Non-termination is the typical case in scenarios where the agent performs an open-ended task, such as in the example of an autonomous mobile robot. Simply applying existing model checking techniques here is not appropriate as they work on a single, finite, and complete model of the system, which is not given in the case of a GOLOG agent with incomplete world knowledge, as explained above. To tackle the verification problem for non-terminating GOLOG programs, we designed an extension of the modal situation calculus variant ES that allows to express programs and their properties in a way that resembles branching time temporal logics, but that includes first-order quantification and where each path quantifier contains a GOLOG program over whose execution traces the quantification then ranges. Based on this logic we developed an automated verification method that relies on the standard situation-calculus-style reasoning using regression and first-order theorem proving, and that could handle a class of properties
resembling the branching time logic CTL (but again includes first-order quantification and GOLOG programs). Recently (ECAI 2010), we extended these results by devising a new algorithm that allows for a more general, CTL*-like class of queries.

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 partly 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 Nao platform, manufactured by the French company Aldebaran. The robot is a 58 cm tall biped humanoid robot with 25 degrees of freedom. Figure 3 shows a photo from the Standard Platform League competition at the RoboCup 2009 in Graz. During the last year good progress was made with stabilizing the software framework Fawkes for the robot platform. Fawkes is the deployed control software framework for controlling the low-level system of the Nao platform. It showed its stability during the participation in RoboCup 2009, where our Team Zadeat, which is run by the three project partners, reached a tenth place in the competition. With most of the low-level components running, we started addressing the high-level control. During the report period, a Behaviour Engine based on extended hybrid automata was developed (Niemüller, Ferrein, & Lakemeyer, 2009). The implementation was done in the scripting language Lua which is an interpreted language with a small memory footprint. The Behaviour Engine was designed as a behaviour middle-ware, leaving room for a dedicated high-level control component. This component will be a Golog-based deliberative component which makes use of the underlying behaviour engine. The deliberative component is subject for future work.

Figure 3: Standard Platform League Competition, RoboCup 2009
Logic-based Learning Agents
Daniel Beck, Gerhard Lakemeyer

The agent programming language GOLOG allows the specification of so-called partial programs. That means the programmer doesn’t have to provide a completely specified program but might leave certain choices on how to proceed with the program open to the agent. The objective, then, is to find an execution trace of the partial program that is legal and optimal wrt. an optimization theory in the current situation.

Contrary to the decision-theoretic planning approach which solves the above problem too, we employ reinforcement learning techniques to learn what the best way of executing a program is by interacting with the environment. This has the advantage that it is not necessary to provide a probabilistic model of the agent’s actions.

The number of training iterations which are necessary before learning shows any beneficial effects highly depends on the number of states the environment can be in. This imposes a severe problem to learning in more complex systems which are made up of huge numbers of different states. Quite often groups of states can be made out whose differences are absolutely irrelevant to the decision that has to be learnt but nevertheless these are handled as separate states. We make use of the basic action theory (BAT) which describes the preconditions and effects of the agent’s actions in order to compute state formulas. Those state formulas are first-order formulas and describe the set of states that are equally good with respect to the remaining program to be executed and the optimization theory.

We have laid out the theoretical foundations for computing those state formulas and integrating the reinforcement learning process into a GOLOG interpreter (Beck & Lakemeyer, 2009). In the future, we intend to adapt our framework to accommodate for more advanced reinforcement learning techniques (e.g., hierarchical reinforcement learning).

Multi-Agent Only-Knowing
Vaishak Belle, Gerhard Lakemeyer

In the area of Knowledge Representation and Reasoning, a fundamental problem is to capture the beliefs of a knowledge-base. For instance, we may want to model that the rules of Poker (every player has 3 cards, the cards are unique, etc.) are all that a game playing agent knows. This would allow the agent to reason that if he has the king of hearts, then an opponent does not, but would not allow the agent to know which precise set of cards an opponent has (at least, not initially).

While beliefs are typically modeled with epistemic logics, it was Levesque, in the early nineties, who proposed the logic of only-knowing where it is possible to say that a set of sentences in a first-order language is precisely all that is known. In this way, he was able to capture both beliefs and also what is not believed. He also discussed how such a logic can
capture default reasoning mechanisms. For instance, if all I know is that Tweety is a bird, and birds typically fly, then I come to believe that Tweety flies (unless, I am told otherwise).

Clearly, such a framework is also desirable in a many agent setting, so that one agent may capitalize on what she believes another agent to know, so as to coordinate tasks or plan strategies against another. Much work went in to extend this logic to the case with many agents, but unfortunately none without problems. The most recent solution, by Halpern and Lakemeyer, forces us to introduce proof-theoretic notions in the semantics, for instance.

In a recent paper (KR 2010), we introduce a new semantics, which we show has two notable properties. The semantics is natural, unlike the Halpern and Lakemeyer approach, and correctly captures the intuitions of only-knowing for the many agent case. The second property is that we have an axiomatization, that succinctly captures the properties of the new logic. So it appears, that for the first time, we have a natural generalization of Levesque’s logic, allowing us, besides other things, to capture knowledge-bases (and beliefs about opponent’s knowledge-bases) in a precise manner.

One of the main goals of Knowledge Representation, besides capturing the static beliefs of an agent, is to allow the agent to reason about the dynamics inherent in the world. For instance, an agent, say Alice, may want to reason that her opponent, say Bob, who just read his card knows what the card is, although Alice herself has no clue about it. A first-order dialect called the situation calculus is one formalism to reason about action and change. However, capturing knowledge in the situation calculus and proving properties pertaining to the beliefs of an agent is not straightforward. For this reason, Lakemeyer and Levesque propose a first-order modal logic, a logic called ES, that not only captures the main ideas of the situation calculus but also allows for easy semantic proofs.

In a multi-agent setting, one utility of such frameworks is in reasoning about beliefs and strategies in games. Indeed, we may want to reason about properties precisely like the card example above. It is well known in the game theoretic literature, for instance, that their standard models to capture beliefs are not expressive enough for such tasks.

In a recent paper (AAAI 2010), we build on our new semantics, to propose extensions to the logic ES. We show how knowledge about games can be captured in this new framework, and we also show how properties like the one discussed can be analyzed as logical entailments. Additionally, the situation calculus is endowed with a regression property, that allows one to reduce arbitrary entailments to a sentence that should hold initially. This way, one can reason about consequences after any history, all from the initial situation. We show that such a property exist when many agents are involved, and what they only-know is nested to some finite depth. Thus, if Alice believes that all the Bob knows are also just the rules of the game, then she knows that Bob cannot know what her cards are initially (just as she does not know what his cards are initially; its a fair game! ).

Much of our work, in principle, should resort to first-order modal theorem proving. There are some techniques, such as the representation theorem introduced by Levesque and Lakemeyer, that may reduce reasoning to pure first-order theorem proving. But, reasoning about validity in first-order logic is undecidable. Our notion is that, in many interesting scenarios, full first-order expressivity is not needed. Thus, it may be possible to handle incomplete knowledge, and yet remain tractable in some sense. Some recent papers by Liu and Levesque, and Vassos and Levesque, look at such issues. The main idea is to typically reduce reasoning with incomplete knowledge to query evaluation in databases. It is, for instance, known that reasoning about queries that only use a bounded number of variables, is tractable. In fact, although it is exponential in the number of variables used, it is polynomial for some fixed bound. Our current interests lie in understanding and exploring tractability results in our
framework, by restricting the types of logical theories (axiomatizations of the domains) that we reason with.
Other Activities

Program Committees
Gerhard Lakemeyer was PC member of numerous international conferences. He is on the Editorial Board of Artificial Intelligence, 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 2010 and of the ERLARS Workshop in 2010.

Dagstuhl Workshop “Cognitive Robotics”
Together with Hector Levesque and Fiora Pirri Gerhard Lakemeyer organized the Cognitive Robotics Workshop in Dagstuhl which took place between the 21st and the 26th of February.

While the earlier workshops were largely a forum for presenting state-of-the-art research results, the purpose of the Dagstuhl event was to broaden the view and bring together people from various disciplines to shed new light on the issues in cognitive robotics. Among the participants were researchers from areas such as robotics, machine learning, cognitive vision, computational neuroscience, and knowledge representation and reasoning.

Service
Since October 2007, the Knowledge-Based Systems Group is hosting the RoboCup@Home Wiki (http://robocup.rwth-aachen.de/athomewiki), a platform for researchers and participants in the RoboCup@Home league to foster exchange and collaboration and to facilitate progress in domestic service robotics.

Research Visits
• Prof. Gerhard Lakemeyer and Stefan Schiffer visited the University of Cape Town, South Africa, in December 2009, to work with Dr. Alexander Ferrein. Both gave a talk on their current research activities as part of an open house event at the Robotics and Agent Research Lab.

• Between March 2010 and June 2010, Prof. Gerhard Lakemeyer visited the University of New South Wales, Australia and the University of Toronto, Canada on a sabbatical. He collaborated with Prof. Pagnucco from Australia and Prof. Levesque from Toronto in the research area of cognitive robotics.

• In August 2010, Prof. Thomas Meyer from the Meraka Institute in South Africa visited our research group for a month. Prof. Thomas Meyer is known for his work on belief revision, and ontologies. Currently, his main focus is on description logics, and is one of the main researchers of the Knowledge Systems Group at the Meraka Institute. He gave a short talk titled "Reasoning about Ontologies using Description Logics" at the Informatik 5 Doctoral Seminar in Bitburg.

• From September 2010 to December 2010, Prof. Hector Levesque from the University of Toronto is visiting our institute. Prof. Levesque will be collaborating with Prof. Gerhard Lakemeyer on reasoning about knowledge and action.
From September 2010 to July 2011, Radhakrishnan Delhibabu from Anna University, India, is visiting our research group as part of a scholarship he received from the India4EU European-funded project. Mr. Delhibabu’s research interest primarily lie in the view-update problem and belief revision. His current focus is at the intersection of the situation calculus and belief revision.

**Tournaments and Competitions**

**RoboCup German Open 2010.**

In April 2010, we participated in the RoboCup German Open 2010 in the Middle Size League which took place in Magdeburg.

**Demonstrations**

**Schüleruniversität 2010.**

The KBSG demonstrated the robot Caesar to students participating the Schüler-Universität in August 2010. We explained some principal methods in autonomous mobile robotics by showcasing a domestic service robotics scenario and elucidating the underlying techniques.

**China Areospace.**

We demonstrated our domestic service robot Caesar to a delegation of China Aerospace. While presenting and explaining the capabilities of our autonomous mobile robot we discussed possible connecting factors.
Talks and Publications

Talks
Stefan Schiffer: Towards Integrated Self-Maintenance for Domestic Service Robotics, DAIDO/RWTH Workshop on Metal Forming and Autonomous Systems, RWTH Aachen University, Germany, October 2010.[1]

Publications
Thomas Wisspeintner, Tijn van der Zant, Luca Iocchi, Stefan Schiffer: RoboCup@Home: Scientific Competition and Benchmarking for Domestic Service Robots, Interaction Studies, Special Issue: Robots in the Wild, 10(3), November, 2009[1]
V. Belle, and G. Lakemeyer: Reasoning about Imperfect Information Games in the Epistemic Situation Calculus, Twenty-Fourth Conference on Artificial Intelligence (AAAI-10), Atlanta, Georgia, USA, AAAI Press, 11/07/2010.[1]
K. Subramanian: Task Space Behavior Learning for Humanoid Robots using Gaussian Mixture Models, Twenty-Fourth AAAI Conference on Artificial Intelligence (AAAI 2010), Student Paper, Atlanta, Georgia, USA, AAAI Press, 2010.[1]
Human Language Technology and Pattern Recognition

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  Prof. Ashish Ghosh (Indian Statistical Institute)
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, and image and optical character recognition.

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

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

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

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

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

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

In addition, it offers a couple of advantages like increased robustness and easy adaptation to a new task.

In summary, the research activities of the ‘Lehrstuhl für Informatik 6’ cover the following applications:

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

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

**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 below). 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 2008/09:
• The phrase-based translation system was improved with a focus on search organization, including new knowledge source and better coupling with automatic speech recognition systems.

• Additionally to the phrase-based translation system, a hierarchical translation system was implemented using the cube growing and cube pruning algorithms in decoding. It performs similar to the phrase-based system and thus has been extensively used in evaluations. Further extensions to this are being investigated.

• Two extensions of standard word lexicons in machine translation have been implemented: A discriminative word lexicon that uses sentence-level source information to predict the target words and a trigger-based lexicon model that extends IBM model 1 with a second trigger, allowing for a more fine-grained lexical choice of target words.

• A consistent phrase model training using a forced alignment procedure has been implemented. This novel method utilizes phrase-alignment data in order to make training consistent with the translation decoder.

• Different possibilities for handling large language models in the translation process have been investigated. These approaches allow the usage of large language models with a relatively small memory footprint and have been successfully applied in the systems used in evaluations.

• Our method for system combination for statistical machine translation, inspired from methods in speech recognitions, was improved.

• Research efforts were continued in the area of automatic translation between German written text and German Sign Language. In April 2009 the SignSpeak project started.

Speech Recognition

![Architecture of an automatic speech recognition system](image)

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 above) 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 (ASR) were pursued in 2008/09:

The generation of the European Parliament Plenary Session (EPPS) corpus for speech recognition and speech-to-speech translation was continued for the main European languages. This corpus consists of transcribed speech and parallel texts in the languages
Methods for unsupervised training were improved to take advantage of completely untranscribed speech.

The cooperation with the Dalle Molle Institute for Perceptual Artificial Intelligence (IDIAP), Martigny, Switzerland, on data-driven methods to extract acoustic features using neural networks was continued. Hierarchical phoneme posterior features and further approaches to combine systems based on different acoustic features were investigated.

Speaker adaptive training was further investigated w.r.t. projection transforms, shift-only transforms, and the application of advanced training criteria.

Log-linear, discriminative transforms of speech features were developed.

For Arabic speech recognition, a morphological decomposition of the recognition vocabulary was investigated to reduce the considerable vocabulary sizes needed to obtain a good coverage of Arabic.

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

Word graph based system combination methods and their relation to Bayes decision rule were investigated, and a simplified to confusion network construction was developed.

Methods for log-linear modeling and discriminative training were investigated. Especially, initialization of log-linear acoustic models without using previous Gaussian mixture distributions was investigated. In addition, discriminative training criteria for ASR were generalized to include a margin term and regularization, and a close relation to support vector machines was shown.

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. 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.

**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 2008, 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 by combining different data sources, suitable language modelling, temporal contexts, and model combination.

Since 2009, RWTH is involved as coordinator in the SignSpeak project.

Examples from the RWTH-Fingerspelling and the RWTH-BOSTON-104 databases
Handwriting Recognition

The RWTH-OCR system is based on the open-source speech recognition framework RWTH-ASR - The RWTH Aachen University Speech Recognition System, which has been extended by video and image processing methods.

RWTH developed a novel confidence-based discriminative training for handwriting recognition. In particular, a writer adaptation approach for an HMM based Arabic handwriting recognition system to handle different handwriting styles and their variations has been presented in TOCITE-ICDAR-DT.

All proposed methods were evaluated on the IFN/ENIT Arabic handwriting database. In particular, and to the best of our knowledge, the presented results could outperform all error rates reported in the literature. The approach presented in TOCITE-ICDAR-DT ranked third at the ICDAR 2009 Arabic Handwriting Recognition Competition. In comparison to a preliminary evaluation of the RWTH-OCR system in 2008, the official results from 2009 show significant improvements.

Face Recognition

An interest-point based extraction of local features is widely used in object recognition tasks. Recently, a comparative study in 2008 has shown the superior performance of local features for face recognition in unconstrained environments. Due to the global integration of Speeded Up Robust Features (SURF), the authors claim that it stays more robust to various image perturbations than the more locally operating SIFT descriptor.

An interest point based feature extraction leads to sparse description of the image in comparison to grid-based dense description. Furthermore the interest points are not stable enough and might change depending on facial expressions.

However, no detailed analysis for a SURF based face recognition has been presented so far. RWTH provides in TOCITE-BMVC a detailed analysis of the SURF descriptors for face recognition, and investigate whether rotation invariant descriptors are helpful for face recognition.

Image Distortion Models

The Euclidean distance has been successfully used e.g. in optical character and object recognition and has been extended by different methods. As the Euclidean distance does not account for any image transformation (such as the affine transformations scaling, translation and rotation) if they are not part of the training corpus, the tangent distance or image distortion model are approaches to incorporate invariance with respect to certain transformations into a classification system.

The image distortion models have been examined at the Lehrstuhl für Informatik 6 over the last years. Since 2008, further research and more complex image distortion models are analyzed and presented in various works.
Research Projects

Global Autonomous Language Exploitation (GALE)

The goal of the GALE program is to develop automatic systems to extract information from a variety of sources, such as broadcast news, newswire text or usenet newsgroup articles in the languages English, Chinese and Arabic.

In 2010, the "Lehrstuhl für Informatik 6" participated as a member of the ROSETTA team, led by IBM. RWTH contributes translations from Arabic to English from two translation engines to this project. In addition, RWTH provides consensus translations generated from translations of all team members in this language pair.

Quaero

Quaero is a large 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 of multimedia and multilingual documents, including written texts, speech and music audio files, and images and videos.

Quaero responds 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.

JUMAS (Judicial Management by Digital Libraries Semantics)

The JUMAS project aims at researching and developing tools for assisting the judicial process, specifically related to court room activities. The goal is to show possibilities of integrating information from many different sources, collecting, enriching and sharing
multimedia documents annotated with embedded semantics, and thus minimising the need for manual transcription.

One important part of the project is the development of automatic speech recognition (ASR) systems for recordings of court trials. RWTH contributes to the project by developing an ASR system for Polish court room recordings. Research challenges include dealing with the varied quality of the audio signal in a real life court room, without excessive degradation of signal quality. The objective is to integrate the ASR system into a working pilot system usable and useful to officials of the Polish courts.

**SCALE**

The European Marie Curie Initial Training Network SCALE aims at the education of researchers in all aspects of speech processing, to accelerate the rate of advance in speech technology and thereby supporting the growing speech processing market.

SCALE stands for Speech Communication with Adaptive Learning, Initial Training and is concerned with adaptive learning approaches to all areas of speech processing, with particular focuses on automatic speech recognition and synthesis, signal processing, human speech recognition, and machine learning. In particular, SCALE has three principal scientific objectives: bridge the gaps between speech recognition and speech synthesis, between human and automatic speech recognition, and between signal processing and adaptive learning.

**SignSpeak**

*(Scientific understanding and vision-based technological development for continuous sign language recognition and translation)*

The overall goal of the SignSpeak project is to develop technologies for recognition and translation of continuous sign language to text, in order to improve the communication between deaf and hearing communities.

Complete six components-engine necessary to build a Sign-To-Speech system (components: automatic sign language recognition (ASLR), automatic speech recognition (ASR), machine translation (MT), and text-to-speech/sign (TTS))
The interpersonal communication problem between signer and hearing community could be resolved by building up a new communication bridge integrating components for sign-, speech-, and text-processing. To build a complete sign-to-speech translator for a new language, a six component-engine must be integrated (see above), where each component is in principle language independent, but requires language dependent parameters/models. The models are usually automatically trained but require annotated corpora. In SignSpeak, a theoretical study is carried out about how the new communication bridge between deaf and hearing people could be built up by analyzing and adapting the ASLR and MT components technologies for a Sign-To-Text sign language processing engine.

T4ME

T4ME - Technologies for the Multilingual European Information Society - is a 3-year (2010-2012) EU-FP7-funded network of excellence (NoE) that launched META-NET, a network aiming to build the Multilingual Europe Technology Alliance (META). It is is dedicated to the technological foundations of the European multilingual information society consisting of applications that enable communication and collaboration among people without language boundaries, secure users of any language equal access to the information and knowledge society, and include and push forward functionalities of networked information technology. Massive research and engineering in language technology is needed before this will be achieved, and META-NET brings together the players in the field and helps preparing the European strategic research agenda.
Publications


D. Rybach, and M. Riley. Direct Construction of Compact Context-Dependency Transducers From Data. In Interspeech, pages 218-221, Makuhari, Japan, September 2010. (corrected Figure 2). Computer Speech & Language Best Paper Award Shortlist.


**PhD Thesis**


Staff

- **Faculty**
  Prof. Dr. Dr.h.c. Wolfgang Thomas
  Priv.-Doz. Dr. Christof Löding
  Prof. Dr. Walter Oberschelp, Emeritus

- **Secretary**
  Marianne Kuckertz (until August 2010)
  Silke Cormann (since May 2010)
  Helen Bolke-Hermanns (Research Training Group AlgoSyn Administration)

- **Technical Staff**
  Rolf Eschmann

- **Research Assistants**
  Namit Chaturvedi, M. Sc.
  Dipl.-Informatik Ingo Felscher
  Dipl.-Informatik Wladimir Fridman
  Dipl.-Informatik Michael Holtmann
  Dipl.-Informatik Daniel Neider
  Dipl.-Informatik Jörg Olschewski
  Dipl.-Informatik Frank Radmacher
  Dipl.-Informatik Stefan Schulz
  Dipl.-Informatik Michaela Slaats
  Dipl.-Informatik Alexandra Spelten
  Dipl.-Informatik Karianto Wong
  Dipl.-Informatik Martin Zimmermann
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.

Major projects in which our group participates are the following:

- DFG-Research Training Group 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 for analysis and synthesis of interactive computational systems”) of the ESF (European Science Foundation).

The group is also present in the B-IT Research School, an institution for integrated doctoral studies in cooperation with the Department of Computer Science of the University of Bonn. One member of the group (W. Fridman) pursues a doctoral research project within the school.

Highlights

The dominating event of the year was the farewell to our secretary Marianne Kuckertz who served for more than 20 years at the Lehrstuhl, first under the direction of Walter Oberschelp (until 1998 “Lehrstuhl für Angewandte Mathematik, insbesondere Informatik”) and then with Wolfgang Thomas (from 1998 “Lehrstuhl Informatik 7”). Many generations of students and group members have appreciated her absolutely perfect and competent style of work and her friendly attitude to all failures that occurred around her (including those of the professors...). In a farewell party on 9th June at the Lehrstuhl (see photo), we expressed our deep thanks to her and wished her a wonderful time in her new and more relaxed status as “retiree”. Since that day, Marianne Kuckertz still helped in several cases via the “telephone hotline”, for example supporting her successor Silke Cormann as new secretary.

From 28th June to 2nd June, the Summer School MoVeP (“Modelling and Verifying Parallel Processes”) took place in Aachen, organized by Christof Löding. More than 60 participants from 12 countries attended; the program included tutorials by K. Chatterjee (Stochastic games), V. Cortier (Verification of security protocols), B. Jonsson (Testing and model generation), J.-P. Katoen (Model checking probabilistic systems), A. Phillips (Programming languages for biology), and J. Worrell (Timed systems).

Within the Research Training Group AlgoSyn (Algorithmic Synthesis of Reactive and Discrete-Continuous Systems), two special events are to be mentioned: First, the annual
meeting of all German DFG-research training groups in Dagstuhl (May 2010) was organized, and on 7th July 2010 the evaluation meeting (regarding the application for continuation 2011-2015) took place in Aachen. More information is provided in the section on research training groups in this report.

In the journal of Gesellschaft für Informatik, “Informatik-Spektrum”, two special issues were edited by members of the group: The last issue of 2009, featuring Computer Science and Astronomy, was edited by Prof. W. Oberschelp (see [17, 18]), and the 5th issue of 2010, edited by Prof. W. Thomas, was devoted to Theoretical Computer Science (see [22, 23, 24]). Several survey papers on automata, logic, and verification were completed; see [12, 13, 26].
Research Projects

Infinite Games and Controller Synthesis


Funding: DFG, ESF (European Science Foundation), B-IT Research School

Much of this research was carried out in the framework of the DFG Research Training Group AlgoSyn (Algorithmic Synthesis of Reactive and Discrete-Continuous Systems); other parts were supported by the project GASICS (Games for the Analysis and Synthesis of Interactive Computational Systems) of the European Science Foundation.

• **Controller Synthesis**
  A result of interdisciplinary work is in the framework of the Research Training Group AlgoSyn, the paper [2] in which the automatic extraction of a controller from a Petri net specification is developed, including case studies carried out with an implementation of the synthesis algorithm.

• **Time-Optimal Winning Strategies**
  M. Zimmermann addressed the problem of finding optimal solutions in games where the winning condition involves parametrized temporal operators (e.g. “eventually within k steps”). Extending work of Alur, Etessami et al. on parametrized model-checking, it was shown that similar results can also be established for the solution of games (see [28]).

• **Relating Winning Conditions and Winning Strategies**
  This project is dedicated to a deeper understanding of the connection between the format of the winning condition of an infinite game and the type of winning strategy needed for solving such a game. W. Fridman [8] obtained results that clarify for several versions of infinite state games (in particular, games over pushdown systems or counter systems) how the format of winning strategies can be linked with the format of winning conditions. The studies are presently continued towards a general framework that “explains” the obtained results.

• **Winning Strategies with Delay**
  In practical applications of game-theoretic models, one can only rarely assume a clean alternation of moves between the two system components under consideration. A possible modification of the basic game-theoretic setting is obtained when (say) the second player is allowed to defer his moves for a number of rounds. In work of M. Holtmann and Ł. Kaiser, the solvability of regular infinite games by such “strategies with delay” was analyzed. It was shown that the solvability in this generalized setting is decidable, and that the delay can be bounded to a (computable) fixed number of moves [10]. These investigations are now continued also for infinite-state games where several new phenomena arise.

• **Infinite Games played in finite time**
  In a cooperation with J. Fearnley (Warwick), M. Zimmermann extended results of McNaughton on conditions which allow to stop infinite games after a finite time with correct outcome regarding the winner. A refined analysis of the problem showed the
A surprising result that McNaughton’s “score function” (giving such a condition on termination of plays) can be bounded to values up to 3; see [7].

**Tree Automata**

*K. Wong, C. Löding, W. Thomas*

Funding: DFG

The goal of our research, 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 results obtained in previous years were compiled into the doctoral thesis of K. Wong [27]. Two tracks of research were pursued: the enrichment of specification languages for unranked trees by cardinality constraints (keeping however basic decidability properties), and the enrichment of automata over unranked trees by operations that allow to check equality between brother subtrees [14]. For the latter purpose, a rather expressive MSO-logic over trees was suggested as a component of the automaton transitions.

In work of C. Löding and co-authors, the theory of automata theory over finite trees and infinite trees was enriched by several new concepts and methods. Main results are concerned with

- a solution of the uniformization problem for monadic second-order definable tree relations, using automata theoretic methods [4],
- an extension of monadic second-order logic that allows to specify properties of the cardinalities of sets [6].

**Automata Theory and Infinite-State System Verification**

*I. Felscher, A. Spelten, W. Thomas*

The research in this field is concerned with the application of logic and automata theory to the analysis of infinite structures, in particular of transition graphs that arise as state-based models of software systems.

- *Compositional Methods in Model-Checking*
  
  In the doctoral project of I. Felscher, the model-checking problem over products and sums of structures is analyzed. A fundamental background result is the “Feferman-Vaught Theorem” of first-order model theory which allows to derive information about a product (or sum) structure from properties of the components and certain information about the way they are composed. The obtained results (not yet published) clarify under which circumstances (and with which computational complexity) the model-checking problem over a product can be reduced to its components when the involved
second-order quantifiers are path quantifiers that allow to capture also conditions on lengths of paths.

• **Logics over trees**
  In the doctoral work of A. Spelten, the power of logics that quantify over paths (such as path logic, chain logic, or branching time logics over tree structures) is characterized by special types of tree automata. Another track of research is concerned with new approaches to the model constructions of unfolding and interpretation over labelled graphs. A result on the separation of weak from strong monadic second-order logic over the binary tree was published in [21].

• **Reachability over infinite graphs**
  In his diploma thesis work (see also [20]), Stefan Schulz obtained new results on decidability and undecidability of reachability properties over infinite graphs. The operation of set based unfolding is analyzed and it is shown that it transforms graphs with a decidable monadic second-order theory into a graph with a decidable first-order theory with regular reachability predicates. Another way of generating infinite structures with a decidable first-order theory with reachability predicates is obtained by using parametrized tree rewriting systems.

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**A Game Theoretic Approach to Dynamic Networks**

*F. Radmacher W. Thomas*

Funding: DFG (Excellence Cluster UMIC)

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. In a framework developed in [11], we analyze the solvability of games that model a routing problem under randomized failures in the considered network and show that – perhaps surprisingly – this problem is precisely as hard as in the non-randomized setting.

In a cooperation with the UMIC group of Jun.-Prof. James Gross, we clarify the conditions under which the channel allocation problem (of “cognitive radio”) can be solved, and how far an algorithmic method of generating correct (or even optimal) controllers that implement routing schemes is possible [9].

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**Finite Automata in Algorithmic Learning Theory**

*C. Löding, D. Neider*

In this project we apply techniques from algorithmic learning theory to solve games over finite and infinite graphs. Although (infinite) games on graphs are well understood and there
exist practical algorithms for such games, these algorithms often perform badly on large scale
instances or are not applicable on infinite graphs. In such situations, where the given instances
are huge or the complexity of known algorithms is high, learning can offer a useful alternative
to develop algorithms that quickly identify small solutions if they exist.

As a first intermediate result we developed techniques to symbolically compute winning
strategies for reachability games on automatic graphs [15]. Using a proof-of-concept
implementation, we were able to prove that our techniques are competitive to known
approaches, such as SAT-solving or BDD-methods, on finite graphs. Moreover, on infinite
graphs we can guarantee to compute the solution, if we require that target to learn can be
represented symbolically. Our proof-of-concept implementation uses the learning framework
libalf, which is developed at the Chairs of Computer Science i2 and i7 [1].

Moreover, as a contrary area of interest in this project, we developed a novel learning
technique for visibly one-counter automata [16], motivated by an application for the
validation of XML streams.

Further Studies on Finite Automata

J. Olschewski, C. Löding

During his internship N. Bousquet from ENS Cachan worked with C. Löding on the
equivalence problem for Büchi automata. In [3] it is shown that for the class of strongly
unambiguous Büchi automata it is possible to solve the equivalence problem in polynomial
time. J. Olschewski and M. Ummels give a detailed complexity analysis of the problem of
finding shortest reset words in finite automata (see [19]).
Other Activities

W. Thomas

- Chairman of the senate of RWTH Aachen
- Speaker of the DFG-Research Training Group (Graduiertenkolleg) 1298 “Algorithmische Synthese reaktiver und diskret-kontinuierlicher Systeme”
- Member of Academia Europaea
- Member of the Editorial Board of the following proceedings series and journals:
  - Leibniz International Proceedings in Informatics (LIPIcs), Schloss Dagstuhl
  - Electronic Proceedings in Theoretical Computer Science (EPTCS)
  - ACM Transactions on Computational Logic
  - Logical Methods in Computer Science
  - RAIRO Theoretical Computer Science and Applications
  - Discrete Mathematics and Theoretical Computer Science
- Chairman of Section Grundlagen der Informatik of GI (Gesellschaft für Informatik), and member of the extended executive board of GI
- Member of the Executive Committees of two projects of the ESF (European Research Foundation): the Research Network AutoMathA (Automata Theory: From Mathematics to Applications) and the project GASICS (Games in Analysis and Synthesis of Interactive Computational Systems).
- Member of the Steering Committee for the conference STACS (“Symposium on Theoretical Aspects of Computer Science”)
- Chairman of the Presburger Award Committee 2010 of EATCS (European Association of Theoretical Computer Science)
- Member of the program committees of
  - Workshop on Logical Approaches to Barriers in Computing and Complexity (Greifswald, 17th-20th February 2010)
  - LICS 2010 (24th IEEE Symp. on Logic in Computer Science, Edinburgh, 11th-14th July 2010)
  - LPAR-17 (17th International Conference on Logic for Programming, Artificial intelligence, and Reasoning), Yogyakarta, 10-15 October, 2010)
  - RP10 (4th Workshop on Reachability Problems, Brno, 28-29 August 2010)
• Member of the Evaluation Committee of ILLC (Institute of Language, Logic, and Computation), University of Amsterdam
• Member of Conseil Scientifique d’Ecole Normale Superieure de Cachan
• 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 Advisor for Teachers’ Curricula and for the subject “Computer Science” in the Curriculum of “Technical Communication”
• Member of Programme Committees:
  ◦ *Summer School MoVEP* (Modelling and Verification of Parallel Processes), Aachen, June-July 2010 (Chair)
  ◦ *CloDeM 2010* (FloC Workshop on Comparing Logical Decision Methods, Edinburgh, July 15, 2010)
  ◦ *GandALF 2010* (First International Symposium on Games, Automata, Logics and Formal Verification, Minori, Italy, June 17-18, 2010)
  ◦ *CSL 2010* (19th EACSL Annual Conference on Computer Science Logic, Brno, Czech Republic, August 23–27, 2010)
Talks and Publications

Talks

W. Fridman: Six Types of Pushdown Games, GASICS Meeting, Aachen, Germany, October 2009


W. Fridman: Formats of Winning Strategies for Six Types of Pushdown Games, GandALF 2010, Minori, Italy, June 2010

M. Holtmann: Degrees of Lookahead in Regular Infinite Games, Seminar of AlgoSyn Research Training Group, Aachen, November 2009

M. Holtmann: Degrees of Lookahead in Regular Infinite Games, 13th International Conference on Foundations of Software Science and Computation Structures, Paphos, Cyprus, March 2010

C. Löding: Automata for Boundedness Problems on Trees, Workshop on Distance Automata, Paris, France, November 16, 2009

C. Löding: Boundedness Problems for Finite Automata, CFV Seminar, Brussels, Belgium, November 27, 2009


C. Löding: Infinite Games and Program Synthesis from Logical Specifications, Tutorial at ASE 2010, Antwerp, Belgium, September 20, 2010

D. Neider: Learning to Win Reachability Games, Workshop on Timed and Infinite Systems, Warwick, UK, March 31, 2010

D. Neider: Winning Reachability Games, Seminar of AlgoSyn Research Training Group, Aachen, April 15, 2010


D. Neider: Reachability Games on Automatic Graphs, CIAA 2010, Winnipeg, Canada, August 12, 2010

J. Olschewski: The Complexity of Finding Reset Words in Finite Automata, MFCS 2010, Brno, Czech Republic, August 23, 2010


F. Radmacher: A game-theoretic approach to routing under adversarial conditions, 6th IFIP International Conference on Theoretical Computer Science, IFIP TCS 2010, Brisbane, Australia, September 23, 2010
F. Radmacher: A Game for Reliable Routing in Dynamic Spectrum Access Networks, UMIC Performance Optimization and Prediction Meeting, RWTH Aachen, April 9, 2010

S. Schulz: Decision Problems for First-Order Logic with Reachability, AlMoTh 2010, Frankfurt am Main, Germany, February 26, 2010

S. Schulz: Decision Problems for First-Order Logic with Reachability, AlgoSyn Workshop 2010, Rolduc, Netherlands, March 02, 2010


K. Wong: Finite automata on unranked trees: extensions by arithmetical and equality constraints, Oberseminar der Fachgruppe Informatik, RWTH Aachen, Germany, June 22, 2010

M. Zimmermann: Playing Muller Games in a Hurry, Games Workshop 2010, Oxford, United Kingdom, September 2010

M. Zimmermann: Playing Muller Games in a Hurry, MoVeP 2010, Aachen, Germany, June 2010

M. Zimmermann: Playing Muller Games in a Hurry, GandALF 2010, Minori, Italy, June 2010

M. Zimmermann: Playing Muller Games in a Hurry, Gasics Meeting, Aalborg, Denmark, May 2010

M. Zimmermann: Time-optimal Strategies for Infinite Games, DIMAP Seminar, University of Warwick, Coventry, United Kingdom, March 2010

M. Zimmermann: Parametric LTL Games, AlMoTh 2010, Frankfurt am Main, Germany, February 2010

M. Zimmermann: Parametric LTL Games, GASICS Meeting, Aachen, Germany, October 2009

**Publications**


Mathematical Foundations of Computer Science

Staff

- Faculty
  Prof. Dr. Erich Grädel

- Secretary
  Marianne Kuckertz (until August 2010)
  Silke Cormann (since May 2010)

- Research Assistants
  Dipl.-Inform. Diana Fischer
  Dipl.-Inform. Tobias Ganzow
  Dr. Łukasz Kaiser
  Dipl.-Math. Bernd Puchala
  Dipl.-Inform. Roman Rabinovich
  Dipl.-Inform. Michael Ummels (until January 2010)
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)

E. Grädel, D. Fischer, T. Ganzow, Ł. Kaiser, M. Ummels

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.

Computational Model Theory and Descriptive Complexity

E. Grädel, 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, D. Fischer, Ł. Kaiser, B. Puchala, R. Rabinovich, 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 automated design of soft- and hardware. AlgoSyn is funded by the German Science Foundation (DFG).

Inside this Graduiertenkolleg, our research group mainly focuses 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.

Algorithmic Strategies in Multi-Player Games

E. Grädel, 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, 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
• Editor of the Journal of Symbolic Logic
• Editor of Logical Methods in Computer Science
• Editor of the Journal of Logic and Computation
• Programme Chair of CSL 2009
• Member of the Programme Committee FSTTCS 2009, GAMES 2009, GAMES 2010
• Organiser of the GAMES Spring School 2009, Bertinoro, June 2009.
 Talks and Publications

Talks

E. Grädel, Positional Determinacy of Banach-Mazur Games, Workshop on Logic and Game Theory, Amsterdam, January 2010.
E. Grädel, Tutorial on Infinite Games in Logic and Verification, Swiss Winter School, Champery, February 2010.
E. Grädel, Definability in Games, Invited Keynote Talk at CSL + MFCS 2010, Brno, August 2010.
E. Grädel, Simple Winning Strategies for Banach-Mazur Games on Graphs, Symposium in Honor of Ernst Specker, Zürich, October 2010.
B. Puchala, Knowledge and Cooperation in Infinite Games, LINT midterm meeting, Paris, July 2010.


R. Rabinovich, Parity Games of Imperfect Information on Graphs of Bounded Complexity, Third GASICS Meeting, Aalborg, May 2010.

R. Rabinovich, Parity Games of Imperfect Information on Graphs of Bounded Complexity, LINT midterm meeting, Paris, July 2010.

R. Rabinovich, Parity Games of Imperfect Information on Graphs of Bounded Complexity, Annual Workshop of the ESF Networking Programme on Games for Design and Verification, Brno, September 2010.


Publications


Computer Graphics and Multimedia
Mobile Multimedia Processing

Staff

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Overview

The Chair of Computer Graphics, Computer Vision, and Multimedia at RWTH Aachen University has three major focus areas within the field of Visual Computing: Geometry Processing, Mobile Multimedia, and Computer Vision.

The Geometry Processing Unit addresses research questions in the context of the generation, reconstruction, optimization, and modification of digital 3D models most often represented by polygonal meshes. The typical application domains for the algorithms developed in our group are CAD/CAM in architecture and engineering, simulation sciences, rapid prototyping, as well as medical applications. Our recent activities in Geometry Processing were concerned with the automatic generation of high-quality quad meshes and the robust, efficient, and exact implementation of geometric operators like Minkowski sums and swept volumes.

The Mobile Multimedia Unit emerged from our activities in various third party funded projects, including the excellence cluster UMIC. Here we are investigating fundamental functionalities that make high performance graphics and vision capabilities useable on mobile devices. In particular we are looking into ways how to overcome the restrictions implied by limited resources (e.g. compute performance, memory, transmission bit-rate) and how to recover and exploit the location context of the mobile user for novel application scenarios.

The Computer Vision Unit is concerned with the reconstruction of faithful 3D models from images and video as well as with the detection and recognition of objects. For 3D reconstruction we distinguish different classes of objects, i.e. human faces in motion, static medium sized 3D objects, and entire urban environments. On the detection, tracking, and recognition side, real-time performance and the combination of different detection modules are our major interest. Some topical overlap with the Mobile Multimedia Unit exists in the area of image-based self-localization, where the location of a mobile user is determined by feature-based comparison of his view with a large database of street-level photographs.

Our research is applied to basic research in the sense that we develop fundamental algorithms and apply them to practical real-world problems. This is why our results are on the one hand published in academic papers at the major international conferences and journals, while on the other hand they are being used in practical applications by our industrial partners.

A fully integrated Geometry Processing Pipeline is one of the long term goals on our research agenda. It 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) or they turn unstructured polygon meshes into CAD-type quad meshes where the orientation and alignment of the quad faces reflects the intrinsic geometric structure of the given surface.

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.

Besides the reconstruction of existing objects, we are also investigating new algorithms and concepts for the generation, modelling, and manufacturing of new designs. This is supported by novel algorithms for the efficient, robust and precise computation of geometric operators like Boolean operations, Offsets, Minkowski sums and swept surfaces.
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 way beyond classical CAD/CAM tasks. Through the availability of high performance computer hardware and highly efficient numerical algorithms, various phases of the industrial development process are being based on computer simulations today. In order to guarantee the reliability of these simulations one needs very detailed 3D models. Well known examples for this scenario are flow or crash simulation in the early stages of automotive and airplane development. Further applications are reaching from bio-medical engineering to rapid prototyping and to multimedia data archives. Especially in 3D medical image processing, geometric algorithms gain increasing relevance. We are exploring these applications in the context of the DFG international research training group on "Schizophrenia and Autism" in collaboration with the RWTH Aachen University Hospital and the University of Pennsylvania. In all these applications the cost efficient generation and modification of complex 3D models is essential for the successful use of computers.

To promote this fresh and highly relevant research area we have started an international symposium series on Geometry Processing which after its successful inauguration in Aachen in 2003 has now established as the major international forum specialized to this field. On the national level, we founded a “Geometry Processing” section as a sub-organization of the national Gesellschaft für Informatik. As the speaker of this section, Leif Kobbelt's goal is to join the forces of the various research groups in industry and academia.

On the Computer Vision side, our main research theme is the connection of different areas of vision and graphics into so-called “cognitive loops”, collaborative feedback cycles in which multiple modalities mutually support each other in order to solve a bigger task than any could do on its own. Object recognition and categorization take a key role in those integrations, since they can deliver a semantic interpretation of the image content, which considerably simplifies other tasks such as segmentation, 3D reconstruction, and tracking. For this goal, we have developed efficient approaches for object categorization in difficult real-world scenarios. By combining those approaches with components for ego-motion estimation and tracking, we are building mobile vision systems for localizing other traffic participants (cars, pedestrians, bicyclists) in a vehicle’s field-of-view and for tracking them over time. This research has direct applications for automatic scene interpretation in mobile robotics and automotive platforms.

In addition, we are developing core components for large-scale 3D city reconstruction and mobile visual search applications. Cameras have become a ubiquitous accessory in mobile phones. The goal of this work is to make it possible for people to use their cell phone’s camera as an interface to the real world, recognizing objects of interest in the mobile user’s immediate surroundings and feeding back information and 3D visualizations to the mobile device. As above, this research aims at leveraging the connections between multiple vision modalities, in this case object recognition and 3D reconstruction. Thus, we are developing
technologies for using recognition to help create compelling 3D reconstructions and for using the resulting 3D data to again improve mobile recognition.

Our teaching curriculum currently comprises a number of basic and advanced courses covering the most important sub-disciplines in Graphics and Vision. Besides the “Introduction to Computer Graphics” course, Prof. Kobbelt is offering advanced courses on “Geometry Processing”, “Global Illumination” and “Polynomial Curves and Surfaces”. In addition, Prof. Leibe is offering courses on “Computer Vision” and “Machine Learning”. On the undergraduate level we offer an introductory seminar and practical exercises on topics in Computer Graphics.

This year our group was again able to publish quite a few innovative research papers on internationally recognized conferences and journals in Computer Graphics and Computer Vision.

Marcel Campen received a best paper award at the Symposium on Geometry Processing, SGP 2010.

In the last year, Prof. Kobbelt has received two very attractive external offers from the Universities of Karlsruhe (KIT) and Tübingen. However, eventually he turned down both of them because of a generous counter-offer by RWTH, which will provide the funding and infrastructure for an optimal environment around his future research activities.

On the following pages, we are going to give a brief overview of our current research projects.
The problem of generating high quality quad meshes from unstructured triangle meshes has received a lot of attention recently. The reason for this interest is that quad meshing converts raw geometric data into a higher representation which effectively supports sophisticated operations like texturing and shape modification. The difficulties in quad meshing arise from the fact that the quality criteria are diverse and their optimization often requires the consideration of global dependencies. The most common quality aspects are individual element quality, element orientation, alignment to sharp features, global structure and additional semantical requirements.

In this project we developed a two-step approach which is able to optimize all of these criteria simultaneously. In the first step we extrapolate the most reliable principal curvature directions to achieve a complete four symmetric orientation field, as shown in the picture below (a) \( \rightarrow \) (b). This orientation field is then used in the second step to guide a global parametrization which maps the grid of integer iso-lines seamlessly to a quadrangulation on the surface (b) \( \rightarrow \) (c). The resulting quad mesh is shown in (d).

In both steps of the algorithm the task can be formulated in terms of a mixed-integer problem. These are linear problems where a subset of the variables is continuous (\( \in \mathbb{R} \)) and the others are discrete (\( \in \mathbb{Z} \)). Therefore we developed an efficient greedy solver for this class of problems (see project ‘Practical Mixed-Integer Optimization for Geometry Processing’ on the next page).
Practical Mixed-Integer Optimization for Geometry Processing

Henrik Zimmer, David Bommes, Leif Kobbelt

Solving mixed-integer problems (MIP's), i.e. optimization problems where some of the unknowns are continuous while others are discrete, is NP-hard. Unfortunately such real-world problem instances in the field of geometry processing, arising e.g. in quadrangular remeshing, usually have a large number of unknowns such that exact methods become unfeasible. In this project we developed a greedy strategy to rapidly approximate the solution of large quadratic mixed-integer problems up to a practically sufficient quality. We also provide an open source software library implemented in C++ (www.graphics.rwth-aachen.de/comiso).

The algorithm greedily determines the values of the discrete variables one after another until all of them are found. In each step one discrete variable, which is continuously estimated through a relaxed problem, is rounded to the closest integer and henceforth used as an additional linear constraint for the subsequent relaxed problems. By greedily choosing the continuous estimate which has the smallest deviation from an integer these subsequent relaxed problems can be solved very efficiently by our specially designed three-level solver. The performance can be further improved by simultaneously rounding bunches of relaxed variables which do not interfere too much.

Additionally it is possible to specify a set of linear equality constraints which typically arise as side conditions of the optimization problem. In order to facilitate an efficient solution of the successive relaxed problems we propose to eliminate one variable for each constraint and support this approach by a fill-in minimizing constraint reordering which in practice drastically reduces the runtime.

The capabilities of the presented optimization algorithm is illustrated exemplarily by applying it to the quadrangulation problem (see project "Mixed-Integer Quadrangulation"). A large variety of optional user given meshing constraints like e.g. prescribing some singularities or exactly preserving curves of the input geometry in the generated quadrangulation is achieved by simply adding additional linear constraints. Therefore the presented algorithm enables a very flexible quadrangulation method supporting a wide range of different application scenarios ranging from a fully automatic setting up to completely user guided meshing.
Various applications in the areas of Computer Graphics, Geometry Processing, and CAD/CAM ranging from the computation of Boolean combinations of geometric objects to the repair of raw models and the tracking of sweep surfaces, require methods that are able to cut and recombine intersecting surfaces. The most common representation for geometric objects is the polygon mesh. Performing cuts and recombinations on such polygonal surfaces along curves of intersection has proven to be a complicated task. The correct and consistent determination of the intersection loci is numerically hard to handle with limited precision machine arithmetics, and the discrete nature of a polygonal mesh introduces further challenges that have to be met in order to obtain a working method for industrial applications.

In this project we developed a general scheme that is able to perform topology-changing cut and recombine operations on polygonal meshes exactly and robustly, i.e. it is algorithmically correct and complete, producing accurate output for any valid input. Compared to previous methods that also provide these features, we achieve significantly higher performance and a smaller memory footprint.

The main ingredient, which is the key to achieving robustness and exactness while maintaining high performance, is a paradigm of plane-based geometry representation and processing that encodes the geometry of a polygon mesh through a set of planes rather than a set of vertices. The input geometry is losslessly converted into a hierarchical representation which simplifies computations and reduces algorithmic complexity. Applying this paradigm rigorously allows us to completely avoid slow software-implemented full-precision arithmetics that are commonly employed for the sake of robustness in this context.

The image illustrates examples of topology changes at intersections as they can accurately and robustly be performed by our method. For clarity the objects are depicted cut open and the cuts are highlighted yellow. On the left a Boolean subtraction of the red sphere from the blue one is depicted, the right example removes self-intersections in a so-called orientation-sensitive outer hull operation.
A Sketching Interface for Feature Curve Recovery of Free-Form Surfaces

Ellen Dekkers, Leif Kobbelt

In this project, we developed a semi-automatic approach to efficiently and robustly recover the characteristic feature curves of a given free-form surface where we do not have to assume that the input is a proper manifold. The technique supports a sketch-based interface where the user just has to roughly sketch the location of a feature by drawing a stroke directly on the input mesh. The system then snaps this initial curve to the correct position based on a graph-cut optimization scheme that takes various surface properties into account. Additional position constraints can be placed and modified manually which allows for an interactive feature curve editing functionality.

We demonstrate the usefulness of our technique by applying it to two practical scenarios. At first, feature curves can be used as handles for surface deformation, since they describe the main characteristics of an object. Our system allows the user to manipulate a curve while the underlying non-manifold surface adapts itself to the deformed feature.

Secondly, we apply our technique to a practical problem scenario in reverse engineering. Here, we consider the problem of generating a statistical (PCA) shape model for car bodies. The crucial step is to establish proper feature correspondences between a large number of input models. Due to the significant shape variation, fully automatic techniques are doomed to failure. With our simple and effective feature curve recovery tool, we can quickly sketch a standard set of characteristic features on each input model which establishes the correspondence to a pre-defined template mesh and thus allows us to generate the shape model. Finally, we can use the feature curves and the shape model to implement an intuitive modeling metaphor to explore the shape space spanned by the input models.

The images show examples where we established correspondence between three car models by registering them to the same template mesh.
Generating Animations for movies or games is a time consuming task. The process includes two major steps. The first is to generate a skeleton for the new character and is called *rigging*. The animation data is given as a time-series of angles between the bones of the skeleton and describes the pose of the skeleton in every frame. In order to animate a character, a polygonal surface mesh has to be bound to the skeleton that models the characters skin. This step is called *skinning* and is often done manually by the animator. Having the correspondence between the surface mesh and the skeleton bones, each animation frame defines a new pose of the skeleton and the surface is deformed accordingly.

In order to simplify this process, we created a pipeline of algorithms which mostly automates the rigging as well as the skinning. For each step, the computer makes a suggestion for a possible solution which can be modified interactively by the user. As input we accept arbitrary skeleton based animations. These could be hand modeled by animators or acquired using a motion capture system. Additionally a new character skin is given that is to be animated using the skeleton.

First, a preliminary skeleton is extracted from the input mesh. Next we create a correspondence between the input animation skeleton (sources) and the automatically extracted one (target). The user can manipulate the correspondences supplied by the algorithm such that arbitrary skeleton structures could be transferred to a new character with a different skeleton topology. Afterwards the extracted skeleton is adapted to match the topology of the input skeleton. Given the updated skeleton and the correspondence to the animation skeleton we can simply transfer the animation data. The last step is the skinning, where the new skeleton is bound to the input mesh by an automatic algorithm.

The end result is a fully animated new character like in the example on the right, that has been created in a few minutes only compared to several hours in the established workflows.
Procedural modeling has become a well established approach in applications where highly complex three-dimensional scenes with rich detail have to be generated. In movie production and game industry, this approach is often used for the mostly automatic generation of realistically looking architecture, landscapes, or plants.

In this project we developed the new procedural modeling language "Generalized Grammar" which adapts various concepts from general purpose programming languages in order to provide high descriptive power with well-defined semantics and a simple syntax which is easily readable even by non-programmers. The term "Generalized" reflects two kinds of generalization. On the one hand we extend the scope of previous architectural modeling languages by allowing for multiple types of non-terminal objects with domain-specific operators and attributes. On the other hand the language accepts non-terminal symbols as parameters in modeling rules and thus enables the definition of abstract structure templates for flexible re-use within the grammar.

Our generalized approach is capable of generating architecture (a), plants (b) or even a combination of both (c).

The figure shows three different examples that were generated by our grammar. In the first two images we used our system to reconstruct existing objects such as a building (a) or a lily (b). The last image demonstrates the descriptive power by combining the two different modeling domains in a single, artistic scene (c).
In recent years, oblique aerial images of urban regions have become increasingly popular for 3D city modeling, texturing, and various cadastral applications. In contrast to images taken vertically to the ground, they provide information on building heights, appearance of facades, and terrain elevation. Despite their widespread availability for many cities, the processing pipeline for oblique images is not fully automatic yet. Especially the process of precisely registering oblique images with map vector data can be a tedious manual process. We address this problem with a registration approach for oblique aerial images that is fully automatic and robust against discrepancies between map and image data. As input, it merely requires a cadastral map and an arbitrary number of oblique images. Besides rough initial registrations usually available from GPS/INS measurements, no further information is required, in particular no information about the terrain elevation.

The registration process consists of three steps. For each individual image our algorithm first detects the vanishing point that corresponds to the scene's vertical direction. This vanishing point reduces the degrees of freedom of the extrinsic calibration from 6 to 4, thereby effectively simplifying the subsequent search for registration parameters. In the second step, the algorithm then computes an individual registration of each oblique image in the reduced parameter space. In the final step all parameters of all images are optimized simultaneously with respect to a global objective function to improve the quality of the resulting registration.

Given a set of oblique aerial images (left) and a cadastral map (center), our method fully automatically computes the registration of the images with the map (right).
Vision-Based Analysis and Reconstruction of Realistic Image Geometry for Noisy Facades

Jun Cao, Leif Kobbelt

Our goal is to generate high-quality textures for facades in 3D city models from aerial photos. The technique of recovering high resolution (HR) textures from given low resolution (LR) facades is essential for image-based 3D city modeling. However, current image super-resolution methods are not sufficiently robust to be applied to aerial facade images. The reason for this is the image noise level in the available photo material which does not allow for a proper estimation of high-frequency components or structure elements such as image gradients.

In order to overcome these shortcomings, we propose a novel approach. The new approach is going to apply a global structure analysis based on a generic procedural model for facades, as shown in the illustration below.

Our vision-based approach transforms a single facade image into a textured model by recovering its semantic structure: (i) detect the architectural elements, e.g., windows, doors, balconies, etc., in noisy LR facade image. We can use the shape grammar method of procedural facade modeling to subdivide the input LR facade into floors and tiles. Then segment each individual tile into smaller regions, and match these smaller regions with 2D elements from an architectural library, (ii) classify the textures of these elements into a set of predefined categories, e.g., a wall in red bricks, a wall painted in white, or a wall in gray breeze block, etc.

Based on the detected element structure, an image synthesis technique can be applied to reconstruct a HR facade image from its semantic description obtained by steps (i) and (ii).
The generation of images is one of the major objectives of human creativity. However, with the existence of large image collections on the internet the necessity to generate new images and illustrations from scratch becomes less and less important since for most objects and scenes some image material is already available. Hence, techniques are coming into focus that support image synthesis by decomposing and recombining existing material. Such techniques find more and more applicability in movies or computer games where the repetition of textures appears unnatural.

We propose an approach to generate images that contain branching structures like rivers, cracks, lightnings, mountain ranges, or blood vessels. Our algorithm is able to geometrically synthesize similar structures as seen in the input image. Our algorithms for image analysis and synthesis are integrated into a three stage interactive workflow that provides various semi-automatic selection tools in order to effectively control the process. From an input image a user extracts the branching structures. The structure is analyzed in the second step in order to derive a statistical model which captures the characteristic style of the branching structure. This model is applied to synthesize new abstract branching structures, i.e., polygonal skeletons with associated thickness coefficients. Technically our model describes a Markov process where new extending segments are selected by matching sub-sequences of segments in the input structure. In the final step the output image is generated by a fragment-based image completion technique which first copies matching fragments from the input image to cover the region where the branching structure passes through and then fills the unstructured regions between the branches. In order to produce high quality images we employ Graph Cuts to optimize seams between fragments, Poisson image editing to reduce the gradient across the seams, and image warping techniques to avoid discontinuities along the polygonal skeletons.
The current state-of-the-art systems for registering two images first extract local features in each of the images, match those features using their descriptors and then try to estimate the transformation between the images. Since some of those correspondences might be wrong, it is crucial to use a robust estimator when computing the transformation. The most popular robust estimator is the RANdom SAmple Consensus (RANSAC) algorithm. RANSAC operates in a hypothesize-and-verify framework by randomly selecting subsets of the correspondences to compute transformations and then verifying those hypothesizes against the whole set. It terminates when the probability of finding a better transformation explaining more correspondences falls below a certain threshold.

In this project, we developed a RANSAC extension that is several orders of magnitude faster than standard RANSAC and as fast as and more robust to degenerate configurations than PROSAC, the currently fastest RANSAC extension from the literature. Our proposed method is simple to implement and does not require parameter tuning. Its main component is a spatial consistency check that results in a reduced correspondence set with a significantly increased inlier ratio (see the figure below), leading to faster convergence of the remaining estimation steps. In addition, we experimentally demonstrate that RANSAC can operate entirely on the reduced set not only for sampling, but also for its consensus step, leading to additional speed-ups. The resulting approach is widely applicable and can be readily combined with other extensions from the literature.

Figure: (a) The initial set of correspondences contains mostly false correspondences. (b) Our spatial consistency check removes nearly all false correspondences, keeping only the correct ones.
Conventional beam tracing can be used for solving global illumination problems. It is an efficient algorithm, and performs very well when implemented on the GPU. This allows us to apply the algorithm in a novel way to the problem of radio wave propagation. The simulation of radio waves is conceptually analogous to the problem of light transport. We use a custom, parallel rasterization pipeline for creation and evaluation of the beams. We implement a subset of a standard 3D rasterization pipeline entirely on the GPU, supporting 2D and 3D framebuffers for output. Our algorithm can provide a detailed description of complex radio channel characteristics like propagation losses and the spread of arriving signals over time (delay spread). Those are essential for the planning of communication systems required by mobile network operators.

Our approach rapidly and accurately computes two important aspects of radio wave propagation at arbitrary points in the scene: the average field strength and a delay spread histogram. The algorithm consists of two parts: First, it builds a beam hierarchy that describes the propagation of the electromagnetic radiation, and second it evaluates the radio field properties based on this beam hierarchy. The tracing algorithm relies on a small rendering pipeline similar to OpenGL, but implemented in CUDA, to determine the split positions inside of each beam. For efficiency, unnecessary geometry is clipped away by the use of a quadtree that is intersected with the beam.

For validation, we compare our simulation results with measurements from a real world network. This can be done by educated guesses, or by using sparse measurements and our optimization framework. Not using either will lead to wrong results. Furthermore, we account for characteristics of different propagation environments and estimate the influence of unknown components like traffic or vegetation by adapting model parameters to measurements. For any simulation method, a way of setting the simulation parameters needs to be used to provide sensible results. The advantage of our method is that measurements lead to more correct results and the computed parameters are valid for different variations of a scenario.
Ad-Hoc Multi-Displays for Mobile Interactive Applications

Arne Schmitz, Ming Li, Volker Schönefeld, Leif Kobbelt

There is currently a large class of mobile devices emerging which have several properties in common. First, those devices are essentially general purpose computers, i.e. they use adapted desktop operating systems and are programmable using standard programming languages. Second, they all have relatively large touch sensitive screens. Third, they have advanced graphics capabilities, often supporting 3D graphics via the use of OpenGL ES. Lastly, all those devices have some sort of wireless communication system built in, either GSM or 3G based, WiFi or Bluetooth. Those devices are mostly mobile phones and media players and they are receiving a huge popularity. Until recently, those devices and especially the applications running on them rarely utilized peer to peer communication between multiple devices of a kind. Such a network of devices can in turn be used for distributed rendering purposes and exploration of new interactive systems consisting of multiple, touch sensitive devices.

In this work we have designed a system that uses those emerging smart mobile devices to build an ad hoc network of displays, and to explore possible settings for multimedia applications and interaction scenarios. Our project focused on three parts: First, we extended the traditional multi-touch interfaces to support multiple mobile devices, where gestures can span many screens. Second, we developed a simple and efficient calibration workflow which includes an automatic calibration step and a simple, additional manual calibration step for the imaging device, that has not been considered in the automatic setup. We designed an intuitive pattern that effectively supports the manual calibration. The figure below shows an overview of the calibration workflow. In addition, the use of a wireless network for such an interactive system gives rise to possible problems such as loss of packets or latency. This is tackled by our system as well.
In the past few years mobile platforms have made important advances. With increasing processor speed, wireless connection, multiple sensors, and even hardware accelerated graphics units, nowadays it is feasible for a mobile phone to process high definition videos, access the internet and render 3D geometries. But we are still limited by some inherent characteristics of mobile platforms, such as the physical screen size, the compute power, the memory size, the battery life, etc. Therefore it is still challenging to fluently render and interact with complex multimedia data.

In this work, we propose a server-client architecture to bring the functionality of desktop PC to mobile devices, i.e. the screen content of the desktop server can be interactively displayed on a handheld device with low latency. In order to make our application platform friendly, we utilize a web-server on the server side. Thus, as soon as the mobile client has web-browser and internet connection, it can access the service. No installation of special software on the mobile client is necessary. The server needs to capture the screen contents, preprocess the data and stream the data to the client. The mobile client displays the received image sequence and sends the user's action back to the server.

The left image shows controlling "OpenFlipper" in mobile Safari via our application, which enables the interactive display of highly complex 3D models (with millions of polygons) on a mobile device. The right image shows a user playing "Quake Arena" in mobile Safari.
The aim of this research project is to explore a new way to represent continuous digital images in general. In particular, the paradigm of continuous image representation is totally new for medical imaging and contrasts with established discrete image models based on histograms. With a sparse and continuous model, the image space is not limited by sharp boundaries and the number of image elements, hence the resolution, can be adapted locally as a function of the amount of acquired input information for image reconstruction.

The competition toward higher-resolution medical imaging is an exiting driving application. The size of medical images tends to grow dramatically (cubic law) with the increasing potential resolution of medical scanners. Furthermore, traditional image processing tasks such as image transformation, low- and high-pass filtering, registration and segmentation could be solved more naturally on alternative sparse image models instead of being limited by hard constraints associated to the classical regular grids of identical image elements.

From a stream of 100K random point sample data (a), a robust online statistical method estimates an adaptive resolution continuous image representation of 128 multivariate Gaussian components (b) that approximates the ground truth image (c). This experiment was conducted on a brain slice acquired in a positron emission tomography (PET) scanner.
In this project we address the problem of multi-person tracking with a camera mounted on top of a moving vehicle, e.g. a mobile robot. This task is very challenging, since multiple persons may appear or emerge from occlusions at every frame and need to be detected.

In contrast to already existing multi-person tracking-by-detection approaches, our framework employs an efficient level-set tracker which unifies segmentation and tracking in order to follow individual pedestrians over time. This low-level tracker is initialized and periodically updated by a pedestrian detector, performing short-term data association and creating so-called tracklets. In order to cope with drift and to bridge occlusions, the resulting tracklet outputs are fed to a high-level tracker, which performs longer-term data association by placing the tracklets in a 3D world coordinate system using scene geometry and finding physically plausible trajectories. This design has the advantage of simplifying short-term data association, resulting in higher-quality tracks that can be maintained even in situations where the pedestrian detector does no longer yield good detections. In addition, it requires the computationally expensive pedestrian detector to be active only part of the time, resulting in significant computational savings.
Level-Set Tracking for Automotive Applications

Esther Horbert, Dennis Mitzel, Bastian Leibe

Object tracking from a mobile platform is an important problem for many applications as for example driver assistance systems. Taking as input the video streams from a stereo camera pair mounted on a moving vehicle, our goal is to track other traffic participants for dynamic scene analysis. This is highly challenging since both the cameras and other vehicles can move very quickly through an unknown and complex environment with changing illumination and weather conditions.

In this project, we are working on the integration of geometric scene knowledge into a level-set tracking framework. We use a level-set tracker to track an object's shape, in this case a car's trunk, and estimate not only its displacement, but also how much the car rotated between the two video frames. Our approach is based on a novel constrained-homography transformation model that restricts the deformation space to physically plausible rigid motion on the ground plane. This model is especially suitable for tracking vehicles in automotive scenarios. Apart from reducing the number of parameters in the estimation, the 3D transformation model allows us to obtain additional information about the tracked objects and to recover their detailed 3D motion and orientation at every time step. This information is fed to a higher-level tracker which associates the tracked positions over time and produces car trajectories that are consistent with the scene. The orientation estimate is here used to improve a Kalman Filter estimate of the tracked vehicle dynamics. This leads to more accurate object trajectories, which in turn enables the system to make more accurate predictions about the future positions of the tracked vehicle.
Multi-object tracking from a moving platform is an important problem with direct applications in the near future of mobile robotics and smart vehicles. Considerable progress has been achieved on this task in recent years, and several approaches have been proposed that reach good performance in challenging real-world scenarios. However, computational complexity is still a major issue, since the difficulty of the task requires the successful integration of several complex vision components.

In this project, we are working on an integration of object recognition, 3D reconstruction, and tracking for dynamic scene analysis in challenging inner-city scenarios, with a real-time potential. Taking as input the video streams from cameras mounted on top of a moving vehicle (either a mobile robot or a car), our goal is to detect other traffic participants in the vehicle’s field of view (pedestrians, bicyclists, cars, etc.) and track their motion over time. These capabilities are important building blocks for applications in mobile robotics and automotive driver assistance systems (either for driving safety or for collaborative environment sensing in car-to-car communication applications).

Our approach combines stereo visual odometry estimation, pedestrian detection, and multi-hypothesis tracking-by-detection running together on a single laptop with a CUDA-enabled graphics card. Real-time processing is achieved by shifting expensive computations to the GPU and making extensive use of scene geometry constraints. As a result of this integration, our system can robustly track multiple persons at interactive frame rates from a mobile setup. It thus provides a good example for the vision capabilities that are already possible now for mobile robotics and car safety applications.
Visual object detection is a core component for many applications. The capability to efficiently recognize objects in one's field of view is of interest for many fields, including self-navigating robots. This is especially true for important object categories such as pedestrians or cars. In recent years, a large number of more complex detection approaches have been proposed in the literature. Current visual object recognition technology is reaching a level where satisfactory detection rates are becoming feasible. However, processing speed is still a major issue.

In this work, we have developed a real-time implementation of the popular HOG detector. Our implementation harnesses the parallel computing power of the GPU through NVIDIA’s CUDA framework. It allows to perform object detection at frame rates up to 20-25fps for images of size 640x480. Compared to the original implementation, this represents a 200-250-fold speedup.

In addition, we derived a general algorithm for incorporating ground plane constraints directly into the detector computation. For each object type, we assume that it can only occur in a fixed relative height to the ground plane, i.e. pedestrians are always standing on the ground. This allows to significantly reduce the region of interest where the detector needs to search. The resulting groundHOG approach achieves the same detection accuracy for pedestrian detection as the original HOG detector, while running at 42fps for a street scene scenario, and it can be sped up to a multiple of this value at a small loss in detection accuracy.
In order to make large-scale mobile recognition applications feasible, it becomes important to create and update the application content with as little effort as possible. In our work, we therefore use the wisdom of crowds to determine which landmarks in a city are most important. Using 500k images from the inner city of Paris (Fig. (a)) collected from community photo collections such as Flickr, our goal is to develop an efficient clustering algorithm that divides these photos into clusters that each correspond to a landmark building. We then associate these image clusters with landmark information (e.g. Wikipedia articles) by matching photos from the cluster to photos associated with the articles (Fig. (b)). The clustering algorithm will be designed to continually run in the background and to regularly update the set of landmark clusters and associated information.

Using this data we are building an image-based tourist information system. In order to look up a landmark building, the user takes a photo of it using a cell phone. This photo is sent to our server and is matched against our landmark database using efficient object retrieval methods. The information associated with the recognized landmark is then presented to the user.
Other Activities

Prof. Dr. Leif Kobbelt

Committees and Organizations:

- Member of the Paper Sorting Committee, ACM SIGGRAPH Asia 2010
- Member of the International Program Committee of the Computer Graphics International Conference, CGI 2010
- Member of the International Program Committee of the 23rd Conference on Graphics, Patterns, and Images (SIBGRAPI 2010)
- Member of the International Program Committee of the 6th International Symposium on Visual Computing (ISVC 2010)
- Member of the international Program committee: ACM Symposium on Solid and Physical Modeling 2010 (SPM '10)
- Member of the international Program Committee: Pacific Graphics 2010 (PG '10)
- Member of the International Program Committee of the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games 2010 (I3D 2010)
- Member of the international program committee: Geometric Modeling and Processing Conference, GMP 2010
- Member of the international program committee: Shape Modeling International Conference, SMI 2010
- Member of the international program committee: Fifth International Symposium on 3D Data Processing, Visualization and Transmission, 3DPVT 2010
- Member of the Scientific Committee of the Curves and Surfaces Conference 2010, Avignon, France
- Member of the international program committee: Eurographics / ACM SIGGRAPH Symposium on Geometry Processing, SGP 2010, Lyon

Offices:

- Deputy Member in the Senate
- Member of the Eurographics Award Committee
- Member of the Scientific Advisory Board of the Wales Research Institute of Visual Computing (RIVIC)
- Elected Member of the Executive Committee of the Eurographics Association
- Associate Editor, Computers & Graphics Journal, Elsevier
- Member of the Editorial Board of the Graphical Models Journal (Elsevier)
- Member of the Editorial Board of the IEEE Transactions on Visualization and Computer Graphics Journal
- 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)
- Co-Editor of the Springer book series “Geometry and Computing” (Computer Science & Mathematics)
- 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.
- Director of the Steinbeis Transfer Center for “Geometry Processing and CAGD”

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

Awards

• M. Campen, L. Kobbelt
  Polygonal Boundary Evaluation of Minkowski Sums and Swept Volumes
  Eurographics/ACM Siggraph Symposium on Geometry Processing 2010
  Best Paper Award (3. Prize)

Prof. Dr. Bastian Leibe

Committees

• Area chair, IEEE Conference on Automatic Face and Gesture Recognition (FG 2011), Santa Barbara, USA, March 2011
• Program committee member, European Conference on Computer Vision (ECCV’10), Hersonissos, Greece, September 2010
• Program committee member, IEEE Conference on Computer Vision and Pattern Recognition (CVPR’10), San Francisco, USA, June 2010
• Program committee member, International Conference on Pattern Recognition (ICPR’10), Istanbul, Turkey, August 2010
• Program committee member, IEEE International Conference on Advanced Video and Signal Processing, August 2010
• Program committee member, Canadian Conference on Computer and Robot Vision (CRV 2010), Ottawa, Canada, May 2010
• Program committee member, DAGM Annual Pattern Recognition Symposium (DAGM’10), Darmstadt, Germany, September 2010
• Program committee member, DAGM Annual Pattern Recognition Symposium (DAGM’10), Darmstadt, Germany, September 2010
• Program committee member, International Workshop on Structured Models in Computer Vision (SMiCV’10), San Francisco, USA, June 2010
• Program committee member, International Workshop on Parts and Attributes (PnA’10), Hersonissos, Greece, September 2010
• Program committee member, International Workshop on Sign, Gesture, and Activity, Hersonissos, Greece, September 2010
• Program committee member, International Workshop on Vision, Modeling, and Visualization, Siegen, Germany, November 2010
• Reviewer for IEEE International Conference on Robotics and Automation (ICRA’11), Shanghai, China, May 2011
• Reviewer for Eurographics 2011, Llandudno, Wales, April 2011
• Reviewer for SIGGRAPH 2010, Los Angeles, USA, July 2010
• Reviewer for IEEE Intelligent Vehicles Symposium, San Diego, USA, June 2010
• Reviewer for International Journal of Computer Vision
• Reviewer for IEEE Transactions on Pattern Recognition and Machine Intelligence
• Reviewer for Computer Vision and Image Understanding

Offices and Organizations

• Scientific Advisor, kooaba AG
• Member, Gesellschaft für Informatik (GI)
• Member, Institute for Electrical and Electronics Engineers (IEEE)
• Member, Deutsche Arbeitsgemeinschaft für Mustererkennung (DAGM)
• Member, European Network for the Advancement of Artificial Cognitive Systems (euCognition II)

**Major Research Grants**

**Prof. Dr. Leif Kobbelt**

• “Mobile Aachen City-wide Communication Environment for Secure Internet Services” (Mobile Access)  
  Wettbewerb “IKT.NRW”, Ziel 2-Programm (EFRE), 2009-2012

• “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

• “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”  

**Prof. Dr. Bastian Leibe**

• “EUROPA – European Robotic Pedestrian Assistant”  
  FP7 EU Project (STREP), ICT-2008-231888, 2009-2012. Principal investigator
Talks and Publications

Invited Talks

L. Kobbelt: "Reconstruction and Synthesis of Dynamic Facial Expressions". IUTAM Symposium on the Analysis and Simulation of Human Motion, September 2010, Leuven


B. Leibe: „Object Categorization Interleaved with Figure-Ground Segmentation – An Algorithmic Perspective“, IGSN Symposium, Ruhr University Bochum, November 8, 2010.


Conference presentations


D. Bommes, Practical Mixed Integer Solver for Geometry Processing, 7th International Conference on Curves and Surfaces, June 2010

M. Campen, Polygonal Boundary Evaluation of Minkowski Sums and Swept Volumes, Eurographics Symposium on Geometry Processing, July 2010

M. Campen, Exact and Robust (Self-)Intersections for Polygonal Meshes, 31st Annual Conference of the European Association for Computer Graphics, Eurographics 2010, May 2010


M. Habbecke, Automatic Registration of Oblique Aerial Images with Cadastral Maps, ECCV Workshop “Reconstruction and Modeling of Large Scale 3D Virtual Environments” 2010

J. Möbius, Open Flipper - an open source geometry processing and rendering framework, 7th International Conference on Curves and Surfaces, June 2010


T. Weyand, An Evaluation of Two Automatic Landmark Building Discovery Algorithms for City Reconstruction, ECCV’10 Workshop on Reconstruction and Modeling of Large-Scale 3D Virtual Environments (RMLE’10), 2010
E. Horbert, *Geometrically Constrained Level-Set Tracking for Automotive Applications*, DAGM'10 Annual Pattern Recognition Symposium, Darmstadt, Sept. 2010

D. Mitzel, *Multi-Person Tracking with Sparse Detection and Continuous Segmentation*, European Conference on Computer Vision (ECCV’10), 2010

G. Floros, *Real-Time Multi-Person Tracking from a Mobile Platform*, Demo at European Conference on Computer Vision (ECCV’10), 2010

**Publications**


**Patents Granted**

Data Management and Exploration

Staff

- **Faculty:**
  Univ.-Prof. Dr. rer. nat. Thomas Seidl
  E-mail: Seidl@informatik.rwth-aachen.de
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- **Secretary:**
  Hedi Klee

- **Technical Staff:**
  Detlef Wetzeler

- **Academic and Research Staff:**
  Dipl.-Inform. Christian Beecks
  Dipl.-Inform. Brigitte Boden
  Dipl.-Inform. Sergej Fries
  Dipl.-Inform. Ines Färber
  Dipl.-Inform. Stephan Günnemann
  Dipl.-Ing. Marwan Hassani
  Dipl.-Inform. Anca-Maria Ivanescu
  Dipl.-Inform. Philipp Kranen
  Dipl.-Inform. Hardy Kremer
  Dr. rer. nat. Emmanuel Müller
  Dr. rer. nat. Marc Wichterich

- **External PhD Candidates:**
  Dipl.-Inform. Philipp Meisen
  Dipl.-Inform. Matthias Schiffer
  Dipl.-Ing. Roland Assam
Overview

Research at Computer Science 9 aims at data mining and database technology for multimedia and spatio-temporal databases. In many applications, more and more digital information is generated and needs to be stored, processed, explored and analyzed. In our projects, we consider data from mechanical engineering, civil engineering, mobile communication, medical diagnostics, molecular biology, environmental sciences and multimedia scenarios in general.

Data Analysis and Knowledge Extraction. Increasingly large data resources require automatic techniques for gaining knowledge which means extracting interesting, unknown patterns from the data. In scenarios with many attributes or with noise, these patterns are typically hidden in subspaces of the data and do not show up in the full dimensional space; therefore, we develop new data mining techniques including subspace clustering or outlier detection. For data streams which constitute endless data resources, we develop specialized algorithms that can handle both the infinite amount of data and the limited and often varying amount of time available between two stream data items. Typical tasks are clustering of streaming data or classification on data streams. Besides mining vector data, we focus on extracting interesting patterns from complex data sources as graph databases.

Exploration of Multimedia Databases. Today's scientific, commercial, and entertainment applications produce large amount of multimedia data. In order to get insight into these data, new exploration models are needed. Aiming at reflecting the user's perception, we develop new content-based similarity models based on adaptable distance functions, novel relevance feedback concepts that allow exploring comprehensive multimedia databases, and new interactive visualization techniques to make the exploration process more accessible and more intuitive for the user. These models are computationally expensive and we develop new methods for efficient query processing.

Fast Access to Spatial-Temporal Data. Tasks as similarity search or data analysis demand for fast access to spatio-temporal data. For this, we develop new techniques, as for example index structures, approximation methods and efficient query processing algorithms for complex objects including high dimensional data, time series, or interval data.
UMIC (Ultra High-Speed Mobile Information and Communication) is a research cluster established under the excellence initiative of the German government. The goal of this cluster is the interdisciplinary design of communication systems providing an order of magnitude improvement of the perceived quality of service for the next-decade mobile Internet. We are participating in two of the four research areas: Mobile Applications and Services (B) and Cross Disciplinary Methods and Tools (D).

**Mobile Stream Data Mining.** This project investigates exchange and analysis of continuous data streams. Health-net applications for example monitor vital functions of patients, such as blood pressure or pulse by means of various mobile sensors. Continuously measuring and collecting of these sensor values leads to huge volumes of data which are impossible to store or even transmit using mobile devices. In this context we focus our research on mobile stream data mining and develop new techniques for the aggregation of measurements, continuous modeling of streaming data and the detection of anomalies in order to enable fast reactions, e.g. emergency situations in the above mentioned Health-net scenarios.

![Architecture of HealthNet as a sample scenario for mobile stream mining](image)

**Energy Awareness of Application.** While bandwidth of mobile networks and processing power of mobile devices are enhanced continuously, the energy capacity of mobile clients remains a bottleneck of mobile applications. To overcome the limitation, energy efficiency has to be considered through all layers of mobile communication up to the application layer. We focus our research on the energy awareness of applications for two communication types: First, data dissemination, where data is broadcasted from one central server to multiple mobile clients. In this subproject we enhance fundamental data broadcast techniques by our novel air-indexing structure. We use available broadcast channels to disseminate data to a large scale of mobile clients.

And second, data provisioning, where data is gathered from a set of mobile clients. We develop data analysis techniques based on such gathered data out of mobile clients. By aggregating information in clusters or by detecting outliers in the data one achieves lower
energy consumption for data transmission and overall a longer lifetime for the set of mobile clients.

In both cases we consider energy efficient data transmission on the application layer incorporating also lower layer techniques for even more efficient cross-layer solutions.

![Figure 2.: Tackling the increasing energy gap in UMIC](image)

**SFB 686**

**Model-Based Control of Homogenized Low-Temperature Combustion**

*Anca Maria Ivanescu, Christian Beecks, Philipp Kranen*

The aim of the SFB 686 is a model-based control of homogenized low-temperature combustion for efficient and low-emission energy provision. This requires the cooperation of several fields, in order to build up a thorough understanding of the complex physical processes, as well as the investigation and breakdown of the whole chain of effects, which leads from flow and mixture to ignition and then combustion, to finally end up with the combustion instabilities. To make the gained understanding usable, a description of the physical effects on the basis of mathematical models follows.

Besides intensive research in core areas of automatic control, the application and development of computer-science methods have contributed to the advancement of MPC over the past years. Further synergies between automatic control and data exploration are to be used and extended on the basis of the experiences made so far.

Project A provides the basics and methods of automatic control for the entire CRC. This includes the control and stabilization of highly dynamic processes in combustion chambers and the model-based MIMO control of combustion engines. In the course of research on the processes in combustion chambers during the first funding period, a stabilization of combustion could be reached in simulation for both the well-stirred reactor and the surface burner. The controls' evaluation on the test benches is currently being done. The feasibility of model predictive control of low-temperature combustion in engines was shown in a
prototypical one-cylinder engine for the spark ignition CAI process, and in a close-to-production complete engine for the diesel-engine PCCI/HCCI process.

We are in charge of the subproject A6, in which approaches to extending the Model Predictive Control (MPC) are worked out that allow an improvement of performance through a constantly optimal usage of the computing time available. For that purpose anytime variants of MPC are developed and validated. Instead of having to meet a given time budget, the new methods can always provide an actuating variable at any time, according to the anytime paradigm known from classification. It is expected here that the quality of reference increases with the available computing time. Although anytime procedures can achieve more for predictive control than just meeting a given time budget, they contribute greatly to the attaining of real-time capability, due to their conceptually new approaches. The analysis of process characteristics, as well the development of new local and global methods for the identification and dynamic adaptation of models, is planned as the basis for the anytime concepts. These models take up and continue current developments in high-dimensional spatial and multi-media data bases, as well as in management and analysis of multi-dimensional time series data. The results of these new analysis methods and reduction techniques combined are eventually applied to the planned anytime procedure for the predictive control.

Besides intensive research in core areas of automatic control, the application and development of computer-science methods have contributed to the advancement of MPC over the past years. Further synergies between automatic control and data exploration are to be used and extended on the basis of the experiences made so far; according aims and work packages are stated in the following. The above-mentioned development of methods for Anytime MPC, for instance, is linked to current research at the Chair of Computer Sciences 9 and presents a valuable innovation to automatic control.

**Subspace Mining for High Dimensional Data**

*Stephan Günnemann, Ines Färber, Emmanuel Müller, Hardy Kremer*

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.

![Figure 4: Multiple hidden concepts in subspaces of a high dimensional database](image)

**OpenSubspace: An Open Source Framework for Evaluation and Exploration of Subspace Clustering Algorithms in WEKA**

*Emmanuel Müller, Stephan Günnemann*

Subspace clustering and projected clustering are recent research areas for clustering in high dimensional spaces. As the field is rather young, there is a lack of comparative studies on the advantages and disadvantages of the different algorithms. Part of the underlying problem is the lack of available open source implementations that could be used by researchers to understand, compare, and extend subspace and projected clustering algorithms. We propose OpenSubspace, an open source framework that meets these requirements. OpenSubspace integrates state-of-the-art performance measures and visualization techniques to foster research in subspace and projected clustering. We currently use this framework both in our lectures for teaching and in our research projects for experiment evaluation. Our recent evaluation study published at VLDB 2009 is based on this framework. For further details please refer to our paper and to the supplementary material to this evaluation study. There, you can also find further details about possible parameterization of the underlying algorithms for running experiments. The system is available at http://dme.rwth-aachen.de/OpenSubspace/.
Management of data streams plays an important role, especially data mining tasks such as clustering, 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 apriori 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 varying time constraints and high data volumes as described above. The advantages of anytime algorithms 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).

![Bayes Tree as hierarchical organization of (Gaussian) mixture models for density estimation](image)

**Figure 6:** Bayes Tree as hierarchical organization of (Gaussian) mixture models for density estimation

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**MOA – Massive Online Analysis**

*Philipp Kranen, Hardy Kremer*

MOA (Massive On-line Analysis) is a framework for data stream mining. It includes tools for evaluation and a collection of machine learning algorithms. It is related to the WEKA project, is also written in Java, but scales to more demanding problems. The goal of MOA is a benchmark framework for running experiments in the data stream mining context by providing

- storable settings for data streams (real and synthetic) for repeatable experiments,
- a set of existing algorithms and measures form the literature for comparison and
- an easily extendable framework for new streams, algorithms and evaluation methods.
Outlier Ranking in High Dimensional Data
Emmanuel Müller

Detecting outliers is an important task for many applications including fraud detection or consistency validation in real world data. Particularly in the presence of uncertain or imprecise data, similar objects regularly deviate in their attribute values. Thus, the notion of outliers has to be defined carefully. When considering outlier detection as a task which is complementary to clustering, binary decisions whether an object is regarded to be an outlier or not seem to be near at hand. However, for high dimensional data objects may belong to different clusters in different subspaces. More fine-grained concepts to define outliers are therefore demanded. By our new outlier ranking approaches, we address outlier detection in subspaces of high dimensional data. We propose novel scoring functions that provide consistent models for ranking outliers in the presence of object deviation in arbitrary subspace projections.

Figure 7: Outliers hidden in arbitrary subsets of the attributes

Clustering in Attributed Graphs
Stephan Günnemann, Brigitte Boden

The aim of data mining approaches is to extract novel knowledge from large sets of data. These data can be represented in different manners: high-dimensional attribute data to characterize single objects and graph data to represent the relations between objects. While the first data type is analyzed by subspace clustering approaches, the second one is analyzed by dense subgraph clustering methods. For many applications both types of data (attributes and relationships) are available and can be modeled as graphs with attributed nodes. Analyzing both data sources simultaneously can increase the quality of mining methods. However, most clustering approaches deal only with one of these data types. In our works, we develop novel methods that use both data types simultaneously and thereby obtain better clustering results.
For modern information systems, the efficient retrieval of multimedia data and complex objects is a crucial task for many applications including medical imaging, video analysis, molecular biology or mechanical engineering. Whereas the mapping of complex objects to feature vectors has proven its usefulness in many examples, the limitations of the common Euclidean distance become obvious in case of correlated dimensions in the feature space.

In order to face these problems, the Earth Mover's Distance (EMD) explicitly regards connections of the components while being based on a ground distance schema. Whereas algorithms to compute the EMD for pairs of vectors exist, they are too expensive to be applied to large database of 100,000 or millions of objects. The goal of this research is to develop new algorithms to efficiently support EMD-based similarity search on very large databases.
Relevance Feedback for the Exploration of Large Multimedia Databases
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 an efficient search process, we develop new interactive visualization techniques to make the exploration process more accessible and more intuitive. The interaction allows for exploration of large amount of data with modest effort for the user.

Figure 10: Feedback loop for interactive database exploration

Signature Quadratic Form Distances for Efficient Multimedia Database Retrieval
(partially funded by the Excellence Initiative of the German federal and state governments, RWTH Aachen Seed Funds 2009)
Christian Beecks

This project considers the problem of querying large multimedia databases efficiently and effectively with the concept of Quadratic Form Distances based on flexible feature representations. We recently introduced the Signature Quadratic Form Distance as a generalization of the Quadratic Form Distance and showed its good retrieval performance compared to state-of-the-art distances. In ongoing work, we plan to develop further models, methods, and techniques which enable users to query large multimedia databases intuitively, effectively, and efficiently.
Rapid technological development and the desire for custom solutions have lead to an enormous information flood in manufacturing engineering. In spite of high-performance database systems, it is getting more and more complicated for companies to generate knowledge from stored information and therefore to use this knowledge for improving productivity. This project aims for making a contribution to make knowledge management feasible in the manufacturing engineering.

To achieve this aim it is intended to develop new methods and utilities which make the available implicit technology knowledge explicit and in this way noticeably speed up industrial engineering. Exemplarily this task shall be solved for machine tool industry. One of the envisioned results of the project is the creation of a semantic search engine which is able to combine different types of databases and generates new knowledge from different information sources.

The joint project MachInNet is conducted in collaboration with the CIM Aachen GmbH and the EXAPT Systemtechnik GmbH.

BioKeyS
(in collaboration with BSI, Fraunhofer IGD, Hochschule Darmstadt, LMU München)

Ines Färber, Sergej Fries

The identification of a person is a common task in many day-to-day situations. Withdrawing money or shopping on the internet are only two scenarios where a person has to identify and
authenticate himself or herself in order to gain access to some resource. In most cases the identification process is based on ID-cards and passwords which a person has to enter. However, both have to be owned either physically or mentally by the person and therefore suffer from the problem that they can get forgotten, lost, distributed or stolen which may result in potential identity abuse.

The aim of this project is to provide a solution for this problem by using something that every person has and cannot forget - fingerprints. Since the fingerprints of each person in the world are unique, the identification of a person by his or her fingerprint is a much more secure way than using passwords. However, one of the problems concerning the collection of fingerprints in databases is the possibility of the misuse and privacy concerns in general. For that reason one of the objectives this project is aiming at is a secure way of storing the fingerprints such that the only way of using such databases is for identification or authentication purposes, i.e., no reconstruction of fingerprints should be possible.

The joint project BioKeyS is conducted in collaboration with the “Bundesamt für Sicherheit in der Informationstechnik” (BSI), Fraunhofer Institut für Graphische Datenverarbeitung Darmstadt (IGD), Hochschule Darmstadt (h_da) and Ludwig-Maximilians-Universität München (LMU).

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Sequence Similarity Search

Hardy Kremer

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 and for interactive applications efficiency of the search process is essential.

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 proposed a novel technique that exploits the inherent properties of multivariate 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 significant efficiency improvements achieved result in substantial performance gains that scale well to long multivariate time series with large DTW bands. Our technique is highly flexible and can be combined with existing indexing structures and DTW filters.
Fast Access to Spatial-Temporal Data

High Dimensional Indexing

Stephan Günnemann, Hardy Kremer

Recent applications demand fast query response times on high dimensional data. For this purpose index structures were introduced. Existing multidimensional indexes like the R-tree provide efficient querying for only relatively few dimensions. Therefore we develop new index structures for efficient retrieval and similarity search.

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. By exploiting inherent properties of the indexed data, our new index structures, the TS-Tree and the OF-Tree, can index high-dimensional data in an overlap-free manner; during query processing, powerful pruning via quantized separator and metadata information greatly reduces the number of pages which have to be accessed, resulting in substantial speed-up.

Due to the increasing main memory capacity of modern computers, a high percentage of datasets fits into main memory. We develop novel main memory based index structures that use individual dimensions for each data object by applying the method of subspace clustering. By a local selection of dimensions we increase the information content for objects compared to a global approach; this higher information content enables a better pruning of the search space.

Figure 12: Representation in data space (left) and data structure (right) of an overlap free R-tree.
Other Activities

Teaching

Winter term 2009:
- Lecture on “Data Mining Algorithms” (V3)
- Lecture on “Index Structures for Databases” (V3)
- Seminar on “Data Management and Exploration”
- Contribution to the lecture on “Bionics”
- Contribution to the lecture on “Data Intensive Computing”
- Contribution to the lecture on “Medical Image Processing”

Summer term 2010:
- Lecture on “Advanced Data Mining Algorithms” (V3)
- Lecture on “Algorithms and Data Structures” (V2)
- Seminar on “Recent developments in Multimedia Retrieval”
- Lab course “Data Mining Techniques in Sensor Networks”

Dissertations


Institutional Collaborations

- B-IT Research School
- REGINA Regional Industry Club Informatics Aachen, Aachen
- SFB 686 Modellbasierte Regelung der homogenisierten Niedertemperatur-Verbrennung
- THESEUS Program Research Consortium
- UMIC Research Cluster of Excellence

Collaborations with industrial partners

- Aucos Elektronische Geräte GmbH, Aachen
- CIM Aachen GmbH, Aachen
- EXAPT Systemtechnik GmbH, Aachen
- Fraunhofer Institut für graphische Datenverarbeitung, Darmstadt
- INFORM GmbH, Aachen
- SAP Research, Karlsruhe
Collaborations with academic partners

- Univ. Aalborg, Dänemark (Dr. Assent, Prof. Jensen)
- Univ. Antwerp, Belgium (Prof. Goethals)
- Hochschule Darmstadt (Prof. Busch)
- LMU München (Prof. Kriegel, Prof. Böhm)
- Nanyang Technological University, Singapore (Prof. Gopalkrishnan)
- Univ. Trento, Italy (Prof. Palpanas)
- RWTH Civil Engineering (Prof. Nacken)
- RWTH Computer Science (many colleagues)
- RWTH Electrical Engineering (UMIC partners)
- RWTH Life Sciences (Prof. Deserno, Prof. Zenke)
- RWTH Mechanical Engineering (Prof. Abel, Prof. Kneer, Prof. Peters, Prof. Schmidt)
- RWTH Virtual Reality Center Aachen (Prof. Bischof, Prof. Kuhlen)
- Waikato University, New Zealand (Dr. Bifet, Prof. Pfahringer, Prof. Holmes)

Reviewing Activities

Prof. Seidl is an Associate Editor of the VLDB Journal (Int. Journal on Very Large Data Bases), and he is Member of the Scientific Advisory Board of the ArchaeoBio-Center at LMU München.

Members of the group performed reviews for the following Journals:

- Data Mining and Knowledge Discovery (DMKD)
- Knowledge and Data Engineering (TKDE)
- The International Journal on Very Large Data Bases (VLDBJ)
- International Journal of Information Technology & Decision Making (IJITDM)

Prof. Seidl was a member of the Program Committees of the following conferences:

- ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD 2010)
- IEEE International Conference on Data Engineering (ICDE 2010)
- SIAM International Conference on Data Mining (SDM 2010)
- International Conference on Extending Data Base Technology (EDBT 2010)
- Statistical and Scientific Database Management (SSDBM 2010)
- Prof. Seidl was a member of the Program Committees of the following workshops:
- First International Workshop on Novel Data Stream Pattern Mining Techniques (StreamKDD 2010)
- MultiClust: Discovering, Summarizing, and Using Multiple Clusterings (MultiClust 2010)
Awards

- Dipl.-Inform. Stephan Günnemann received the Friedrich-Wilhelm-Preis 2009 handed out by Univ.-Prof. Dr.-Ing. Ernst Schmachtenberg for his diploma thesis “Approximations for efficient subspace clustering in high-dimensional databases”. Established in 1865, the Friedrich-Wilhelm-Stiftung honors outstanding scientific works at the RWTH Aachen.
- Dipl.-Inform. Ms. Brigitte Boden was successful in applying for a PhD scholarship at the B-IT research school for the years 2010-2013.
- Brigitte Boden won the award for the best paper contribution at the GI Informatic Days 2010 at the B-Bonn-Aachen IT Center for Information Technology.
- Prof. Dr. Thomas Seidl and the co-reviewers from his group received the Outstanding Reviewer Award of the IEEE 26th International Conference on Data Engineering (ICDE 2010) on March 1-6th, 2010, in Long Beach, CA, USA.

Other Activities

- Coordination of cross-disciplinary research fields energy efficiency in the cluster of excellence UMIC
- Variety of duties for the RWTH Aachen department of computer science (chair of the commission for the use of tuition fees; deputy financial chair; member of the jury for industrial stipends and prices; coordinator of the “bright brains in computer science” program for elementary schools; etc.)
- Variety of duties for the Faculty of Mathematics, Informatics, and Natural Sciences (member of the committee for tuition fees; deputy member of the faculty’s board, deputy member of the committee for finances and structure)
- Tutorial on “Discovering Multiple Clustering Solutions: Grouping Objects in Different Views of the Data” at IEEE International Conference on Data Mining (ICDM 2010), Sydney, Australia (2010)
Publications

Müller E., Günnewmann S., Färber I., Seidl T.: Discovering Multiple Clustering Solutions: Grouping Objects in Different Views of the Data. Tutorial at IEEE International Conference on Data Mining (ICDM 2010), Sydney, Australia (2010)


Günnewmann S., Kremer H., Seidl T.: Subspace Clustering for Uncertain Data. SIAM International Conference on Data Mining (SDM 2010), Columbus, Ohio, USA. P.385-396 (2010)


Müller E.: Mining Subspace Clusters: Enhanced Models, Efficient Algorithms and an Objective Evaluation Study. PhD Workshop of the 36th International Conference on Very Large Data Bases (VLDB 2010), Singapore (2010)


Assent I., Kranen P., Baldauf C., Seidl T.: Detecting Outliers on Arbitrary Data Streams using Anytime Approaches. International Workshop on Novel Data Stream Pattern Mining Techniques (StreamKDD 2010) in conjunction with 16th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD 2010), Washington, DC, USA (2010)

Kremer H., Günnemann S., Seidl T.: Detecting Climate Change in Multivariate Time Series Data by Novel Clustering and Cluster Tracing Techniques. Proc. 2nd IEEE ICDM Workshop on Knowledge Discovery from Climate Data: Prediction, Extremes, and Impacts (CLIMKD 2010) in conjunction with IEEE International Conference on Data Mining (ICDM 2010), Sydney, Australia (2010)

Beecks C., Uysal M., Seidl T.: Efficient k-Nearest Neighbor Queries with the Signature Quadratic Form Distance. Proc. 4th International Workshop on Ranking in Databases (DBRank 2010) in conj. with IEEE 26th International Conference on Data Engineering (ICDE 2010), Long Beach, California, USA P.10 - 15 (2010)


Günnemann S., Färber I., Kremer H., Seidl T.: CoDA: Interactive Cluster Based Concept Discovery. Proc. 36th International Conf. on Very Large Data Bases (VLDB 2010), Singapore P.1633-1636 (2010) (Demo)

Kranen P., Kremer H., Jansen T., Seidl T., Albert Bifet, Geoff Holmes, Bernhard Pfahringer: Benchmarking Stream Clustering Algorithms within the MOA Framework. 16th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD 2010), Washington, DC, USA (2010) (Demo)


Computer-Supported Learning

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  Dipl.-Gymn. Nadine Bergner (partly funded by MINT research grant, excellence program of RWTH since February 2010)
  Dipl.-Inform. Philipp Brauner (partly funded by the Boost Funds of RWTH Aachen University)
  Dipl.-Inform. Anna Lea Dyckhoff (partly funded by Gender research grant, excellence program of RWTH since May 2009)
  Dipl.-Inform. Daniel Herding (funded by BMBF since October 2008)
  Dipl.-Gymn. Thiemo Leonhardt (partly funded by MINT research grant, excellence program of RWTH since October 2008)

• External doctoral candidates
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Overview

Our focus in research and teaching covers various topics in computer-supported learning, Web technologies, user-centered design methodologies, and computer science education. This includes:

- **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 (specifically Web 2.0 in teaching and learning).

- **User-centered construction of eLearning components and systems:**
  - Analysis, design, and implementation of eLearning systems.
  - Frameworks for the implementation of innovative instructional theories.

- **Development of sophisticated learning and authoring tools:**
  - Informative, individualized, and semi-automatic feedback in (self-)assessments.
  - Intelligent feedback focusing on the learning process.
  - Innovative technology for mobile learning, including (simple) augmented reality, app-development, and eLearning Web services.

- **Tools for user-centered design of interactive systems:**
  - Seamless integration of different level prototypes.
  - Automatic evaluation of user interaction with prototypes.

- **Computer science education:**
  - 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.

Our major achievements in the academic year 2009-2010 include co-chairing the 8th eLearning conference in computer science (DeLFI 2010), the successful applications for funding of new research projects, founding and elaboration of the computer science lab for pupils (InfoSphere), the establishment of privately sponsored activities to foster interest in computer science in schools, as well as further establishing and advancing CiL services.
Prof. Ulrik Schroeder was Program Co-Chair of the 8th eLearning conference in computer science DeLFI 2010 (http://www.delfi201.de/) and workshop chair of the multi-conference “Interaktive Kulturen” (http://interaktive-kulturen.de/). Altogether the conference offered 36 sessions with more than 90 presentations to more than 450 participants. Main topics were research in design and implementation of interactive systems specifically for eLearning, collaboration and networking. Almost the same number of presentations was actively discussed in 12 co-located workshops. Mostafa Akbari stepped in to co-organize the 4th workshop on “eLearning 2.0 – social software in the field of technology enhanced learning”, which was held at DeLFI 2010.

A new scholarship in the STEM research program for Excellency was granted to Nadine Bergner for her research proposal on New ways to teach Theoretical Computer Science, which will be integrated into the program of the computer science lab InfoSphere. Our interdisciplinary research project to evaluate follow-up measures for introductory programming workshops in schools within the newly acquired virtual project house for gender research (http://www.exzellenz.rwth-aachen.de/ca/bt/sqp/?lang=en) was successfully finished in cooperation with the research group in didactics in technical subject areas. Both projects have been funded from the third funding line within the Excellence Initiative of the German federal and state governments.

Universities and industries lament the decrease in numbers of students in the field of technology, specifically the very low numbers of women as well as the general lack of interest in STEM topics in schools. Our activities and research in this area thus focus on the public image of computer science and measures to foster sustainable interest in technology, STEM topics, and computer science in particular. In 2010, we continued the successful go4IT!-project (http://lehramt.informatik.rwth-aachen.de/go4it), which is funded by a research grant and private sponsors. In this academic year we have carried out more than 60 two-day workshops in 6th and 7th grades to teach girls programming of robots. The workshops are very successful; the girls show a much higher interest in technology and programming after the workshops and many of them can even imagine studying computer science later on.

In order to integrate the various activities towards schools and pupils of the Computer Science department we founded the Junior Academy for Computer Science (InfoSphere http://www.schuelerlabor-informatik.de – see preface for more details). The inauguration of InfoSphere was celebrated in July. Our team has been developing the didactic concept and the exploratory learning modules to experience computer science fundamentals as well as computer science applications in everyday life scenarios.

26 students successfully finished their Diplom-, Master- and Bachelor theses with our team. This is a new peak value for our team and will result in new research projects and publications.

The Center for Innovative Learning Technologies of RWTH Aachen University (CiL) has further established its services and advanced the learning portal L²P. Some of the highlights were reaching a new peak of 2,200 virtual course rooms in winter term 2009/10, successful application for ETS-funding of the L²P-project “Monitoring-Tools in L²P” in cooperation with i9 research, as well as being selected as the only member from a European university in the Microsoft Business Division Advisory Council, informing and influencing future product developments along with a small number of strictly and globally appointed enterprises.

The spin-off CoboCards (http://www.cobocards.com), co-founded by our business mentee Tamim Swaid, keeps being successful. In the second year they founded the limited company
CoboCards GmbH and penetrated the E-Learning market with applications for Micro- and Mobile Learning. They enhanced their product portfolio through cooperation with publishing houses and are now offering them a distribution channel for professionally created micro-content.
Research Projects

**L²P – eLearning and eTeaching Portal of RWTH Aachen University**

Ulrik Schroeder, Philipp Rohde, Anna Lea Dyckhoff, Patrick Stalljohann, Stefan Weidner, Harald Jakobs (CiL) in cooperation with CCC of RWTH Aachen University

The Center for Innovative Learning Technologies (CiL), being responsible for the sustainable introduction of eLearning elements into the university study programs, designs the technological, instructional and administrative framework for blended learning at RWTH Aachen University. Main focus of 2009/10 activities were the further design, development, deployment and advancement of the central learning management system L²P in cooperation with the Computer and Communication Center and the Computer-supported Learning research group. Several new functionalities were successfully tested and introduced. Furthermore, supportive measures such as first level support for all questions concerning L²P as well as a target-oriented eLearning training program including individual, on-demand training courses were helpful for newcomers and advanced learners to the field of technology-supported teaching.

The L²P portal usage continues to be very successful with an increasing number of regular courses using the system (more than 2,200 per term). Within the three and a half years since its launch, L²P continues to be an established, stable and well-adopted eLearning platform. These numbers put RWTH Aachen University into the top universities in Europe concerning its adoption of a blended learning approach.

**SAiL-M: semi-automatic analysis of individual learning processes**

Daniel Herding (funded by BMBF) and Ulrik Schroeder in collaboration with M. Zimmermann, Ch. Bescherer, A. Fest (PH Ludwigsburg), Ch. Spannagel (PH Heidelberg), U. Kortenkamp (PH Karlsruhe), M. Hioh, S. Rebholz, M. Bauer, W. Müller, M. Ludwig (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.
In the last year, we have offered two eLearning applications in courses for mathematics teacher students at PH Ludwigsburg. The ColProof-M application gives feedback and hints to students who are doing proofs by deduction. The SetSails! application uses an integrated term replacement system to support students in transforming terms in set algebra. Both tools incorporate a reusable feedback module called Feedback-M, which has also been used in other eLearning applications developed by our project partners.

In order to evaluate our tools, we used the Jacareto capture and replay toolkit. Jacareto is a framework that offers the functionality necessary for capturing user-program interaction on graphical user interfaces written in Java. 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. This enabled us to detect usability problems and to analyze the usage of the feedback system.

How is my teaching? Tools for gender- and diversity-sensitive action research in blended learning scenarios

Anna Lea Dyckhoff (funded by a gender research grant within the excellence program of RWTH Aachen University) and Ulrik Schroeder

The underlying assumption for the dissertation project is that action research, which is carried out by teachers and learners themselves, improves the quality of their computer-supported teaching and learning scenarios. The concept of action research combines teaching and research for the purpose of quality assurance. As teachers and learners attempt to describe, explore, evaluate and redesign teaching processes and their effects systematically and iteratively, they work for the improvement of their teaching and learning and its environment. While adopting a gender and diversity perspective on the subject, the dissertation project
focuses on the research question: How can technology facilitate and support the activities and processes of action research sustainably? The perception as well as the reflection of learning and teaching processes for example is to be augmented through continuous, integrated data acquisition and visualization. During the dissertation project, new software-based research tools are going to be designed and implemented to support monitoring and evaluation of the learning and teaching process. The intended research tools are going to be implemented and integrated in the learning and teaching portal L²P of RWTH Aachen University (http://www.elearning.rwth-aachen.de). They will be tested and evaluated by teachers and learners of RWTH. In a first step to reach this goal, a basic monitoring tool, which is compliant to the German Data Protection Act, has been designed and implemented in L²P. The dissertation project is placed in an interdisciplinary context, since research methods and expertise of the different disciplines computer science, psychology, and sociology are considered and combined.

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 everyday life. 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 learners’ 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.

Gender-sensitive interdisciplinary computer science approaches for school education in MINT subjects

Thiemo Leonhardt (funded by a MINT research grant within the excellence program of RWTH Aachen University) and Ulrik Schroeder

Teachers play a significant role in supporting young women to follow their interests. Unfortunately, they also increase the social prejudice that young women are not suitable for
mathematics, computer science, natural science and technology. Our conviction is that teachers hold a key position for changing the cultural assignment of males to engineering. For this reason our focus is to implement gender-sensitive teaching practice seminars as a regular part of the didactic teaching module of teacher training at RWTH Aachen University. In addition to the effect that more teaching material will be developed, tested at school and scientifically evaluated, it is our goal to raise the awareness of students completing teaching degrees for secondary school for gender and diversity issues in the MINT field.

Therefore, the central objective of this doctoral thesis project is to develop further learning units exemplarily based on results of the evaluated, successful project Roberta - Mädchen erobern Roboter. As a priority, results of gender and diversity research and concrete examples will be integrated conceptually into lectures and seminars of the didactic computer science module. In this case, gender-sensitive learning materials for lecture series and workshops are designed by the students. Thus, we teach the theoretical knowledge about gender and diversity research results to enable all students to develop gender and diversity awareness in the classroom.

All learning units for the schools are didactically designed in such a way that pupils can discover, test, and enhance their computer science and technology skills. This includes perception, observation, testing and activity planning. At the same time, team work and communication skills are trained and "social skills" are fostered by collaborative knowledge acquisition, and group presentations.

In a second step, we expand the practical school studies by testing and evaluating the learning materials in everyday school life and in new specific workshops. This way, graduates get experience in gender-sensitive teaching practice, and can transfer this into their professional life to further teaching units. They also take these experiences and materials to the learners in school, so that awareness can be raised and a multiplication of the approach is possible.

We are convinced that these theoretical and practical measures (self-reflection on own behavior and teaching) can improve the teacher training in computer science at the RWTH Aachen significantly. On the other hand, we try to transfer the above research results regarding girls in the MINT.

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go4IT! project

Thieme Leonhardt and Ulrik Schroeder (partly funded by private sponsors: THINK ING of Gesamtmetall, Inform, regio iT, Regina e.V.)

Since January 2009, our team offers regional schools free robot workshops for girls to awaken interest in MINT-subject and especially in Computer Science. Content of the workshop is the internationally proven didactic approach on robots. The workshops are offered for girls of the 6th until 8th grade to increase the interest of the pupils in school at a high stage and making the decision for a technical study easier. The innovations in “go4IT!” are an offer of continuative workshops in 8th and 9th form that aim at a sustainable change in the attitudes of participants towards MINT and are integrated into the computer science teacher training at the RWTH Aachen. The “go4IT” project provides students in teacher training the opportunity to get practical experience in teaching successful gender and diversity lessons. Due to a
successful sponsor acquisition, at least 70 workshops were held since 2009. Thus, over 700 girls attend the workshops in the two year.

Results: 97% of the participants had fun at the workshop; 87% of the participants have implemented their own ideas; after the course, over 55% can imagine to be a computer expert; 71% refused to study computer science, after the course, it was 15% less.

Informatics School Laboratory— Extracurricular Place of Learning for Pupils of all Ages

Nadine Bergner, Thiemo Leonhardt and Ulrik Schroeder

The school laboratory for computer science InfoSphere opened in summer 2010 at RWTH Aachen University. It offers several ways to numerous facets and applications of computer science for children and teenagers. It should even awake interest in those who are not technology-friendly. InfoSphere offers a wide range of courses and modules for half a day, a full day, or several days. These modules provide experimental and action-oriented learning with connection to everyday experiences. Examples of such modules include “A journey into a computer”, “Android programming” and “Diffie-Hellman key exchange”.

InfoSphere has been designed as a research laboratory for teachers to test and practice different eLearning experiences. Moreover, it offers a plethora of modern media and technology to help teachers and students implement innovative eLearning scenarios. Furthermore, teachers get the chance to acquire crucial media competences in practice.

Virtual Project House Gender and Technology: Igniting STEM interest by adaptive interventions

Philipp Brauner, Thiemo Leonhardt and Ulrik Schroeder in cooperation with Birgit Ziegler, Institute for Educational Science (funded by Germany’s Excellence Initiative and the Boost Funds of RWTH Aachen University)

The main aim of this project is to design and systematically evaluate measures to increase Science, Technology, Engineering, and Math (STEM) interest. We augmented one well-established course concept for introducing technology and computer programming to (mainly female) pupils by a sustainable follow-up measure. In the courses, students can experiment by designing, constructing, programming, and testing mobile autonomous robots. Thus, they learn how technical systems are developed and that technology design is fun. As additional measure to increase interest in STEM topics, we developed an innovative community platform to engage students in further online learning activities. Furthermore, a guide was developed to facilitate a transition from the programming concepts learned during the workshops to the visual programming language Scratch.
The effect of the different measures was formally evaluated with classes from local schools (the pupils in focus are 11 to 12 years of age). One class received only a workshop, one received a workshop and the follow up measures and one class served as a control group. To identify factors that provoke or hinder interest in STEM pre and post-tests inquired various psycho- and sociometric factors like ICT knowledge and vocational interests. The data gathered is not yet completely analyzed and understood. Preliminary results suggest that the development and application of follow-up measures is not only necessary but also effective. The projects results are fed back into our other activities like the teachers training in computer science and the Schülerlabor Informatik (InfoSphere).

The project is carried out in cooperation with Prof. Birgit Ziegler of the Institut für Erziehungswissenschaften (Institute for Educational Science) of RWTH Aachen University.

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Web-based management of assessment methods in a university-wide learning and teaching portal

*Patrick Stalljohann and Ulrik Schroeder*

In this dissertation project, we try to facilitate a central management of different assessment methods for students’ performances in a university lecture. Therefore, we analyze what kind of assessment methods, like weekly assignments, active participation at projects or writing wiki pages, are currently in use. Especially the individual settings of the most scenarios have to be detected to support them as a central service for potentially all lectures of a university. We intend to develop a web-based module for the learning and teaching portal L²P of RWTH Aachen University that allows lecturers to have a central overview of all assessment elements they are using in their lecture, as well as the corresponding results of their students. An important aim is the possibility to integrate assessment definitions and results of various sources, e.g. an external system for the realization of the latest assessment method. It is planned to enhance this overview of all relevant assessment results of a lecture by the definition of criteria over these results that a student has to fulfill to pass a lecture or to get admission to the final exam of the lecture.
Other Activities

Ulrik Schroeder

- Assistant chairman of GI expert group eLearning (http://www.e-learning.gi-ev.de/)
- Member of steering committee of GI department Computer Science Education (http://www.e-learning.gi-ev.de/)
- Scientific director of CiL (http://www.cil.rwth-aachen.de/) – Center for Innovative Learning Technologies at RWTH Aachen University
- Scientific director of InfoSphere (http://schuelerlabor-inforamtik.de/) the Computer Science Lab for Pupils
- Program Chair of the 8th eLearning conference of computer science DeLFI 2009 in Duisburg (http://interaktive-kulturen.de/DeLFI)
- Program Committee member of DeLFI 2010 (8th conference on eLearning in Computer Science), Duisburg, Germany
- International program committee member of ICWL 2010 (9th International Conference on Web-based Learning) – Shanghai, VR China
- International program committee member of ISSEP 2010 (4th International Conference on Informatics in Secondary Schools) – ETH Zürich, Switzerland
- International program committee member of the 10th IEEE International Conference on Advanced Learning Technologies, ICALT 2010, Tunisia
- International program committee member of CATE 2010 (13th IASTED International Conference on Computers and Advanced Technology in Education) – Maui, Hawaii, USA
- International program committee member of the 4th International Conference eLearning Baltics, eLBa 2010, Rostock
- Program Committee member of HDI 2010 “Fachtagung Hochschuldidaktik Informatik”
- Program Committee for the 4th workshop on eLearning 2.0, 8th German eLearning conference, DeLFI 2010
- 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 the steering committee for Campus-Management-Systems, RWTH Aachen
- Development of a communication concept for computer science faculty
- Development of B.Sc./M.Sc. examination regulations for teacher education in computer science

Mostafa Akbari

- Program Committee for the 4th workshop on eLearning 2.0, 8th German eLearning conference, DeLFI 2010
- Chair of 4th workshop on eLearning 2.0, 8th German eLearning conference in computer science, DeLFI 2010
- Organization of the Google WAVE Workshop, on the PLE Conference 2010, Barcelona
Nadine Bergner
- Co-organization of the “Schüleruniversität Informatik 2010”
- Co-organization of the “MINT Winter School 2010”

Philipp Brauner
- Project Igniting interest in Science, Technology, Engineering and Mathematics by adaptive interventions
- Co-organization of the Schüleruniversität Informatik 2010
- Co-organization of the lecture series “Computer Science for school children”
- Co-organization of the “Girls Day” for Computer Science
- E-mentor in the program “TANDEM kids”

Anna Lea Dyckhoff
- Co-organization of the “Girls Day 2010” for Computer Science
- Co-organization of the “Schnupperstudium 2010” for Computer Science
- E-mentor in the program “CyberMentor”
- E-mentor in the program “TANDEM School”

Thiemo Leonhardt
- Organization of the “Schüleruniversität Informatik 2010”
- Organization of the “MINT Winter School 2010”
Publications


Media Computing Group

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Overview

The Media Computing Group at RWTH Aachen University conducts research in Media Computing and Human-Computer Interaction (HCI) that goes beyond today’s graphical user interface and desktop metaphor. Grounded in computer science, we develop and study new interaction theories, techniques, and systems in the areas of interaction with multimedia ubiquitous computing environments, tangible user interfaces, and HCI design patterns. Our goal is to make the Brave New World of ubiquitous multimedia technologies useful by making it usable.

New media technologies, such as interactive TV or electronic books, often distinguish themselves through their capability for interaction. Their user interface, however, lags far behind its technological potential: today’s “media players” still largely resemble a 1950’s tape recorder. Multimedia interaction is stuck in the 30-year-old desktop metaphor—perfect for document work, but not for media processing. This bottleneck is giving HCI a significance push similar to the explosion of Computer Graphics in the 1990’s. It enables, but also requires us to rethink some central paradigms of interacting with information, especially time-based media.

New interaction techniques can re-enable established routines from the pre-digital world, or create new ones unique to the interactive medium. Our interactive exhibits, for example, enable users to interact with the rich structure of musical data streams—to find a piece in a musical database by humming it, improvise to a piece with computer support, or conduct an actual audio and video recording of the Vienna Philharmonic. This inevitably leads to fundamental research questions in computer science, such as real-time time stretching of A/V streams, conducting gesture recognition, and cognitive modeling of the human conducting process.

Beyond such individual systems lies the realm of media spaces, entire environments in which several key dimensions of complexity increase—multiple users interact with multiple media, using multiple systems, devices, and applications. History has shown that, as technology matures, it fades into the background of a newly augmented reality, instead of leading to virtual realities. But which devices and interaction modalities, if any, will be playing an equally dominant role in this post-desktop scenario as mouse, keyboard, and monitor in today’s desktop-centered systems? We have built the Aachen Media Space at our department, a next-generation interactive environment, to further explore this exciting new area of research.

Trying to prototype new, physical post-desktop user interfaces for such interactive spaces has led us to the development of toolkits for physical computing. 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 Berkeley, MIT, UCSD, Apple Computer, and others.

We are a member of the DFG-funded UMIC Excellence Cluster in Ultra-Highspeed Mobile Information and Communication. We partner with researchers in Humanities in the DFG-funded Brain\Concept\Writing and eHealth HumTec programs, and 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. We are also a member of the B-IT Research School that offers PhD-level compact classes with international speakers to our PhD 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, Christian Remy*

HCI Design Patterns are a format to capture golden rules, design guidelines, and design rationale when building interactive systems. Building on our past work in this area, we have established a collaborative web site for the growing international community of researchers working on this topic (http://www.hcipatterns.org/), which we host as heads of the IFIP task group on this topic.

In 2003, we worked with international partners both at the CHI 2003 Patterns Workshop and online, to create a structural specification for HCI Design Patterns. The result, PLML (the Pattern Language Markup Language, pronounced pell-mell), is expressed as a Document Type Definition (DTD) in XML, and can be found on our web site. Several pattern languages, including our own HCI Design Patterns for Interactive Exhibits, have been converted by their authors into PLML and been made available online for general use.

In 2009, we completed a new pattern language for interactive environments such as the Aachen Media Space. It captures 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. It has been published as a book chapter by Springer.
In 2010, we developed a pattern language for interactive tabletops: As tabletops are becoming commercially available, they might be part of everyday's life in the near future. However, the diversification of hardware designs, interaction techniques, and research findings has led to a highly specialized knowledge that lacks consensus and induces a high threshold for designers, non-researchers, and practitioners, to approach the field, to develop new solutions, or to refine their existing systems. We address this lack of guidelines by presenting a Human-Computer Interaction (HCI) design pattern language that bundles existing knowledge on tabletop design and offers solutions to recurring problems.

Organic Interfaces
Thorsten Karrer, Jan Borchers

Organic Interfaces are an attempt to carry over the ideas of the Organic Computing initiative into the user interface. Nature-inspired properties of artificial systems like self-healing, self-organization, self-configuration, etc. are not only desirable for the system itself but also for the UI. This is closely related to Mark Weiser’s ubicomp vision of the computer as a ‘calm’ device: smooth and fluent change of states and graceful degradation in case of errors allow for a non-distracting and productive user experience. Information representations that are modeled after human learning strategies and thought patterns facilitate the understanding of and the communication about complex data.
The idea has been explored in three sub-projects so far, which will be continued to expand our concept of Organic Interfaces:

Fly is an organic presentation software that moves from the current linear and slide-based presentation style to dynamic concept maps. We believe that this approach is more suitable for humans to understand complex topics. First test results support this claim and show the potential of the system.

DRAGON 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 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.

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**Silhouettes: An Interactive Collaborative Gesture-Based Experience for the World EXPO 2010 Shanghai**

Jan Borchers, Sarah Mennicken, Moritz Wittenhagen, Thorsten Karrer, Chatchavan Wacharamanotham, Leonhard Lichtschlag, Jan-Peter Krämer

Silhouettes is an interactive collaborative gesture-based experience for the German-Chinese House at the World EXPO 2010 in Shanghai. It was developed by Prof. Peter Russell's CAAD group and Prof. Jan Borchers' Media Computing Group at RWTH Aachen University.

Echoing the theme of EXPO 2010, the German-Chinese House and its host, the German-Chinese government initiative Germany and China - Moving Ahead Together, EXPO visitors can create a virtual city neighborhood together by interacting with a large-scale display wall using only their body silhouettes. Their city neighborhood becomes part of a growing 3D virtual city that can be seen online. The system was developed under Mac OS X and runs on an array of Apple Mac Pro and Mac mini computers.

The exhibit opened on May 1st along with the rest of World EXPO 2010, and was on display until October 31st. On the first day, more than 2,000 visitors enjoyed the interactive experience, and the German-Chinese House estimated more than 340,000 visitors during the first 2 months Silhouettes and the house were open.

Germany's Federal President Horst Köhler and his wife visited the German-Chinese House at EXPO 2010 in Shanghai on May 19th, and played the Silhouettes city building game with a group of German school children.
On Nov 27th 2009, the House of Music Vienna launched our redesigned Personal Orchestra exhibit. Using an infrared baton, visitors can conduct the Vienna Philharmonic by controlling speed, volume, and the emphasis of different instrument sections. The new system now features our PhaVoRIT continuous real-time high-quality audio stretching, six new recordings of the orchestra in full HD video, an electronic music stand displaying the score, and helpful hints by maestro Zubin Mehta. Our original exhibit was installed in 2000, and has been used by 1.5 million visitors since, making it the most successful station in the house, and a top tourist attraction.
The key idea of Pinstripe is to build a user interface upon two affordances of textiles: grasping and deforming. Most clothes exhibit loose folds in different areas when worn, and Pinstripe makes use of this fact: It lets wearers provide input by pinching a part of their clothing between their thumb and another finger, creating a fold in the garment, and then rolling this fold between their fingers.

It is a textile user interface element for eyes-free, continuous value input on smart garments that uses pinching and rolling a piece of cloth between your fingers. Input granularity can be controlled by the amount of cloth pinched. Pinstripe input elements are invisible, and can be included across large areas of a garment. Pinstripe thus addresses several problems previously identified in the placement and operation of textile UI elements on smart clothing.
Patients suffering from hand tremor have difficulties in interacting with touch screens. Tremor also limits the possibilities of UI design, requiring larger buttons in more spacious layouts. In cooperation with the Institute of Industrial Engineering and Ergonomics at RWTH Aachen, we developed and evaluated “swabbing”, an input technique for discrete target selection on touch screens. Swabbing is an input technique in which users slide their finger over the screen towards a target on an edge of the screen to select.

We found that using swabbing, tremor users can select a touch screen target more accurately than via tapping. The measurement of finger oscillation shows that the oscillation is reduced while sliding the finger. We believe that the reduced oscillation and increased accuracy give tremor patients more control.

**SLAP Widgets and Madgets**

*Malte Weiss, Florian Schwarz, Simon Jakubowski, Jan Borchers*

**SLAP Widgets**

On-screen controls are flexible but directly manipulating them using fingers introduces occlusion and precision issues. Furthermore, the user must focus on the control instead of the data she manipulates. SLAP Widgets address these issues by combining the benefits of physical widgets and on-screen controls. SLAP Widgets are general-purpose controls made from silicone and acrylic. They provide haptic feedback and allow a precise eyes-free interaction while using the table’s back projection to change their appearance dynamically. They are untethered, low-cost, and easy to prototype. Our widget set contains keyboards, sliders, knobs, and keypads.

**Madgets**

SLAP Widgets provide a physical communication in only one direction: from the user to the system. The table cannot change the physical state of a control. This can cause visual-physical inconsistencies. Madgets, magnetic widgets, extend SLAP Widgets with the ability of actuation. Our interactive table integrates electromagnetic actuation and fiber optical tracking in a single device without using external projectors or cameras. The table can move and configure Madgets consisting of multiple parts. Our system enables well-known GUI concepts for tangible tabletop controls, such as undo or remote collaboration, as well as new actuation dimensions, like height, force feedback, or power transfer.
To thoroughly comprehend application behavior, programmers need to understand the interactions of objects at runtime. Today, these interactions are often poorly visualized in common IDEs except during live debugging. In an exploratory user study we could confirm, that programmers are often unsatisfied with available tools for code browsing, because the common file-based representation of source code does not reflect how methods call each other at runtime to create the application behavior developers intended.

The information about potential call stacks can mostly be obtained from the source code. Stacksplorer introduces a novel visualization technique for this information and allows to navigate through these potential call stacks. It is realized as a plugin for Xcode, Apple’s standard IDE.

The figure below shows the user interface of Stacksplorer. The central editor is equivalent to Xcode’s standard editor, retaining all its features and functionality. The method, in which the cursor is placed, is called focus method. The left column shows methods calling the focus method, the right column shows all methods called from the focus method.

Besides navigating through a class by scrolling vertically in the editor, our design allows navigating horizontally through the call stack, by clicking a method in one of the side columns. For example, navigating to a method that calls the focus method, will cause all 3 columns to shift to the right. The method that was selected moves to the center and opens in the central editor, the previous focus method appears in the list of called methods to the right, and the left column is updated with new information. Important paths through the code may also be stored for later reference.

Initial results of a user study, which tests quantitatively if users can solve tasks faster using Stacksplorer than without it and qualitatively how satisfied users are with our plugin, indicate, that our visualization technique is highly appreciated and helps users to perform maintenance tasks in large software more efficiently.
In pair programming, two software developers work on their code together in front of a single workstation, one typing, the other commenting. This frequently involves pointing to code on the screen, annotating it verbally, or sketching on paper or a nearby whiteboard, little of which is captured in the source code for later reference. CodeGraffiti lets pair programmers simultaneously write their code, and annotate it with ephemeral and persistent sketches on screen using touch or pen input.
Our design rationale is to give the navigator a way to support team conversation by sketching directly on the shared screen. Sketching and annotating should be as easy as picking up a pen to draw or write on paper or a whiteboard. The driver is still the only person entering syntactical code while the navigator enters semantic graphics that do not compile, making it easy to quickly jot down a sketch, explain a design idea or point out a typo to the driver. We integrated CodeGraffiti into the Xcode software development environment, to study how these techniques may improve the pair programming workflow.

TaPS: Tangible Private Spaces
Maximilian Möllers, Stephan Deininghaus, Patrick Zimmer, Jan Borchers

Interactive tabletop systems resemble convenient environments for collaborative work. In these multi-user environments, private spaces are an important issue. However, treating information with different privacy levels on the same surface is difficult to realize with current technology. Existing approaches usually apply wearable devices, such as shutter glasses or head-mounted displays, which are expensive and cumbersome to wear.

We present TaPS, lightweight transparent widgets through which light only passes from a particular direction, effectively creating Tangible Private Spaces that shield the content beneath them from the view of other users. These widgets add tangible control over privacy to interactive tabletops while using low-cost hardware.

The widgets are crafted from acrylic with several layers of scattering foil on top. Each of those layers blurs the content beneath, when viewed from a specific 30-degree-wide angle. Combining multiple layers allows us to shield content for an arbitrary large angle.

Each widget has a unique footprint of reflecting foil underneath, which can be registered by the table's camera system. Our system can learn these patterns beforehand in order to track the TaPS widgets live on the digital surface. To achieve this, we use our own touch and pattern detection framework developed in earlier projects.

The widgets themselves are lightweight and can be picked up in order to reposition them or hand them over to other participants. With this, as well as with sliding the widgets over the table, we return to tangible, more natural hand-over gestures. Because content is only displayed while the widgets rest on the table, all these trade gestures warrant privacy of the handled data.
MudPad
Yvonne Jansen, Jan Borchers

Touch screen interfaces are increasingly common input devices. They are intuitive to use and their visual interface can easily be changed or re-arranged. But so far they do not offer localized tactile feedback for individual points of interaction. Several studies published in the last years point to performance increases on touch screen devices when tactile feedback is provided. Unfortunately, none of these studies had access to a device that could actually produce said feedback at the point of interaction on the screen.

MudPad is an overlay for pressure sensitive touch screens that provides localized active haptic feedback at multiple points. We can therefore enrich the entire interface with a haptic layer as each display area can be individually controlled to ‘display’ a distinct tactile feedback pattern depending on the information displayed.

BendDesk
Malte Weiss, Simon Völker, Jan Borchers

For most people from many different disciplines a desk is the main workspace. A typical desk is composed of at least one or more vertical displays that show digital content and a larger horizontal area, containing input devices, such as mouse and keyboard, paper-based documents, and everyday objects. These two areas are clearly separated which make the direct exchange of objects nearly impossible. Furthermore the interaction techniques for each area are very different from each other. For example for drawing on the vertical displays the user has to use the mouse, but for drawing on the horizontal table she has to use a pen.

BendDesk is a multi-touch desk environment that seamlessly combines a vertical and a horizontal surface with a curve into one large but still reachable interactive workspace. This workspace can be use to display any digital content like documents, photos, or videos. Furthermore the multi-touch technology allows the user to interact with the entire system by
direct manipulation. Due to the seamless combination of both surfaces the user can choose separately which area to use for each task. BendDesk is only designed as a workspace it is also designed as a piece of furniture to replace a normal desk with all requirements users have such as placing everyday objects on it, or seating comfortable at it.

Route Charlemagne

Malte Weiss, Max Möllers, Gero Herkenrath, Florian Heller, Jan Borchers

Route Charlemagne is a citywide project to attract tourists to the city of Aachen and to convey historical and cultural information to visitors in a modern and appealing way. Our department has contributed five exhibits to the city hall of Aachen that enable users to explore facts around this influential building in an interactive way.

Aixplorer

Aixplorer is a mobile audio tour guide that seamlessly detects the visitor's position indoors and outdoors by combining a variety of tracking algorithms. While it currently provides detailed information for each historical room in the city hall, it will interconnect the different citywide stations of the Route Charlemagne in the future. This process of extending the device will happen from September 2010 until August 2013, funded through a 1.5M€ federal grant. During that time, the Aixplorer will serve as platform to research user experience with ubiquitous mobile indoor and outdoor location aware devices, group interactions, and city wide games.
**Friedenstisch**

At the *Friedenstisch*, an interactive table, visitors explore the Aachen Peace Treaty of 1758 by arranging blocks on the tabletop. Each block represents a protagonist of this historical event. When placed on the surface, the table projects text and images next to it explaining the particular person and its contribution to the peace treaty. Users can browse through the text by tilting the block. Furthermore, the exhibit puts all historical persons into context by connecting them by red lines. Following these lines, visitors of the city hall learn all important facts and anecdotes around the Aachen Peace Treaty in a playful and informative way.

![Friedenstisch](https://example.com/friedenstisch)

**Photobook**

Photobooks are interactive touch-screen pillars. Visitors interact with these pillars to explore the Charlemagne Prize and famous Charlemagne Prize laureates since 1950. A simple tap on one of the 50 portraits displays a laureate’s biography, excerpts from the laureate’s speech, or the eulogy. The *cloud of words* above each portrait represents a visual depiction of words that frequently appeared in the selected speech (conjunctions such as “and” are automatically excluded). This word summary highlights hot topics in the content of a speech, such as “Europe” and further allows visitors to compare laureates based on their tag clouds.

![Photobook](https://example.com/photobook)
Corona

Many historical buildings are full of surprising details and stories about historic events that occurred at the site. Our aim is to reproduce such an event and let the visitor experience history directly in a vivid and atmospheric way, making history become alive. To achieve this goal, we augmented the physical environment of the Coronation hall of Aachen’s city hall with a virtual continuous audio space. When entering the city hall, each visitor borrows a small mobile device equipped with headphones (Aixplorer). Then she can instantly emerge into virtual audio scenery of a historic coronation feast.

Imagine you are visiting the coronation hall in Aachen’s historic city hall and are able attend a historic coronation feast. You enter the room and hear the sound coulisse of a banqueting crowd around you. Walking through a sea of noises, you pick up some snippets of a melody somewhere to your left and walk towards the sound’s origin. The tunes become louder and clearer and you realize that you are hearing a minnesinger performing a historical song from the time of Charlemagne. After a while you move on, the singing fades away into the ambient sound coulisse of the feast and the next source you are approaching becomes louder. This way you can explore the coronation hall and its “secrets” by navigating with your ears.

We are using an Ubisense indoor tracking system to determine the visitor’s position in the coronation hall. Moreover, a polar sensor retrieves the head orientation. The tracking system has nearly no impact on the visual appearance of the room. Position and orientation are immediately sent to the visitor’s mobile device. Applying this information, the device outputs virtual scenery to the headphones using binaural audio, placing the visitor into a virtual audio space room. Besides the location-aware rendering, the audio guide can be personalized regarding the visitor’s language and profile. This project helped us to investigate how to design an interactive user experience. We examined how exact users are able to localize sound sources in virtual audio spaces depending on the quality of the binaural rendering. Furthermore, we will investigate design approaches to support group experience.
Other Activities

Fab Lab Aachen

On December 7th, 2009, we opened the doors to the first FabLab in Germany. It is part of a worldwide network of more than 50 fabrication laboratories and open to the general public every Tuesday from 11am to 7pm at no cost except for materials. A FabLab is a small workshop with tools that allow digital fabrication. In Aachen, we have a 3D printer (Dimension Elite), a lasercutter (Epilog Zing), and a CNC milling machine (LPKF Protomat S62). With the 3D printer, we can print 3D objects made of ABS plastic, the lasercutter can cut and mark almost any material, and the CNC milling machine can produce high quality printed circuit boards (PCBs) in a few minutes. The Fab Lab Aachen is also used by our students in classes, for our research projects (Madgets, Mudpad, etc.) and by other institutions at RWTH Aachen University. We regularly host pupils (e.g., during Girls Day 2010, RWTH TandemKids, and Kinderferienspiele der RWTH, Wissenschaftsnacht). All Fab Lab projects are documented on our blog at http://fablab.rwth-aachen.de.

World Usability Day

In November 2010, we organized the fifth World Usability Day Aachen Local Event in cooperation with P3 Solutions at our lab. The main purpose of this annual event is 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. This year’s event focused on “Communication”.

Dorkbot Aachen

Since May 2009, we have been hosting Dorkbot Aachen, a new local chapter of an international network of people doing interactive art, design, and electronic hacks. Dorkbot is a fun monthly meeting of hackers, designers, and artists working on interactive technologies (http://hci.rwth-aachen.de/dorkbot).
CocoaHeads

Since April 2008, we have been hosting CocoaHeads, an international group devoted to discussion of Apple’s Cocoa Framework for programming Mac OS X and iPhone OS. During this year, in monthly meetings participants again presented their projects and offered tutorials on various programming topics (http://hci.rwth-aachen.de/cocoaheads).

AATC/e: Apple Authorized Training Center for Education

In early 2009, our group became an Apple Certified Training Center for Education at RWTH Aachen University. This year, we again organized several Apple-certified courses. Example courses include Apple Support, Server Essentials, Directory Services, and Deployment. All our trainers are experienced administrators and scientists from different faculties of RWTH Aachen University. Our goal is to provide certified, high-quality training for Apple systems to our students, staff members, and anyone else interested (http://aatc.rwth-aachen.de/).

Infrastructure

Our infrastructure evolves constantly, but at the time of writing consists of 8 XServe servers with two XServe RAIDs, 18 desktop machines (10 Mac Pros, 8 Mac minis) with 23” and 30” Cinema Displays and iSight cameras for the student laboratory, and individual MacBook Pros and 30” Cinema Displays 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.). The Fab Lab (see above) is another crucial part of our research infrastructure. We create this environment to facilitate experimentation with time-based multimedia and nonstandard interaction techniques for our students and staff.

In 2010, we worked as reviewers for the top ACM conferences on HCI such as CHI, UIST, ITS, MobileHCI, as well as various other conferences and journals in Media Computing and HCI. We also host the hci-patterns.org home page as heads of the IFIP task group.

iTunes U

iTunes U is a site for free course videos from all major universities internationally, available through the Apple iTunes Music store. In January 2009, RWTH Aachen University joined iTunes U as one of only four German institutions selected for Apple's European pilot program. Our group initiated and coordinated this initiative, and continues to provide the project management and technical coordination, in close collaboration with the Computing Center (http://itunes.rwth-aachen.de).

Our lecture “iPhone Application Programming” has become particular popular on iTunes U globally, reaching the worldwide Top 5 of the most viewed lectures in February 2010.
Talks and Publications

Talks
Usability bei interaktiven Geräten: Das Horrorkabinett des Professor B. Jan Borchers, Keynote Speaker, Computer Mediated Communication Conference, University of Mainz, Germany, Nov 12, 2010.
Yvonne Jansen MudPad: Tactile Feedback and Haptic Texture Overlay for Touch Surfaces. ITS, November 2010.
Hybrid Documents Ease Text Corpus Analysis For Literary Scholars. Maximilian Möllers, ITS, November 2010.
Benutzbare Technik erkennen: Wie wir uns vor mürrischen Mikrowellen und rüpelhaften Radioweckern schützen können (in German). Jan Borchers, Senior Study Program
User Interface Design: Schluss mit nervigen Geräten! (in German), Jan Borchers, Ringvorlesung: Was ist Informatik? for high school students, Aachen, June 30, 2010
From Zero To Hero: Der Einstieg in die iPhone- und iPad-Programmierung. Jan Borchers, Invited talk, REGINA e.V. Mitgliederversammlung, Technologiezentrum am Europaplatz, Aachen, May 5, 2010
MudPad: Fluid Haptics for Multitouch Surfaces. Yvonne Jansen, CHI ’10 Student Research Competition, April 2010.

Publications


Martina Ziefle, Carsten Röcker, Eva-Maria Jakobs, Thomas Schmitz-Rode, Peter Russell, and Jan Borchers. eHealth - Enhancing Mobility with Aging. In Conference on Ambient Intelligence, Salzburg, Austria, November 2009.
Embedded Software Laboratory

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• **Guest Researcher:**
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Overview

The Chair “Informatik 11 – Software für eingebettete Systeme”, or short i11, in English, Embedded Software Lab, represents the field of embedded systems and software. 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 developers 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.
The [mc]square verification platform for microcontroller binary code has been under development for more than five years, with steady progress made in different areas of verification. One of the biggest problems in model checking is the so-called state explosion, meaning the runtime requirements of a model checker is exponential in the number of variables and processes. In the early stages of [mc]square, most improvements were related to automatic abstraction to make binary code model checking tractable.

In the last year, however, the project has substantially changed. Most notably, Dr. Bastian Schlich, who started the project back in 2005 as his dissertation topic, left our group to work in industry. In January 2010, Jörg Brauer thus took over the project lead. However, this change in personnel has also changed the focus of [mc]square in that the tool has become more varied verification platform. Whereas it originally started a pure model checker, it has now become a verification platform that also integrates abstract interpretation, testing, and debugging.

Another reason for this wider variety of topics and techniques is that we could convince Sebastian Biallas to join our team. In his first stages in research, Sebastian has developed new approaches for model checking programs written in Instruction List, a programming language used in safety-critical environments running on Programmable Logic Controllers (PLCs). Considering the turmoil caused by the Stuxnet worm for this very platform, we are happy to have powerful mechanisms for PLC verification at hand, possibly the most advanced methods in the field of PLC verification at the moment.

The past year, however, has also shown how the [mc]square project has matured, indicated by several national and international collaborations both with academia and industry. Together with our colleagues Thomas Reinbacher (TU Vienna) and FH-Prof. Dr. Martin Horauer (UAS Technikum Vienna), we could automatically verify the implementation of an industrial monitoring device. Currently, we are involved in a similar project with Dr. Alexander Asteroth (FH Bonn-Rhein-Sieg). Together with Dr. Andy King from the University of Kent in Canterbury, we have developed a fundamentally new approach to optimal abstract interpretation of binary code. In a collaboration with Prof. Dr. Georg Frey (Saarbrücken University), we could automatically verify the correctness of several implementations of functions used in safety-critical systems.

This wide range of collaborations, applications, and techniques resulted in 16 publications from the [mc]square team this year, with the topics covering abstract interpretation, model checking, synthesis, and verification (including a best paper award at MEMICS'10). Additionally, we have given an invited talk at the Technical University of Munich. Over the past decade, we have seen different techniques from the formal methods community converging, which has significantly increased the effectiveness of techniques available. With our tool integrating a variety of different formal methods, we believe that we are well-positioned for the challenges of the future and have a platform at hand to further put forward the state-of-the-art in binary code verification.
This DFG supported project focuses on the formal verification of programmable logic controller (PLC) programs. PLCs are used in the automation industry for controlling plants, machines and assembly lines. As such, they operate in many safety critical circumstances were formal verification of correct program behavior is desired or recommended.

To verify such programs, a PLC simulator is used to create a model that can be checked against logic formulae. For larger programs, abstraction techniques are required to represent all possible program behavior in a compact form. The progress of the project is integrated into [mc]square, a model checker and static analysis tool for microcontroller programs which is developed at the Embedded Software Laboratory at RWTH Aachen.

First results of the project that allow abstraction refinements were presented at the 5th International Workshop on Systems Software Verification (SSV '10) in Vancouver, Canada. Additional results for the automatic derivation of program invariants are accepted for the 8th Symposium on Formal Methods for Automation and Safety in Railway and Automotive Systems (FORMS/FORMAT ’10) in Braunschweig.

CEVTES: CounterExample Validation and Test Case Generation Framework for Verifying Embedded Software

Jörg Brauer, Martin Horauer, Stefan Kowalewski, Thomas Reinbacher, Andreas Steininger

CEVTES is a joint project involving the Embedded Software Laboratory at RWTH, the Technical University of Vienna, and the University of Applied Sciences Technikum Vienna. The project is primarily funded by the initiative FIT-IT of the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) and the Austrian Research Promotion Agency (FFG).

The key idea of this cooperation is to combine formal verification of binary programs with faithfully selected test traces that are executed on a real microcontroller. Since verification computes over-approximations of the behavior of the real program to overcome undecidability, it suffers from the presence of spurious warnings. In this project, counterexamples – that is, error traces exhibiting a potential failure of the program – are executed on a microcontroller core simulated on a FPGA, with a special device attached to monitor the microcontroller. The traces observed on the FPGA are then used to rule out spurious error traces.

First results of the project have been described in a paper „Test-Case Generation for Embedded Binary Code Using Abstract Interpretation“, which has received a best paper award at MEMICS’10 in Mykulov, Czech Republic.
In August 2009, Jörg Brauer and Andy King, have started a joint project to put forward the state-of-the-art in abstract interpretation of binary code. Andy King, who is working with the University of Kent in Canterbury and Portcullis Computer Security Limited, is a widely appreciated expert in reasoning about low-level program semantics using satisfiability solving. The key observation this project is based on is that binary code behaves very differently compared to programs presented in high-level programming languages such as C, and thus requires different verification methods. In particular, a single assignment in C is frequently compiled into a sequence of instructions, which leads to a tight coupling between the semantics of different instructions. Similarly, control logic is typically formulated in terms of Boolean relations over single bits. Following these two observations, the use of SAT-solving appears natural to reason about binary code.

The key contribution of this cooperation lies in novel methods for synthesizing optimal abstract interpretations of binary programs, with a special focus on the integration of overflows that occur in machine arithmetic. The results have been published in two major conferences on program verification, namely the 17th International Static Analysis Symposium (SAS’10, Perpignan, France) and the 15th International Workshop on Formal Methods for Industrial Critical Systems (FMICS’10, Antwerp, Belgium). Two more papers are currently under review. The cooperation of Jörg and Andy has been supported by the Royal Society, the British national academy of sciences, with an international travel grant and an industrial secondment, the UMIC cluster of excellence, and the DFG graduate school AlgoSyn.

The [mc]square model checker verifies microcontroller programs by means of a simulator. The simulator is used to execute the program to be verified, and thus to create the state space. As the model checking algorithm is separated from the microcontroller simulator, it is possible to add support for new platforms by adding new simulators. However, there are certain constraints which prevent us from using just any simulator, such as the ones provided by device manufacturers. Manually implementing simulators is possible, but time-consuming and error-prone.

The goal of our ongoing research in AlgoSyn is to improve the development process in the aforementioned two aspects. For this purpose, we have developed a synthesis system, centered around a new language called State Space Generator Description Language (SGDL). The system is now in its second year of existence. In the first year, the primary goals were to
establish the system as such, to create a first description of a microcontroller, the Atmel ATmega16, and to translate this description into an operative simulator that can simulate any program for this device. All these goals have been met. Therefore, in the second year, we focused on two different goals: creating simulators for more platforms, and adding automatic abstraction to reduce the gap between fine-tuned manually created simulators on the one and generated simulators on the other hand. A new SGDL-based simulator for the Intel MCS-51 family of microcontrollers has been added, and an SGDL description of the Renesas R8C is currently in the works. As to abstraction, generated simulators can now rely on three different techniques, one of which is based on static analysis.

EU project “Integrated Multi-formalism Tool Support for the Design of Networked Embedded Control Systems” (MULTIFORM)

Volker Kamin

MULTIFORM focuses on the development, the integration and the interoperation of techniques and tools to provide coherent tool support for the integrated control design of large and complex networked systems. It is supported by the Seventh Research Framework Programme of the European Commission under grant agreement number INFSO-ICT-224249.

Within this project, the Embedded Systems Laboratory at RWTH Aachen extends the model checker [mc]square to be able to handle complex control software. Firstly, abstraction techniques are developed that constrain the state explosion that usually prohibits the creation of the state space of complex systems. These techniques make use of domain knowledge such as detailed hardware descriptions in order to minimize the loss of information. Secondly, the automatic detection of spurious counter-examples is researched. The goal is to dynamically refine abstraction techniques and/or model checking algorithms to block those counter-examples from yielding invalid results.

In addition to the extension of [mc]square, the Embedded Systems Laboratory collaborated with VEMAC GmbH to create tool support for software developers during requirements analysis. The tool supports optimal hardware choice – and thereby a better cost estimate – by verifying a microcontroller’s ability to run a certain software configuration without violating real-time constraints.

Finally, the Embedded Systems Laboratory is cooperating with the University of Applied Sciences Bonn-Rhine-Sieg. The goal is to verify safety critical software components and to establish an industrial process for doing so.
Within the UMIC Cluster of Excellence, the Embedded Software Laboratory look into the application of formal methods to mobile networks. The different investigations target different layers of the mobile communication architecture.

In the project "Modelchecking of modular protocols" we investigate the application of formal methods to the verification and validation of modular protocols.

The project "QoS Provisioning" investigates formal methods and mobility calculi to guarantee quality of service in mobile networks.

The project "Software Quality Initiative" investigates quality requirements and quality models to improve the quality of applications for mobile devices.

Applying Formal Methods for Quality of Service Provisioning in Wireless Architectures
Kamal Barakat

Applying Formal Methods for Quality of Service Provisioning in Wireless Architectures is a project running under UMIC. This project consists of two parallel paths, the formal method for QoS provisioning and the verification of enhanced protocols using simulation. A compiler for the pi-calculus formal model is implemented considering the polyadic syntax among other important features. The compiler is currently used to generate an executable java code that can be used to simulate the proposed model with all the features of the calculus, such as alpha-conversion, polyadic parameter passing, and replication. This compiler is the central building block for future constructs such as a transformation tool for verification using external systems like UPPAAL and a visualization tool for representing modeled protocols interactively using web browsers.

Simulating Network Mobility (shortly...
NEMO) takes place using the OPNET wireless simulator. The current work item is the creation of test scenarios based on the requirements of Personal Area Networks (PANs) as described in the IP Multimedia Subsystem (IMS) standardization [3GPP-22259]. Improving the QoS in NEMO according to the requirements of IMS-PANs makes the application of such networks using NEMO a more appealing alternative especially that it guarantees interoperability between different brands because of the nativity of NEMO as an extension of MIPv6.

UMIC: Software Quality Initiative
Dominik Franke, Carsten Weise, Mudassir Rasool

The growing complexity of applications, architectures, protocols and hardware in the mobile world makes it increasingly more difficult to develop bug-free software for mobile communication and information systems. The intention of the UMIC Quality Initiative is to seek for methods that are applicable for mobile software to improve the quality of the software engineering process and the quality of the products. This project aims at the development of methods and tools for mobile development, as well as the identification and design of design patterns and architectures for mobile applications, in order to improve the quality of the mobile software. The first step towards this target is capturing the status quo and a clear problem statement. This has already started in a pathfinder project for this Software Quality Initiative project. Within the pathfinder project, it turned out that a quality model for mobile software is basically non-existent, but is needed to clarify the problems, explain solutions, and in the end also to measure the gains that come with the new methods and tools, design patterns and architectures. To manage the special requirements of mobile software, one goal of this UMIC Software Quality Initiative is to create design patterns and methods for improving quality of massively distributed mobile software.

Another goal is the analysis and improvement of mobile application lifecycles. Since lifecycles of mobile applications are stressed in a different way than lifecycles of desktop applications (e.g. incoming calls or SMS) we use formal methods to analyze lifecycles of different mobile platforms and to build tools that deal with lifecycles at development time. The goal is to help developers to implement the lifecycle of their application correctly to prevent data loss or inconsistencies during execution time. As a first step this topic is currently investigated by a diploma thesis, in which we define a common model to express the different lifecycles of different mobile platforms (Android, iOS, J2ME, …). Having a well-defined clear model is the basis to build corresponding tools that can handle various mobile platforms.
Modelchecking Modular Protocols
Carsten Weise, together with Raimondas Sasnauskas (I4)

Future mobile communication needs more flexibility due to the growing diversity in protocols, devices, and wireless standards. An approach to this growing complexity are modular protocols, where protocol stacks are not monolithic entities anymore, but are constructed from smaller modules that can easily be exchanged to adapt the protocols to the context. However, this increases the problem of errors and incompatibilities in the protocol software.

Within the project, we have been investigating the applicability of model checking, but however it turns out that model checking existing protocol software is still not in the scope of available model checking tools. Instead, we are now looking into test tools that allow the symbolic execution of code. While this technique is not as powerful as model checking itself, it shares a lot of features with model checking. The main advantage is that there is a tool for symbolic execution called Klee that can readily be used for protocol software written in C.

Within the project, we have extended symbolic execution to distributed symbolic execution, which allows to debug protocol software in a communication network context. During the year, we were able to show that this technique is useful to find errors in protocols. We are currently working on the theoretical base of the technique, in order to be able to describe the technique formally and in fact to prove correctness of our algorithms.

Heterogeneous Timing Constraints for Applications in Embedded Environments
John Schommer, Carsten Weise

Many applications have both hard and soft real-time requirements that must be fulfilled simultaneously. For hard real-time problems, where accuracy is one of the major obstacles, a wide range of dedicated solutions exist. For applications with less strict timing constraints correlated potential features like usability, interactivity, configurability, and visualization getting more important. For these software intensive applications high-level languages are more suitable, as features can be programmed more efficiently. But these languages are not necessarily real-time capable. Developing a heterogeneous application, which is suited in both domains, is difficult.

We investigate methodologies, architectures, principles, and process calculi, which allow solving the different timing problems within the application. The work is based on our experience in a recent industrial cooperation, where under the increasing cost-pressure, the accelerated development cycles, and a higher change-rate of the solutions it becomes reasonable to search flexible, maintainable, evolvable, modifiable and more economic development frameworks. We started analysing suitability of existing technology with focus on benchmarking several real-time operating systems and middleware.
The amount of software in cars is still increasing. However, future cars will have less Electronic Control Units (ECUs), as increasingly different functionality from multiple vendors is implemented on one hardware platform in order to reduce overall costs. This approach has significant implications on safety-critical functionality, though. The failure of an uncritical task can influence the behavior of a safety-critical task.

In the context of a project funded by the Research Association of Automotive Technology (Forschungsvereinigung Automobiltechnik, FAT) we investigated challenges and techniques with respect to software partitioning. One focus was the investigation of AUTOSAR services, e.g. the AUTOSAR Watchdog Manager. We assumed that a global reset of the ECU caused by the Watchdog Manager might result in a hazard if availability is a safety requirement. Analyzing the current specification of the Watchdog Manager we found that there are currently no mechanisms to prevent that a software partition causes a reset.

Parallel we developed a new tool for static analysis of C code to detect bugs in programs. In this tool we implemented a hybrid microcontroller-specific memory model which uses symbolic addresses for local variables, but concrete addresses for registers and global variables. Considering the state of I/O registers, we were able to implement more precise analyses that produce fewer false alarms. To support software partitioning our tool provides the possibility to define software partitions. Thereby, we can find inadmissible dependencies between partitions.

Description of project: cf. the description of the dissertation of Ashraf Armoush, which is also located in this annual report.

The infrastructure of highways in most major countries is 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.

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.

Within our cooperation with the control engineering institute (IRT) in Aachen, different controllers for the vehicular platoon were designed. Our task was on the one hand to prove the safety of the proposed controllers by formal verification methods and on the other hand to provide a hardware platform for testing.

For the formal verification, we adapted already existing techniques for linear uncertain systems based on overapproximation of reachable sets represented by zonotopes. The most challenging task was to control the increasing complexity of computation, which is closely related to the number of generators describing the zonotope. Therefore, it was necessary to implement order reduction techniques. Further geometric set operations such as the intersection of a zonotope with a hyperplane were implemented to extend the approach to hybrid systems. We were able to check the safety of practically relevant scenarios.

A hardware implementation of the whole system is realized. We designed a 1:14 scaled platoon of four trucks. Each truck is equipped with sensors which provide the required information for the controller in order to guarantee a safe inter-vehicular distance. In our implementation, we use WLAN for the exchange of information between the trucks. Besides, a monitoring system of the networked platoon is supported.
The complexity of embedded systems is growing constantly. This is caused by more functionality and more communication and dependencies. One way to tackle this is the model-based development which provides (1) a high abstraction level, (2) domain specific languages/models and (3) the possibility to simulate.

When applying model-based techniques to the engineering of embedded application software, a typical challenge is to manage the complexity of dependencies process artefacts. In an industrial cooperation with the Daimler AG we tackle such problems with a analysis framework based on the Eclipse Modeling Framework (EMF). We apply model transformation languages to create special “views” on Simulink models which analyse the Simulink model with respect to special questions (e.g. “Which blocks operate on which signals?”, “Which parts of the Simulink model are variant-specific?”). Furthermore we address traceability aspects (e.g. “Which parts of the Simulink model and which test cases are related to a given requirement”).
Another issue in model-based development of embedded systems applications is the evaluation of test runs incorporating continuous data. An example for this is back-to-back testing of original model and generated code, where we have to compare continuous signals representing test runs of both system under test (code) and reference (model). Since continuous data is innumerable equality of those signal is not a usable metric, a kind of similarity is stronger. We developed a method to measure the similarity of two systems showing continuous behaviour based on conformance of signals to abstract behavioural models. By showing that all signals runs of the system under test conform to the abstract model and also the reference’s signals do, we can conclude, that the system under test is similar to the reference with regard to the abstract model.

**Integrative Timed Testing**

*R. Mitsching, C. Weise, H. Bohnenkamp (i2)*

Testing is vitally important in the system development process, and no product would ever go to market without serious testing. But with today’s technological advances, pressure to market quickly, and stiff competition, standard testing simply does not cut it anymore.

Standard testing methods often consume a lot of efforts. One approach to deal with this is Timed Testing. These methods provide prototypes of tools to automatically generate and execute tests from a model of the system under test. These methods are able to increase the reliability of the tested products.

In cooperation with Henrik Bohnenkamp (Lehrstuhl Informatik 2), we investigate the challenges to integrate Timed Testing within an industrial application. Our work will provide indispensable insight to improve functional and real-time testing of embedded systems in industry.

**Simulator for a Rail Testing Environment**

*John Schommer, Ralf Mitsching, Carsten Weise*

A major problem with the testing of the controller of the signaling devices is that availability of the target system is low as well as cost of using the target system for the test is very high.

Rebuilding the system in the lab is tedious - one way is to use hardware miniatures to simulate the railway environment. Still the set up phases for test environments is long; the test environment is rather inflexible and needs a lot of manual intervention.

In a joint project with a local provider for railway signaling devices, we aim at providing a software simulation that allows an efficient and mostly automated testing of the controller software for the required railway configurations. In 2009, the core of the simulator, replacing the hardware miniature of the railway station in the test lab, has been successfully developed.
In 2010, a complete test harness for the railway controller has been constructed and refactored. Additionally, functionality and features have been added. In the summer of 2010, the simulator was successfully used in a greater project of the industrial partner.

It is planned that the project continues with the realization of portability, real-time behavior and more sophisticated architecture-based software design.

SmartECLA

Andre Stollenwerk

In nowadays 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 embedded devices were added to all sensors and actors in the setup. On these distributed units basic aspects of the safety and reliability concept are implemented. In addition to this more complex algorithms modeling the system wide interrelationship are run on the central control unit. These algorithms for instance enable the control to do a better forecast of the systems wearing. This project started in September 2007.

Workshop Formal Methods for Industrial Critical Systems 2010

Jörg Brauer and Stefan Kowalewski

The aim of the Formal Methods for Industrial Critical Systems (FMICS) workshop series is to provide a forum for researchers who are interested in the development and application of formal methods in industry. In particular, these workshops bring together scientists and engineers that are active in the area of formal methods and interested in exchanging their experiences in the industrial usage of these methods.

At September 20-21, 2010, the 15th FMICS took place, this time co-located with the 25th IEEE/ACM International Conference on Automated Software Engineering (ASE) in Antwerp, Belgium. This year’s meeting was organized by Stefan Kowalewski (Embedded Software

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Laboratory, RWTH) and Marco Roveri (Foundazione Bruno Kessler, Trento, Italy), who both served as co-chairs. From the Embedded Software Laboratory, Jörg Brauer was also involved in the conference organization by serving as one of the 27 members of the program committee. In additional to the PC members, 61 external reviewers assisted in the reviewing process.

FMICS 2010 has attracted 30 submissions from 19 countries, 14 of which have been accepted after a thorough reviewing process where each paper received at least four reviews. All accepted papers have appeared in Springer’s Lecture Notes in Computer Science series. The presentations covered a wide range of topics, mostly focusing on the application of model checking and abstract interpretation to reason about software. Following a tradition established over the past few years, the European Association of Software Science and Technology (EASST) offered an award to the best FMICS paper. This year, the contribution „The Metro Rio ATP Case Study“ by Alessio Ferrari, Daniele Grasso, Gianluca Magnani, Alessandro Fantechi, and Matteo Tempistini received the best paper award, reflecting the results of the reviewing process.

In addition to the regular talks, FMICS featured four invited talks by Stephan Tobies (European Microsoft Innovation Center), Axel Simon (Technical University of Munich), Aarti Gupta (NEC Labs), and Bert van Beek (Technical University of Eindhoven). Overall, the talks featured a wide range of topics, from type systems based on abstract interpretation to the process of establishing verification tools in large companies. The keynote talks were kindly supported by the UMIC excellence cluster, the European Consortium for Informatics and Mathematics (ERCIM), and the European Microsoft Innovation Center (EMIC).

Considering the variety of contributions of high quality and the very interesting invited talks, we consider FMICS 2010 a great success and are looking forward to FMICS 2011, which will be announced shortly.


Carolo Cup 2010
Andreas Polzer, Hilal Diab

In 2010 the team GalaXIs (www.galaxis.rwth-aachen.de) supported by the Embedded Software Laboratory won the Carolo Cup for developing autonomous model cars. The five students (Julian Krenge, Philipp Fischer, Stefan Kockelkoren, Matthias May and Yves Duhr) won both the static and dynamic tasks. In this year the competition was coined by three teams from Braunschweig (CDLC), Zwickau (S.A.D.I.) and Aachen (GalaXIs) which had chances to win. The decision was made during the most difficult discipline autonomous driving with obstacles. The car from our team called Sagittarius impressed by a nearly perfect drive around the track.

The main task of the competition is to develop a model car (1:10) realising complex autonomous driving assistants, like automatic parking, autonomous driving of a circuit and autonomous driving of a circuit with obstacles. The competition consists of static and dynamic disciplines. The static tasks were to present the concepts realized to solve the given problems. Within the dynamic disciplines the model car had to show the abilities of autonomous driving and parking. The fastest car wins a discipline where faults are punished with time suspensions.
The aim of the competition is to give students insight into interdisciplinary problems when developing automotive applications. The students have to transfer their knowledge from their studies to practical problems. A lot of interesting videos can be found on the homepage (www.carolo-cup.de).

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Development of Cross Checking Protocol and Parameter for Embedded Network Management System

Chakrit Wannachakrit

Network management system (NMS) is important both in ensuring the correct operation of network devices and in maintaining the services that run on them. However, the relentless growth of DSL’s users, meaning that IP traffic volumes nearly double every two years, renders real-time monitoring and analysis of every customer’s service parameter is a very challenging problem. Firstly, bottleneck and single point of failure are the main issues which cause the service providers to invest more money in centralized NMS such as servers and manpower. Secondly, the service providers aim to expand their DSL’s customers’ coverage area to draw new customers. Sometimes they have to install network devices such as DSL access multiplexers (DSLAMs) in areas where the conditions of their operating environment are unable to be managed, meaning that some conditions such as electromagnetic interference (EMI) radio ingress, harmonic distortion, external temperatures, external humidity and etc cannot be monitored by a SNMP-based system.

This research presents a cross checking protocol and parameter (CCPP) process in Embedded Network Management System (ENMS) to support distributed network devices' operations in a distributed NMS fashion. It will use information from multiple protocols and multiple sources to detect the point of failure and anomaly events. The entire process of centralized NMS can be greatly enhanced with an ENMS, which can gather data from all network devices by using
information from SNMP-based and from customers’ devices via the TR-069 interface and data from external sensors. ENMS can isolate faults in all layers of the protocol stack and in all of the involved network devices by a smart mechanism based on cross check protocol and distributed aggregation trees (DATs) and probabilistic (compressed) data structures to achieve its performance goals. ENMS is able to be integrated with other operations systems to automatically issue trouble tickets to the correct responsible department such as Internet service providers, central offices, outside node station and customers. Thereby, it can then route the trouble to the appropriate work center much faster than successively passing it from one work center to another until it happens to find the right one. Customer expectations with bandwidth requirements and reliability requirements can be improved with an ENMS.
Other Activities

Stefan Kowalewski

• Speaker of the Computer Science Department, RWTH Aachen University (until 09/2010)
• Member of the Board, Regional Competence Network for Information Technology “REGINA”, Aachen, Germany
• Member of the Board, „Forum Informatik“ of RWTH Aachen University (until 04/2010)
• Member of the Steering Committee, Special Interest Group “Automotive Software Engineering” German Society for Computer Science (GI)
• Associate Editor, “Journal on Discrete Event Dynamic Systems: Theory and Applications”, Springer Verlag
• Member Editorial Board, „at-Automatisierungstechnik“, Oldenbourg-Verlag
• Program Co-Chair conference “Formal Methods for Industrially Critical Systems” (FMICS), Antwerp, 2010

Carsten Weise


Jörg Brauer


Andre Stollenwerk

Publications


**PhD Theses**

Institute for Scientific Computing

Staff

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

- **Secretary**
  
  Gabriele Meessen

- **Lecturer**
  
  PD Dr.-Ing. H. Martin Bücker

- **Research Assistants**
  
  Dipl.-Math. Oliver Fortmeier
  Dr. Kathrin Fuchss Portela (since 10/2009)
  Dipl.-Inform. Michael Lülfesmann
  Dipl.-Ing. Monika Petera (until 05/2010)
  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".

FLOWRUN—Numerical simulation and optimization of flood-induced flow phenomena using a parallelized SPH-code
J. Willkomm, C. Bischof, M. Bücker

The objective of this JARA research project is to carry out a novel, coupled, numerical investigation of hydromechanical flow phenomena via an interdisciplinary approach of the disciplines hydraulic engineering, informatics, and mathematics. In this feasibility study the flow over a stepped, pooled spillway is computed on a parallel computer and combined with a sensitivity analysis based on automatic differentiation. For this application an implementation of the SPH-method (Smoothed Particle Hydrodynamics) is intended, which will enable the efficient numerical computation of relevant flows in the long term. In particular in fluid mechanics, high-performance computing has gained in importance due to the long-term and large-scale applications in hydraulic engineering. The participating scientists from Hydraulic Engineering and Water Resources Management (IWW), Scientific Computing (SC) and Continuous Optimization (OPT) aim at establishing an innovative and sustainable cooperation in the field of hydro-informatics.

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.

Towards a Computational Model of Blood Flow in the Left Human Heart, Aorta and Connecting Vessels

M. Lülfesmann, C. Bischof, M. Bücker

The desire to understand the flow of blood through the cardiovascular system and prosthetic devices has stimulated a flurry of activity in related fluid flow studies in recent years. This interest stems from the need to understand the mechanism for the genesis or pathology of cardiovascular disease and the associated cardiovascular flows. Such relationship between blood flow and cardiovascular disease, altered physiological states, thrombus formation and hemolysis in prosthetic devices is complex; however, a better understanding of this relationship is essential to identify potentially pathological flow situations, recognize existing conditions via monitoring fluid pressures and characterize the probable evolution of pathological states. In the final analysis, one wishes to establish cause and effect protocols in terms of primary variables and relate inaccessible variables to those that can be monitored. This requires a detailed modeling of the cardiovascular system, encountering physiological as well as pathological flow conditions, with and without prosthetic devices.

In this interdisciplinary JARA project, the blood flow in the natural left heart and its proximate vascular system is modeled including the coronary arteries, the ascending aorta, the aortic arch, and a part of the descending aorta. Collaborating partners include the following
research groups: Applied Medical Engineering, Computational Analysis of Technical Systems, Scientific Computing, and Helmholtz Young Investigator Group Performance Analysis of Parallel Programs.

**Novel methods for exploration, development, and exploitation of geothermal reservoirs - a toolbox for prognosis and risk assessment**

K. Fuchss Portela, C. Bischof, M. Bücker

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.

**ADiMat—Automatic Differentiation of MATLAB Programs**

J. Willkomm, 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 conditions.
and hydrogeological problems in two or three dimensions. The goal of this project is to develop a parallelization of SHEMAT based on the OpenMP standard for shared memory computers as well as to establish a methodology to reliably estimate model parameters using automatic differentiation. This project is funded by GEOPHYSICA Beratungs-gesellschaft mbH and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

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.

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.
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.
Other Activities

Our institute takes care to maintain and extend its national and international cooperations in the field of High-Performance Computing, in particular through visits of researchers from other institutions:

• Paul Hovland, Argonne National Laboratory, IL, USA, June 7, 2010
• Robert C. Kirby, Texas Tech University, TX, USA, May 7, 2010
• Markus Diesmann, RIKEN Brain Science Institute, Wako City, Japan, May 3, 2010
• Arno Rasch, vtmw, April 7./8., 2010
• Hans-Joachim Bungartz, TU Munich, November 30, 2009
• Mikko Auvinen, Aalto University School of Science and Technology, Finland, Oct.-Dec. 2009

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:

• 10th European Workshop on Automatic Differentiation, Paderborn, Germany, June 3-4, 2010. (Co-organized by Martin Bücker)
• 1st Workshop on Automated Program Generation for Computational Science held as part of the 10th International Conference on Computational Science (ICCS 2010), Amsterdam, The Netherlands, May 31-June 2, 2010. (Co-organized by Christian Bischof)
• Minisymposium on Graduate Education for the Parallel Revolution, 14th SIAM Conference on Parallel Processing for Scientific Computing, February 24-26, 2010, Seattle, USA. (Organized by Christian Bischof)
• 9th European Workshop on Automatic Differentiation, Sophia-Antipolis, France, November 26-27, 2009. (Co-organized by Martin Bücker)

In addition, Christian Bischof served on the program committee for:

• 24th International Parallel and Distributed Processing Symposium (IPDPS-2010), Atlanta, Georgia, USA, April 19-23, 2010.
• Gordon Bell Prize Award Committee, Supercomputing 2009, Portland, November 14-20, 2009.

Martin Bücker served on the program committee for:
• 1st Workshop on Automated Program Generation for Computational Science held as part of the 10th International Conference on Computational Science (ICCS 2010), Amsterdam, The Netherlands, May 31-June 2, 2010.

• 11th IEEE International Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC-10) held in conjunction with the 24th International Parallel and Distributed Processing Symposium (IPDPS-2010), Atlanta, USA, April 19-23, 2010.

## Talks and Publications

### Talks


- **O. Fortmeier.** Hybrid Distributed-/Shared-Memory Parallelization For Re-Initializing Level Set Functions. 12th IEEE International Conference on High Performance Computing and Communications (HPCC'10), Melbourne, Australia, September 1, 2010.


- **O. Fortmeier.** A Parallel Strategy for a Level Set Simulation of Droplets Moving in a Liquid Medium. 9th International Meeting High Performance Computing for Computational Science (VECPAR 2010), Berkeley, CA, USA, June 22, 2010.


- **J. Willkomm.** Generating adjoint expressions for Matlab. Tenth European Workshop on Automatic Differentiation, Paderborn, Germany, June 04, 2010.

- **M. Lülfesmann.** Interactively exploring elimination orderings in symbolic sparse Cholesky factorization. International Conference on Computational Science (ICCS 2010), Amsterdam, The Netherlands, June 01, 2010.


- **O. Fortmeier.** MPI Parallelization of DROPS. PPCES - Parallel Programming in Computational Engineering and Science, Aachen, Germany, March 25, 2010.


J. Willkomm. Introduction to Automatic Differentiation. PLEIAD Seminar, Universidad de Chile, Santiago, Chile, November 27, 2009.


Publications


Software and Tools for Computational Engineering

Staff

• Faculty
  Uwe Naumann

• Secretary
  Gabriele Meessen

• Research Assistants
  Boris Gendler
  Ebadollah Varnik
  Ekkapot Charoenwanit
  Johannes Lotz
  Markus Beckers
  Michael Förster
  Michel Schanen
  Viktor Mosenkis

• Long-term Visitors
  Jan Riehme (U. of Hertfordshire, UK)
  Dmitrij Gendler (U. of Hertfordshire, UK)

• Student Researchers
  Klaus Leppkes
  Lukas Razik
  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

AC-SAMMM

U. Naumann, B. Gendler, M. Förster

Collaborators: Prof. Dr. W. Marquardt, AVT Aachener Verfahrenstechnik Prof. Marquardt,

Funded by: ERS boost fund


The industrial processes are described in mathematical models consisting of algebraic equations, formulated in some high-level modeling language (e.g. gPROMS). The derivatives of these models are highly desirable by the industry.

The first step in the chain of AC-SAMMM is the translation of the algebraic equations into C++. This work is done by AVT. To generate first order derivative code for a given C++ implementation of a numeric function Derivative Code Compiler (DCC) is used. DCC is developed by STCE. It is possible to reapply DCC on its own output to get the derivatives of higher orders. We applied AC-SAMMM on a real-life pharmacological problem, with over 2000 algebraic equations. The resulting C++ code consists of 9.000 lines. Applying DCC to this code yields a derivative code with 44.000 lines. The second order derivative code, generated by DCC, has 180.000 lines.

To simplify the usage of AC-SAMMM we currently develop a library allowing the computation of the first and second derivatives in an automatic way, exploiting the sparsity structure of the Jacobian and Hessian. The user has only to specify a function and a desired order of differentiation.

JURASSIC

E. Varnik, M. Förster, U. Naumann, J. Lotz

Collaborators: ICG-1, Forschungszentrum Jülich

Funded by: DFG

The JUelich RApid Spectral SImulation Code is a radiative transfer model for the infrared spectral region developed at the Institute for Chemistry and Dynamics of the Geosphere (ICG-1) at the Forschungszentrum Jülich. The main focus of our collaboration is a part of the JURASSIC package called retrieval processor, which tries to estimate the retrieval parameters by minimizing the cost function representing the deviations between real and simulated observations for a given state as well as the differences between the estimated state and an a priori state. Our main investigations so far have been focused on enabling JURASSIC to
compute the gradient of the cost function using forward and reverse mode AD. Further effort has been taken to parallelize the AD solutions using MPI parallel concept.

Hybrid Approach to the generation of adjoint C++-Code
J. Lotz, U. Naumann
Collaborators: ICG-1, Forschungszentrum Jülich, Max Planck Institute for Meteorology, Hamburg
Funded by: DFG

In scientific computing a major challenge are derivative computations of implemented mathematical models. For example in (large-scale) Inverse Problems the derivative of the forward model is to be evaluated. AD is a powerful concept for doing this efficiently when the possibility of a reverse (adjoint) execution is provided. This execution reversal can be accomplished by building a computational graph by operator overloading at runtime representing the implemented function. Thereby the derivative is obtained by operations on the created data-structure. Apart from that source code transformation can be used to create C++-Code computing the adjoint. The first approach is robust and suitable for almost any C++-Code but is in comparison relatively slow. Source code transformation on the other hand is applicable only to syntactically simpler code but yields a high efficiency. The aim is to merge both approaches to a hybrid treatment of derivative calculations to combine the advantages, i.e., syntactically complex parts are handled by operator overloading while compact computationally expensive parts are covered by source code transformation. Target application is the JUElich RApid Spectral Slmulation Code (mentioned above) and we aim to consider a C-version of a new atmospheric and oceanic general circulation model (ICON) developed by the Max-Planck-Institut für Meteorologie and the German Weather Service.

CompAD-III
U. Naumann, J. Riehme, D. Gendler
Collaborators: The Numerical Algorithms Group Ltd., University of Hertfordshire, UK
Funded by: EPSRC

The development of the differentiation-enabled NAG Fortran Compiler is a joint effort of the University of Hertfordshire, UK, and the RWTH Aachen University, Germany. The target is the integration of current (or new) Automatic Differentiation technology into the industrial strength Fortran compiler of the Numerical Algorithm Group (NAG), Oxford, UK. The project is currently in the third period of funding by EPSRC.

The AD-enabled NAG Fortran Compiler utilizes a hybrid approach combining automatic datatype changes (source transformation) with overloading techniques. The compiler provides
a number of differentiation modes (tangent linear, adjoint, tape based adjoint, second order adjoint, ...), each one has its own private compad_module. Every compad_module exports a compad_type (and overloaded arithmetic operations, plus a number of support routines) used by the compiler to perform the datatype changes from floating point into compad_type automatically. Any detail of the AD-implementation of a specific module is hidden within the module, the compiler only rely on the existence of a compad_type. The original semantic analysis of the NAG Fortran Compiler resolves operations on compad_type by inserting calls of overloaded operators from the chosen module.

Although the overloaded approach of the AD-enabled NAG Fortran Compiler is very robust and gives good performance already, the compiler can be used to generate differentiated code: in this pure source transformation mode all calls of overloaded operators are replaced by corresponding differentiated code that is inserted into the internal representation directly. Thus all overhead of calling a subroutine for every single arithmetic operations is eliminated.

**Subgradient Propagation for McCormick Relaxations**

_U. Naumann, V. Mosenkis, M. Beckers, M. Maier_

_Collaborators: Prof. A. Mitsos, Phd., MIT, USA_

_Funded by: German Research School for Simulation Sciences_

Optimization problems in engineering often have non-convex objectives and constraints and require global optimization algorithms. In such cases McCormick relaxations can be used to ease the problem. McCormick Relaxations are certain convex and concave under- and overestimators of the objective function and constraints. Since convex functions are possibly non-smooth, subgradients are used instead of usual derivatives. Subgradients are natural extensions of usual derivatives providing similar information for non-differentiable functions.

AD-methods can be used to propagate the values of McCormick Relaxations as well as its subgradients. A first version implementing AD-forward mode based on operator overloading was developed in C++ by colleagues at MIT's Process Systems Engineering Laboratory and Dept. of Mechanical Engineering. STCE developed a reimplementation in Fortran also providing source code transformation. Recently this was extended by a reverse mode which provides the same advantages as normal adjoints.

**Sensitivity Analysis in Telemac/Sisyphé**

_J. Riehme, U. Naumann_

_Funded by: German Federal Waterways Engineering and Research Institute, Karlsruhe_

The morphodynamic model Sisyphé (developed at EDF Department Laboratoire National D'Hydraulique et Environnement, www.telemac system.com) is used at the German Federal
Waterways Engineering and Research Institute (BAW), Karlsruhe, to simulate river bed evolutions. In morphodynamic modelling input parameters are uncertain due to measurement errors, natural variability, or unsatisfactory parameterisation. However, the propagation of uncertainties in the input data might have serious influence on the simulation results. Therefore, it is necessary to quantify their contributions to the model results in order to appraise the reliability of the simulation.

A tangent linear model of Sisyphe generated by the AD-enabled NAG Fortran Compiler (CompAD-III) is used to calculate the sensitivities of the evolution with respect to different input parameters, which were assumed to be uncertain. These sensitivities allow for a first order reliability analysis (FORM) to be performed that estimates the uncertainties of every chosen input parameter.

The aim of further collaboration with the German Federal Waterways Engineering and Research Institute, Karlsruhe, is to apply the AD-enabled NAG Fortran Compiler to Telemac, a numerical modeling system for free surface hydrodynamics, sedimentology, water quality, waves and underground flows, which can be coupled with Sisyphe.

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**Elimination Techniques on Linearized DAGs**

*V. Mosenkis, U. Naumann*

Funded by: DFG

The aim of this research is to minimize the number of operations to accumulate the Jacobian of a given numerical program implementing a multivariate function. This problem is called Optimal Jacobian Accumulation (OJA) problem. OJA was shown to be NP-hard by Prof. Naumann. The problem can be formulated on graphs by attaching the corresponding local partial derivatives to the edges of the computational graph of the underlying program yielding a linearized computational graph. A graph-based interpretation of the chain rule of differential calculus allows to compute the partial derivative by multiplying all edge labels along all paths from the corresponding input to the output and adding the results. In practice to reduce the search space graph transformation techniques like vertex-, edge- and face elimination based on associativity of differential calculus are used. Thereby the linearized computational graph is transformed into a bipartite graph whose edge labels correspond to the entries of the Jacobian. This approach yields the problem of finding a vertex, edge or face elimination sequence with minimal number of operations (costs). Even this version of the OJA problem is believed to be NP-hard although the proof is still outstanding. Henceforth we are interested in developing fast heuristics to find an elimination sequence with costs close to minimal.

To support the theoretical research in this field we provide a Branch and bound algorithm which finds an optimal vertex, edge or face elimination sequence. Depth first search is used for the branching step of the algorithm. Lower bounds for the operation number as well as the knowledge of equivalent elimination sequences are used to reduce the search space. Currently we are working on the proof of sharper lower bounds to be used in the algorithm.
Adjoint MPI

M. Schanen, U. Naumann

Collaborators: Dr. Jean Utke, Argonne National Laboratory, USA, Dr. Laurent Hascoet, INRIA, France

Funded by: Fond National de la Recherche of Luxembourg

We investigate the robust and efficient applicability of reverse mode algorithmic differentiation to numerical simulation codes that use MPI. Since MPI is the de facto parallelization standard in large scale simulation codes, there have been numerous attempts to compute adjoints of MPI parallelized code. Until today, they all heavily rely on manual manipulation of the original code. Our generic approach tries to reverse the entire flow of computation and thus reverse all the MPI communication patterns automatically.

The focus has been on the programming languages C and Fortran. In Fortran, adjoint MPI has been inserted in the development branch of the COMPAD project based on the NAG Fortran Compiler. Additionally, covering the language C/C++, the technique is being used with the in house developed dcc compiler and the dco overloading library.

The outcome should be a generic and versatile adjoint MPI library that may be coupled with any algorithmic differentiation software. It is not restricted to any specific language or tool.

Uncertainty Quantification

M. Beckers, U. Naumann

Collaborators : Prof. B. Christianson, Phd., University of Hertfordshire, UK

Funded by: German Research School for Simulation Sciences

Uncertainty Quantification aims to determine the imprecision in the outputs of numerical programs caused by (measurement) errors in the inputs. For a known error distribution of the inputs, probabilistic methods are used to get information about the distribution of the outputs.

Such investigations are for example desired in the context of engineering or weather simulations. Weather simulations are partly based on measured wind speeds and temperatures used to forecast future weather conditions. Quantifications of the impreciseness in such predictions is needed. Especially if important decisions have to be made based on such simulations, uncertainty information has to be taken into account.

Our approach is based on a Taylor Series Expansion of the function implemented by the simulation, yielding approximations of the mean and variance of the distribution of the output. Because of the complexity of accurate derivative computations mostly first-order methods are used in practice. AD allows the efficient computation of higher order derivatives and therewith more precise approximations. At the moment we apply such higher order
methods to cases were our program represents an iterative optimization algorithm (i.e. steepest-descent or Newton’s method).

**High-Performance AD**

*E. Varnik, E. Charoenwanit, U. Naumann*

*Funded by: NSTDA (Thailand)*

In this project we aim to exploit HPC architectures in the context of accumulating Jacobians of very large numerical simulation programs in AD. This can be performed by application of some elimination techniques to a graphical representation also referred to as the linearized computational graph (L-DAG) of the underlying numerical simulation program. The construction of such computational graphs at runtime often leads to very large graphs. Derivative accumulation by elimination techniques may fail due to the graph size exceeding the available memory. In this project, we build on an existing tool DALG that has been developed to overcome the memory problem by eliminating intermediate vertices and edges on the fly. Thereby, we attempt to come up with efficient techniques for the process of parallelizing large-scale L-DAGs onto large-scale high-performance computer architectures with respect to memory aspects. In shared-memory systems, we investigate cache-related effects. In distributed-memory systems, we investigate the prospect of exploiting secondary storage in storing and retrieving intermediate computations in an efficient way in terms of time and memory usage.

**Adjoint ICON**

*J. Riehme, K. Leppkes, U. Naumann*

*Collaborators: Dr. P. Korn and F. Rauser, Max Planck Institute for Meteorology, Hamburg*

*Funded by: Max Planck Institute for Meteorology*

The Icosahedral Non-hydrostatic General Circulation Model (ICON, icon.enes.org) is developed by the Max Planck Institute for Meteorology (MPI-M), Hamburg, and the Deutscher Wetterdienst (DWD). The AD-enabled NAG Fortran Compiler (CompAD-III) is used to generate a discrete tape-based adjoint version of a geophysical model. It allows to compute the goal sensitivities required for goal oriented dual weight error estimation. Computing adjoints with a tape based approach consists of two steps: All elemental operations performed by the program execution have to be recorded on a so called tape, and given initial adjoints of the outputs have to be propagated by a reverse tape interpretation step resulting in the desired goal sensitivities. Checkpointing techniques allows to restrict the tape of the whole process, which to is big to be kept in memory, to a (sub-)tape of individual time steps (only one at any time) by introducing additional re-computations.
The tape recording for subsequent time steps is independent of each other, whereas the propagation of adjoints through the tape of time step $i$ can start only after finishing the adjoint propagation of time step $i+1$. We exploit this fact by doing tape recording for time step $i$ and tape propagation for step $i+1$ in parallel by two MPI processes. If more processes are used, every process finished with tape recording spent additional time in waiting for adjoints from the subsequent time step. In this case the additional waiting time is turned into productive waiting by optimizing the tape structure for a faster adjoint propagation afterwards.

In addition a special treatment of the underlying linear solver yield to an improved scalability of the approach and a significant reduction in memory consumption and runtime.
Other activities

- Uwe Naumann is member of the Bioeconomy Science Center
- Uwe Naumann is member of the Advisory Board in the EU Project Flow Head (http://flowhead.sems.qmul.ac.uk/)
- Uwe Naumann is chair of the steering Committee for Service Teaching of the Department for Computer Science
- Uwe Naumann is conference chair of the 5th SIAM CSC Workshop, Darmstadt, may 2011
- Ebadollah Varnik is member of the steering Committee for Service Teaching of the Department for Computer Science

Teaching

**Winter Semester 2009/10**
- Lecture: Computational Differentiation (V3, Ü1)
- Lecture: Introduction to Programming - C++ (V2, Ü1)
- Seminar: Automatic Differentiation (S2)
- Proseminar: Graph Algorithms (PS2)
- Lab: Simulation Software Engineering (V1, Ü1, P2)

**Summer Semester 2010**
- Lecture: Derivative Code Compilers (V2, Ü2)
- Lecture: Introduction to Software Engineering (V1, Ü2)
- Seminar: Combinatorial Problems in Scientific Computing (S2)
- Proseminar: Numerical Libraries (PS2)
- Lab: Compiler Construction (P3)
Talks and Publications

Talks

M. Beckers, Propagation of Uncertainties using the Method of Moments, Tenth International Conference on Computational Structures Technology, Valencia, Spain, September 2010

M. Beckers, Subgradient propagation of McCormick Relaxations in Reverse Mode, Tenth Euro AD Workshop, Paderborn, Germany, June 2010

V. Mosenkis, Branch and Bound for Optimal Jacobian Accumulation, Tenth Euro AD Workshop, Paderborn, Germany, June 2010

U. Naumann, Automating the generation of first- and higher-order adjoints, Workshop on industrial design optimisation for fluid flow, Varna, Bulgaria, September 2010, Invited Talk

U. Naumann, Algorithmic Differentiation, ASIM-Workshop, Jülich, Germany, March 2010, Invited Talk

U. Naumann, Low-Memory Control-Flow Reversal, Ninth Euro AD Workshop, INRIA Sophia-Antipolis, France, November 2009

U. Naumann, Low-Memory Tour Reversal in Directed Graphs, SIAM Workshop on Combinatorial Scientific Computing, Monterey Bay, USA, October 2009

J. Riehme, The differentiation-enabled NAG Fortran Compiler, Workshop on industrial design optimisation for fluid flow, Varna, Bulgaria, September 2010


J. Riehme, On the use of discrete adjoints in goal error estimation for shallow water equations, International Conference on Computational Science, Amsterdam, Netherlands, May 2010

J. Riehme, Uncertainty Quantification based on Forward Sensitivity Analysis in Sisyphe. Fifth European Conference on Computational Fluid Dynamics, Lisbon, Portugal, June 2010

M. Schanen, Second-Order Adjoint Algorithmic Differentiation by Source Transformation of MPI Code, 17th EuroMPI conference, Stuttgart, Germany, September 2010

M. Schanen, Adjoint MPI by Tape Interpretation applied to the NAG Fortran Compiler, Ninth Euro AD Workshop, INRIA Sophia-Antipolis, France, November 2009

M. Schanen, Interpretative Adjoints for Numerical Simulation Codes using MPI, International Conference on Computational Science, Amsterdam, Netherlands, May 2010

E. Varnik, What Color is the Non-Constant Part of Your Jacobian, SIAM Workshop on Combinatorial Scientific Computing, Monterey Bay, USA, October 2009

Publications

M. Beckers and U. Naumann, Propagation of Uncertainties using the Method of Moments, Proceedings of The Tenth International Conference on Computational Structures Technology, Civil-Comp Press, 2010


J. Riehme, R. Kopmann and U. Naumann, Uncertainty Quantification Based on Forward Sensitivity Analysis in Sisyphe, ECCOMAS CFD, 2010


Posters

M. Beckers and U. Naumann, Higher Derivatives and the Method of Moments, ASIM-Workshop, Jülich, Germany, March 2010


K. Leppkes, U. Naumann and J. Riehme, On the use of direct vs. iterative solvers in adjoint computations, SIAM Workshop on Combinatorial Scientific Computing, Monterey Bay, USA, October 2009

M. Schanen and U. Naumann, Adjoint MPI, 39th SPEEDUP Workshop on High-Performance Computing, Zürich, September 2010


Diploma/Master Theses

A. Ben Moussa: Algorithmische Erweiterung des Simulationsprogramms ReDrop

J. Lotz: Analyse adjungierten-basierter Optimierungsverfahren unter Verwendung algorithmischen Differenzierens

M. Ngoatchou: Implementation of the UDT protocol in Java

A. Püttmann: Extension of a General Rate Model Solver for Parameter Sensitivity Analysis Capabilities

K. Rattanakornpunt: Sensitivity Analysis of FVCOM

N. Safiran: Sensitivity Analysis of a LIBOR Market Model (collaboration with Bergische Universität Wuppertal)
Virtual Reality Group

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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 objects like complete plants, over mid-size objects 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-HPC, and the CoE “Integrative Production Technology for High-Wage Countries” 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 space.
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 co-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.
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. The 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.

Explorative Analysis of Multiple, Heterogeneous Simulation Data

P. Cerfontaine, T. Beer, T. Kuhlen, C. Bischof

In the “Cluster of Excellence: Integrative 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 provides not only 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. To facilitate the assessment of data uncertainty based on the results of measurements and numerical simulations, we developed an exploratory multiview visualization. Furthermore, to support the geophysical parameter study, we work on direct manipulation user interfaces for optimal experimental design in collaboration with the Institute for Scientific Computing.
Current changes in the development of future hardware architectures in the domain of high performance computing will considerably increase the complexity of scientific simulations. For instance, simulations in computational fluid dynamics (CFD) result in very large three dimensional transient datasets which are usually represented at as unstructured grid. Therefore, interactive visualization techniques are a prerequisite for gaining a deeper knowledge and understanding of the data at hand.

Hence, the main objectives of the BMBF project VisPME, carried out by HLRS Stuttgart, ZAIK and MPI Cologne, the VR Group in Aachen and industrial partners, can be summarized as:

- create a generic and scalable framework for parallel data processing and interactive visualization for a wide range of application domains like CFD, Medical Sciences, etc.
- transform and enhance visualization algorithms (i.e. particle tracing) to a distributed manycore environment in order to benefit from the massively parallel computing power
- parallel approaches to data reduction to support extremely low latency requirements of real-time data interaction techniques
- assure quality and applicability of the developed concepts by close collaboration with application domain experts

The resulting computational requirements will be met by the use of large visualization clusters instead of single workstations. Such clusters are comprised of multiple nodes which are connected by high bandwidth, low latency networks (e.g. Infiniband). Each node is a parallel system itself, composed of several multi-core processors and one or more graphics cards which offer extensive rendering capabilities. Additionally, today's graphics cards can also serve as compute platforms for highly parallel computations that do not have to be directly related to image synthesis, necessarily.

Within the overall project, the VR group focuses on interactive particle tracing, which is an excellent technique for depicting the movement of matter within complex flow phenomena. In an experimental setting particle tracing can be imagined as the injection of smoke or ink in a real world flow field. In virtual environments however, this technique requires considerate computational resources as it relies heavily on the advection of a massive amount of particle trajectories in order to convey distinct flow structures.

For the first time, the widespread availability of massively parallel multi-core architectures, within remote computing resources and nearby visualization systems (e.g. GPUs) as well, allows the application of interactive particle tracing on the original simulation grids, rather than on downsampled Cartesian grids.

Furthermore, with the utilization of parallel manycore architectures the computation of derived quantities like the Eigenvalue analysis now becomes possible to advect in real-time for every single particle. An excellent example for the necessity of such derived quantities is provided by the stress analysis of red blood cells in ventricular assist devices while blood is being pumped through.
Such algorithms will specifically benefit when being optimized for GPU-like manycore architecture and will therefore be developed in close collaboration with NVIDIA GmbH as associated partner.

**Virtual reality based medical training simulator for bilateral sagittal split osteotomy**

*T. Knott, T. Kuhlen*

This DFG-funded research project is focusing on the development of a virtual reality (VR)-based training simulator for a major maxillofacial surgery procedure. It is an interdisciplinary collaboration of dentists, numerical simulation experts, and computer scientists from the RWTH Aachen University and the University Hospital Aachen. The medical procedure in focus, the bilateral sagittal split osteotomy, permits the relocation of the mandible to correct malpositions like over- or underbite. During the intervention a predetermined breaking point is created on the lower mandible with a bone saw or burr. Chisels are then inserted into the prepared line, which is then carefully broadened by twisting the tools. In cases where complications occur during the division, the mandible and a contained neurovascular bundle could be damaged beyond repair. The interactive simulator will provide a training tool to learn the basic manual skills but also to rehearse difficult scenarios.

An important goal of the simulator is the training of specific motor skills. Therefore, one prerequisite to the system is the reproduction of the real interaction with a high degree of realism. For this purpose we utilize a haptic input/output device enabling the surgeon to put pressure on the virtual jaw and feeling its resistance. Furthermore an extended finite element method (XFEM) is used for the real-time simulation of occurring physical effects, including the force exchange between tool and bone and the induced structural changes of the latter. Anatomical models will be extracted from cone beam CT-Scans and will function as the foundation for models used in the physics simulation and visualization.

**RASim - Regional Anaesthesia Simulation**

*S. Ulrich, T. Kuhlen*

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.

**Real-time Room-Acoustics for interactive and dynamic Virtual Environments**

*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.

**VATSS - Virtual Air Traffic System Simulation**

*A. von Kapri, S. Pick, T. Kuhlen*

In this work, which has originally been funded by the Interdisciplinary Pathfinder Projects Initiative and which since recently converted into a Boost Fund Project, we collaborate with the Institute of Aeronautics and Astronautics (ILR) and other RWTH working groups on the development of a concept for an interdisciplinary simulation of the air traffic. The simulation of different aspects of an air traffic system will be combined with a three-dimensional visualization in the virtual environment of the CAVE.
Air traffic is rapidly growing and consciousness for the necessity of global environmental concepts rises. Therefore, new environmentally friendly and energy efficient air traffic concepts have to be developed. An interdisciplinary evaluation of such concepts is mandatory to analyse the ecological, economical and social impacts. Such an interdisciplinary approach requires expertise from different fields and knowledge to integrate the areas of expertise into one master plan.

Examining an entire air traffic system considering the aspects of e.g. the infrastructure, air ports, land consumption, emissions, climate effects, noise exposure and legal requirements represents an interdisciplinary challenge.

With an intuitive visualization which considers all relevant aspects of air traffic enclosed we hope to be able to better understand dependencies between different aspects such as noise and pollutant emissions for example and therefore be able to optimize the complete system.

Interactive Visualization of Uncertainty in Probabilistic Tractography

T. Rick, A. von Kapri, T. Kuhlen

In this JARA project, we work on interactive visualization of uncertainty information in probabilistic fiber pathways of the living human brain as measured by diffusion tensor imaging (DTI). Probabilistic tractography calculates a local probability distribution of the diffusion direction for each voxel, resulting in voxels with a large number of passed traces to
voxels with only a low number of passes. By accounting for the uncertainty, the method of probabilistic tractography allows to draw a clearer picture of the overall fiber architecture within the human brain.

We propose a customized direct volume rendering method through which the probabilities of fiber tracts are conveyed by colors and opacities. By rendering multiple scalar-valued data sets simultaneously we are able to visualize sections where multiple fiber tracts intersect, which is an important methodological issue in DTI tractography (crossing fibers). In the future we plan to conduct a user study with domain scientists in order to quantify the effectiveness of our visualization.
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. Typically, we give more than 100 presentations per year 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 a Cross Sectional Group on Immersive Visualization 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 co-speaker of the “Fachgruppe Virtual & Augmented Reality” within the “Gesellschaft für Informatik”. He is a member in the program committees of several national and international conferences like the IEEE VR. This year, he served as Program Chair for the 2010 Joint Virtual Reality Conference, including the Eurographics Symposium on Virtual Environments.
Talks and Publications


B. Hentschel: "Flow Visualization Applications in Biomedicine." Tutorial "Large Vector-Field Visualization" at IEEE Visualization Conference, Salt Lake City, October 2010.


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  Alexander Urban
Overview

The research group IT-Security was founded in August 2008 as part of the research cluster “UMIC – Ultra high-speed Mobile Information and Communication”. By now the group consists of an associate professor, three research assistants, and 9 student researchers. The group studies and teaches security and privacy problems and solutions in different types of communication networks with a main focus on securing wireless networks. Our newly developed security protocols typically make use of recent developments in cryptography and make new theoretical results directly usable in practice.

In particular, we are interested in the evaluation of the design and implementation of security architectures for newly evolving wireless technologies such as the Evolved Packet System, or the new Bluetooth standard. We develop new solutions to securely support mobility in heterogeneous networks such as multi-domain RFID systems, roaming between different WLAN operators, and key handling solutions for mobility between different access technologies. These solutions include authentication, authorization, and accounting support, as well as efficient key handling and re-authentication.

A newer development in the area of wireless networks are wireless mesh networks in which mobile clients connect to so-called mesh routers that in turn are wirelessly connected to other mesh routers, which may then act as a gateway to other networks. Mesh networks pose new security challenges, mainly due to their multi-hop nature and the problem that nodes may be captured and start acting maliciously. We develop new approaches for secure key management and to identify malicious nodes.

In the area of privacy we work on privacy-preserving distributed multi-party applications some of which are targeted at mobile devices. For this area of research we won a DFG research grant in August 2010.

Finally, we also work on the collection and analysis of (mobile) malware and on botnet protection. In particular we support the MW-Collect Alliance, and have research and development contracts with Nokia Siemens Networks and the National High-tech Crime Unit of the Netherland’s Police. In addition, in 2010 we helped to secure the BMBF-funded research project ASMONIA together with our partners Nokia Siemens Networks, Fraunhofer Institut für sichere Kommunikationstechnologie, EADS Deutschland GmbH, ERNW GmbH, and Augsburg University of Applied Science.

With respect to teaching, the group offers a one-year cycle of four lectures, a seminar, and a laboratory course. This cycle was developed from scratch in 2008/2009. During winter terms we typically offer the lectures IT-Security 1 and Security in Mobile Communications. IT-Security 1 provides an introduction to cryptography and focuses on network security, while Security in Mobile Communications covers the security architectures of attacks against already standardized wireless technologies such as mobile phone networks, wireless local area networks, or Bluetooth. In addition, we offer a seminar on selected topics in mobile security during winter terms. In the summer we offer the lectures IT-Security 2, which focuses on system security and a lecture on Security and Cooperation in Wireless Networks, which covers new developments in wireless technologies such as sensor networks or vehicular networks. Also, in summer terms we offer a security lab in which students learn how to deal with practical attacks against wireless as well as wired networks and systems.
Other Activities

Committees and Organizations

2010

• Member of the program committee: IEEE SICK 2010 LCN Workshop on Security in Communication Networks

• Member of the program committee: SICHERHEIT 2010 held in conjunction with ISSE 2010

• Member of the program committee: CAT2010 Context Awareness and Trust 2010, held in conjunction with CENTRIC 2010

2009

• Member of the program committee: IEEE SICK 2009 LCN Workshop on Security in Communication Networks
Talks, Posters, and Publications

Talks and Posters

J. Barnickel: *Secure WLAN-Roaming to Go*, MyPhD-Workshop, Sept. 2010
G. Neugebauer: *Privacy-Preserving Applications*, MyPhD-Workshop, Sept. 2010
U. Meyer: *Sichere Webanwendungen*, Ringvorlesung Informatik, June 2010
U. Meyer: *Sicherheit in Kommunikationsnetzen*, Studieninformationstag June 2010
A. Egners: *Evaluating IEEE 802.11s Against Security Requirements of Wireless Mesh Networks*, Essener Workshop zur Netz sicherheit, April 2010

Publications


Diploma and Master Theses Advised

Peter Schmitz: *Protecting remotely stored confidential Data*, Jan. 2010
Sergej Firsov: *Comparing rule-based and stochastic approaches to event filtering*, March 2010

Hakan Karahan: *Secure Processing of Vital Signs in HealthNet Applications using Smartphones*, June 2010

Stefan Horst: *Security and performance analysis of non 3GPP access to the evolved packet core on the WLAN example*, July 2010

Till Maas: *Implementation and evaluation of a secure time-synchronization protocol for TelosB Motes with the help of digital signatures*, Sept. 2010

Sharif Rahman: *Analyzing causes of privacy mismatches in a service-oriented architecture*, Oct. 2010
UMIC Mobile Network Performance Group

Staff

- **Faculty**
  - Prof. Dr. James Gross

- **Research Assistants**
  - Oscar Puñal
  - Christian Dombrowski
  - Donald Parruca
  - Di Li

- **Guests**
  - Peter Pisarcik
Overview

The Mobile Network Performance Group is a junior research group that is associated with the DFG Excellence cluster UMIC – Ultra-high Mobile Information and Communication – as well as with the chair computer science 4 Communication and Distributed Systems (Prof. Wehrle). The Mobile Network Performance group deals with research questions at the intersection of computer science and electrical engineering with a special focus on adaptation in wireless networks. Our current research fields include:

- Design & performance of 80 MHz future wireless local area networks
- Energy-efficient adaptation in LTE cellular networks
- Parallel network simulation for wireless systems and networks
- Ultra-high reliability in wireless local area networks for industrial applications
- Clustering and routing in cognitive ad-hoc wireless networks

In our research we rely on a set of different methodologies, namely mathematical analysis, simulations and prototyping. Our research lab consists of a large server for parallel network simulation of LTE networks as well as of a FPGA-based prototyping environment for lower layer wireless network development and research.
Research Projects

Ultra-robust Wireless Transmission

This project covers aspects of highly reliable communication over wireless channels. An application scenario is real-time sensitive message exchange, e.g. in industrial automation. This exchange is carried out as a wired connection in traditional systems. However, using cables not only reduces flexibility but also causes installation and maintenance costs. Developments of wireless transmission systems over the last decades have shown an immense progress. Hence, it is reasonable to think about employing wireless transmission systems instead of using cables.

In this context, a multitude of challenges arise: Beside the problem of radio channel volatility, there is also the task of deterministic medium access in a multi-station scenario. In previous work, these problems were either tackled on a very abstract theoretical level, or by suggesting algorithms dealing with particular scenarios.

That is why we follow an integrated cross-layer approach. Our intention is, on the one hand, to gain insights into theoretical boundaries of reliability over wireless channels, and on the other hand, to develop algorithms which base on these theoretical boundaries and their implications. The next - and most important - step is to realize these algorithms in a practical system, and see how the reliability can be improved under real world conditions.

The Wireless-OpenAccess-Research Platform developed at Rice University, Houston - TX/USA, serves as the basis for our implementations. We have already developed a medium access protocol using a token passing scheme to achieve a decentralized deterministic medium access. This protocol supports differentiated traffic classes, and is flexible and failure tolerant.

UMIC Simulation Framework

(joint project together with Georg Kunz and Klaus Wehrle)

Discrete event-based simulation is a commonly used evaluation methodology throughout the development process of networked systems. However, it currently faces at least two significant challenges: First, recent advances in wireless communication technology demand highly accurate simulation models, resulting in a steep increase in model complexity and runtime requirements. Second, multi-processor computers constitute the de-facto default hardware platform even for desktop systems, thus providing cheap yet powerful “private computing clusters”. As a result, the parallelization of discrete event simulations significantly gained importance and is therefore (again) in the focus of active research.

Simulation models of wireless networks typically require a considerably more detailed modeling of the lower network layers than models of wired networks. In particular, the
wireless channel and the physical layer demand precise models to capture the subtle effects and interactions of advanced wireless communication technologies such as MIMO transmissions or successive interference cancelation. Consequently, simulation runtimes increase drastically which in turn hampers the development process and in-depth evaluations.

Being an active field of research for more than two decades, parallel discrete event simulation is supported by a wide range of network simulation frameworks. Despite this tool support, creating a parallel simulation model is still challenging and running simulations on a distributed simulation cluster is complex. At the same time, the increasing number and speed of processing cores in today’s commodity hardware makes a higher degree of parallelization very attractive and cost-effective for speeding up network simulation. Nevertheless, a key challenge in parallel simulations, in particular of wireless networks, is the efficient utilization of the available processing power.

In this project we address these challenges by developing a novel parallelization architecture that specifically focuses on the efficient simulation of wireless network simulation models on state-of-the-art multi-core computers. We primarily investigate means of extracting a maximum degree of parallelism from a given simulation model and schemes to achieve a balanced work load across computing cores.
Talks and Publications

Talks


Publications


M. Bohge, J. Gross, and A. Wolisz, "Optimal Soft Frequency Reuse and Dynamic Sub-carrier Assignments in Cellular OFDMA Networks", European Transactions on Telecommunications, (accepted for publication).


We are very proud that the group was also able to compile together with several other groups from UMIC and together with the COMSYS group of Prof. Wehrle the following book publication:

Parallel Programming

Staff

- **Faculty**
  Prof. Dr. Felix Wolf

- **Secretary**
  Sabine Blumensath

- **Scientific Staff**
  Dr. Daniel Becker
  Marc-André Hermanns
  David Krings
  Sebastian Rinke
  Christian Siebert
  Zoltán Szebenyi

- **Student Assistants / Researchers**
  Alexandru Calotoiu
  David Montoya
  Elmar Peise
  Suraj Prabhakara

- **Staff of the Associated Young Investigators Group in Jülich**
  David Böhme
  Dominic Eschweiler
  Dr. Markus Geimer
  Dr. Daniel Lorenz
  Jan Mußler
  Christian Rössel
  Dr. Pavel Saviankou
  Alexandre Strube
  Dr. Brian Wylie
Overview

Anchored at the German Research School for Simulation Sciences in Aachen and with part of the staff located at the Jülich Supercomputing Centre as members of a Helmholtz young investigators group, the objective of the Laboratory for Parallel Programming is to develop tools that support simulation scientists in exploiting parallelism at massive scales. Driven by the increasing demand for computing power and accelerated by current trends in microprocessor design, the number of processor cores on modern supercomputers is growing from generation to generation. For example, the IBM Blue Gene/P system at the nearby Jülich Supercomputing Centre already features almost 300,000 cores. To efficiently utilize such expensive devices and to advance the potential of numerical simulations running on them, we design programming tools for the optimization of parallel codes. These tools must be both (i) effective so that performance expectations can be met and (ii) easy to use so that programmer productivity is maximized. A specific challenge to be addressed is the extreme scalability requirements imposed on software tools when deployed on very large processor configurations. Moreover, as a complement to our research activities, we teach the skills required to write correct and efficient parallel programs in science and engineering. Students will be introduced to this domain with the goal of subsequently applying their knowledge in a variety of simulation projects or even of contributing to the software tools we develop ourselves.

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, Michael Knobloch, Dr. Bernd Mohr, Peter Philippen, Morris Riedel, and Marc Schlütter.

University Courses

- SiSc Lab (WS 2010/2011)
- Parallel Programming I (SS 2010, WS 2010/2011))
- Seminar Parallel Programming (WS 2010/20112)
- Behandlung großer Datenmengen (WS 2009/2010)
- Simulation Software Engineering (WS 2009/2010)
Research Activities

Scalable Performance Analysis of Large-Scale Parallel Applications (Scalasca)
Funded by the Helmholtz Association.

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. 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 serious challenges to achieving good performance. A distinctive feature of Scalasca is that it 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, the scalability of Scalasca was further improved by parallelizing internal performance-data management operations. Besides pure MPI codes and hybrid codes, which use a combination of MPI and OpenMP, Scalasca now also supports pure OpenMP codes both in runtime summarization and tracing mode. A generic wrapper generator was developed which reduced the code maintenance effort and helped make Scalasca suitable for a broader range of Fortran applications. The design of a more scalable file format for the representation of analysis results is in progress. Besides purely technical advancements, Scalasca was also presented to supercomputer users during local and external hands-on workshops/tutorials. Finally, Scalasca was successfully used to optimize academic and industrial codes from the areas of plasma physics and mechanical engineering. Further Scalasca-related research results are listed under specific projects.
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 examines the time-dependent behavior of parallel applications and aims at making the performance analysis more scalable with respect to the length of execution. To be able to apply a previously devised algorithm for the semantic compression of time-series call-path profiles also to C++ codes, where direct instrumentation may cause inacceptably high overhead, a hybrid profiling technique was developed that captures key communication metrics via direct instrumentation, while user-code profiling is accomplished via low-overhead sampling. The other project investigates load and communication imbalance in parallel codes to better understand the formation of performance-degrading wait states. First, a terminology was introduced to classify wait states based on their propagation behavior. Building on earlier work by Meira, Jr. et al., a scalable method was then designed that identifies program wait states, classifies them according to the above-mentioned terminology, and attributes their cost in terms of resource waste to their original cause. By replaying event traces in parallel, it is now possible to identify the processes and call paths responsible for the most severe waiting times even for runs with very large numbers of processes. This work won the best paper award of the International Conference on Parallel Processing (ICPP) 2010 in San Diego, California.

Virtual Institute – High Productivity Supercomputing (VI-HPS)
Funded by the Helmholtz Association and carried out in cooperation with Forschungszentrum Jülich, RWTH Aachen University (Institute for Scientific Computing), TU Dresden, University of Tennessee, TU Munich, and University of Stuttgart.

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. During the past year, three tuning workshops with hands-on sessions were organized in Munich, Amsterdam, and the King Abdullah University of Science and Technology in Saudi Arabia. In addition, two conference tutorials also with hands-on exercises were held at the IEEE Conference on Cluster Computing in Heraklion, Greece and at the ACM/IEEE Conference on Supercomputing (SC10) in New Orleans, USA.
Scalable Infrastructure for the Automated Performance Analysis of Parallel Codes (SILC)

Funded by the BMBF and carried out in cooperation with GNS Gesellschaft für numerische Simulation mbH, RWTH Aachen University (Institute for Scientific Computing), TU Dresden, TU Munich, GWT-TUD GmbH and University of Oregon.

Emerged from the Virtual Institute – High Productivity Supercomputing, the goal of the SILC project is the design and implementation of a scalable and easy-to-use performance measurement and monitoring infrastructure for supercomputing applications. The infrastructure will serve as a common basis for the performance-analysis tools Scalasca, Periscope, Vampir, and TAU. The latter three are developed by research groups in Munich, Dresden, and Eugene (OR, USA), respectively. In addition to increasing their scalability, making the four tools rest on this joint basis will allow them to interoperate more easily and simplify their installation. The enhanced tool suite will be used to tune the performance of academic and industrial simulation programs especially from the Gauss Alliance, preparing them for the new exa-scale era. During the past year, a first prototype, which already supports a full end-to-end performance analysis cycle, was completed. Compared to existing measurement systems, distinctive features of the new design include more space efficient memory management and more flexible thread handling, the latter allowing the support of advanced OpenMP features such as nested parallelism.

Performance Refactoring of Instrumentation, Measurement, and Analysis Technologies for Petascale Computing (PRIMA)

Funded by the US Department of Energy and carried out in cooperation with the University of Oregon.

This project pursues the goal of reengineering core components of the two performance-analysis systems TAU, developed by the University of Oregon, and Scalasca for evolution to petascale and beyond. Building on a long history of interaction between the two projects, the two key activities are 1) refactoring certain TAU and Scalasca components for core code sharing, and 2) integrating their functionality more effectively through data interfaces, formats, and utilities. The project is carried out in close cooperation with the SILC project described earlier.
The EFDA Task Force ITM (Integrated Tokamak Modelling) aims at creating a global modelling framework for the International Thermonuclear Experimental Reactor (ITER) currently under construction in Cadarache (France). For this purpose, various codes used to model key physical processes within the core plasma and its interaction with the vessel walls will be coupled together via the KEPLER workflow system.

Many of these codes are already parallelized to decrease their time to solution. However, this implies that an effective data exchange between two or more codes has to be provided, allowing simulation results of one code to be efficiently transferred to the next. Currently the data exchange mechanism works only in a serial way, such that the participating processes of one code first have to gather their simulation data and transfer it serially to the next code. This can lead to serious performance bottlenecks at the interface between the codes.

To optimize the data transfer between the models, the data exchange mechanism is being parallelized in this project. As a first example, two ITM kinetic edge modeling codes with different foci, ERO and B2-EIRENE, will be used to demonstrate the advantages of parallel data exchange. The outcome of this work will be an interface that allows parallel codes to utilize all of their processes for input and output operations. This is expected to significantly improve the performance between interacting codes and eliminate the bottlenecks caused by serial I/O.
Other Activities

Awards

ICPP 2010 Best Paper Award

Our team won the Best Paper Award of the International Conference on Parallel Processing (ICPP) 2010 in San Diego, California. The award was given to the authors David Böhme, Markus Geimer, Felix Wolf, and Lukas Arnold for their paper entitled “Identifying the root causes of wait states in large-scale parallel applications”. The work is a collaborative effort between our group and the Jülich Supercomputing Centre.

The article introduces a scalable technique that enables an improved understanding of how the effects of load imbalance, a well-known problem of many simulation programs that prevents them from exploiting the full power of large and expensive supercomputers such as Jugene in Jülich, slow down program execution. The new approach, which is currently being integrated into the Scalasca performance analysis tool, will allow more target-oriented optimizations of such phenomena.

Academic Workshops

We co-organized the following workshops:

- 3rd Workshop on Productivity and Performance (PROPER 2010) held in conjunction with the EuroPar 2010 Conference, Ischia/Naples/Italy, August 2010.
- 15th International Workshop on High-Level Parallel Programming Models and Supportive Environments (HIPS 2010) held in conjunction with the IEEE International Parallel and Distributed Processing Symposium in Atlanta (USA), April 2010.

Tutorials and Short Courses

Members of our group taught in the following tutorials and short courses:


Talks and Publications

Talks


F. Wolf: *How to exploit the full power of peta-scale supercomputers?*, IRC-CoSiM Workshop, University of Sofia, Bulgaria, October 9, 2010.


F. Wolf: *Application Performance Analysis on Petascale Systems*, Lomonosov Moscow State University, Russia, June 10, 2010.


B. J. N. Wylie, D. Böhme, B. Mohr, Z. Szebenyi & F. Wolf: *Performance analysis of Sweep3D on Blue Gene/P with the Scalasca toolset*, Workshop on Large-Scale Parallel Processing (LSPP@IPDPS), Atlanta, Georgia, USA, April 23, 2010.

Felix Wolf & B. J. N. Wylie: *Application Performance Analysis on Petascale Systems*, 15th International Workshop on High-Level Parallel Programming Models and Supportive Environments (HIPS@IPDPS), Atlanta, Georgia, USA, April 19, 2010.


F. Wolf: *From the American South to the German Midwest*, Innovative Computing Laboratory, University of Tennessee, Knoxville, Tennessee, March 26, 2010.


D. Becker: Timestamp synchronization of concurrent events, PhD defense, RWTH Aachen, Germany, December 10, 2009.


F. Wolf: Kranken Herzen helfen – Ingenieure und Informatiker helfen durch die Entwicklung einer Miniaturblutpumpe, Vortrag im Rahmen der Wissenschaftsnacht, RWTH Aachen University, November 13, 2009.


Z. Szebenyi: A Quick Introduction to Scalasca, Lawrence Livermore National Laboratory, October 1, 2009.

**Publications**


Andreas Knüpf, Markus Geimer, Johannes Spazier, Joseph Schuchart, Michael Wagner, Dominic Eschweiler, Matthias S. Müller: *A generic attribute extension to OTF and its use for*


Advanced Studies in Computational Engineering Science

Staff

• **Faculty**
  Prof. Paolo Bientinesi, PhD

• **Postdoctoral associate**
  Edoardo Di Napoli, Ph.D.

• **Team**
  Matthias Petschow
  Roman Iakymchuk
  Diego Fabregat
  Andrea Benigni
Overview

Paolo Bientinesi is Junior Professor in “Algorithm & Code Generation for High-Performance Architectures” and Young Research Leader at the Aachen Institute for Advanced Studies in Computational Engineering Science (AICES), where he leads a group on “High-performance and Automatic Computing”. His research interests cover the fields of numerical analysis, high-performance & parallel computing, and automation.

In 2010 he has been especially active in Cloud Computing and Computational Physics. The highlights are:

• The research on Clouds appeared in the Handbook for Cloud Computing and was featured in the news websites HPCWire and HPCintheCloud:
  • HPC Sharing in the Cloud.
    o Feature Article, HPC in the Cloud, August 12, 2010. HP Cin the Cloud.com
    o Crowded Clouds, HPCwire, August 12, 2010. HPCWire.com
• The project “Numerical Quantum Physics on Parallel Architectures”, in collaboration with Prof. Stefan Blügel, was funded by the Jülich-Aachen Research Alliance (JARA).
• The project “Parallelization of Large Dense Symmetric Eigenvalue Solvers on Multi-Core Processors”, in collaboration with Prof. Enrique Quintana- Orti, was funded by the Deutscher Akademischer Austausch Diesnt (DAAD).
Research

Cloud Computing

The cloud computing model provides flexible support for “pay as you go” systems. In addition to no upfront investment in large clusters or supercomputers, such systems incur no maintenance costs. Furthermore, they can be expanded and reduced on-demand in real-time. Total cost can be close to zero when resources are not in use. The cloud user can pay costs directly proportional to need rather than allocating resources according to average or peak load. Our research explores whether cloud computing services are suitable for high-performance computing (HPC) workloads. To this end, in addition to traditional metrics such as GFLOPS and efficiency, we introduce and study concepts like average expected performance and execution time, expected cost to completion, flops per dollars.

Eigencomputations in Physics

Density Functional Theory (DFT) [1] is a powerful method of investigation that has become the “standard model” of material science. DFT is one of the most effective frameworks for studying complex quantum mechanical systems. DFT-based methods are growing as the standard tools for simulating new materials. At the core of DFT lie a large number of generalized eigenproblems, to be solved at each iteration of an iterative process. Our goal is to take advantage of physical knowledge to speed up the computation of both each individual eigenproblem, and of the whole sequence.

Parallel Eigensolvers

The computation of eigenvalues and eigenvectors of symmetric tridiagonal matrices is most common in applications, and it is one the steps in the solution of Hermitian and symmetric eigenproblems. While several accurate and efficient methods for the triadiagonal eigenproblem exist, the state of the art libraries only target uniprocessors or large distributed memory systems. We are developing new eigensolvers specifically designed for todays architectures, ranging from multi-core and many-core, to GPUs, to hybrid systems. Our target is to establish the reference parallel library for eigencomputations.
Other Activities

Services
Throughout the year Bientinesi and his team organized a number of events.

• Short courses:
  o Python for Scientific Computing,
  o Development Practices in Extreme Programming,
  o Efficient Solution of Linear Systems arising in Finite Discretization Methods,
  o Matrix Factorization and Approximation Problems;

• Symposium on Numerical Methods for Eigenvalue Problems within the 8th International Conference of Numerical Analysis and Applied Mathematics (ICNAAM 2010).
Talks and Publications

Talks

Speaker: Edoardo Di Napoli, RWTH Aachen.

Speaker: Stefano Masini.

Speaker: Diego Fabregat, AICES.


Speaker: Diego Fabregat, AICES.


Speaker: Matthias Petschow, AICES.

At the Heart of the Automation of Linear Algebra Algorithms. Workshop on Program Composition and Optimization. May 2010, Dagstuhl, Germany.

Speaker: Victor Eijkhout, Texas Advanced Computing Center.

Speaker: Victor Eijkhout, Texas Advanced Computing Center.

Refereed Publication


Paolo Bientinesi, Francisco Igual, Daniel Kressner, Matthias Petschow and Enrique Quintana-Orti. Condensed Forms for the Symmetric Eigenvalue Problem on Multi-threaded
Architectures. Accepted for publication in Concurrency and Computation: Practice and Experience.


**Technical Reports**


Dissertations and Habilitations
Community information systems (CIS) are information systems using a variety of Internet engineering technologies to support communities of practice (CoP). In contrast to organizational information systems supporting defined organizational structures, CIS depend on a complex interplay of informal and evolving CoP structures, evolving technology and the mostly hidden rules of network structures. Therefore, CIS need the possibility to reflect about their development processes and to elicit the networks roles and structures. The advent of the Web 2.0 generates even more demands on CIS, since most business models rely on the networking of people to achieve goals set by the communities. My research has contributed to existing research areas connected to information systems engineering but also to the development of emerging research disciplines like Web Science. In Web Science both engineering and science play important roles in understanding the Web as a social graph and to design for a desired behavior. In addition to a comprehensive survey of literature on CIS, the main contributions of the thesis are the following. These contributions have been developed and evaluated in a lot of projects and case studies.

1. A methodology called ATLAS for the engineering of CIS based on continuous elicitation and assessment of community needs, the reflection on social roles in communities of practice and a socio-technical information system development process incorporating the communities as stakeholders.

2. A service-oriented architecture called LAS for the realization of reflective community information systems by measuring, analyzing and simulating the use of information systems.

3. A model and a repository for community-centered cross-media social network analysis called the MediaBase.

**Evaluators:**
- Prof. Dr. Matthias Jarke
- Prof. Dr. Klaus Tochtermann (TU Graz)
- Prof. Dr. Wolfgang Nejdl (University of Hannover)

**Habilitation Colloquium:** 14th July, 2010
Reachability over Word Rewriting Systems
Jan-Henrik Altenbernd

Word rewriting systems have been studied over the last century under several aspects. In the beginning, they were considered as a framework for the representation of computation processes and as a tool for generating formal languages. In more recent years, they have also been investigated as a mechanism to represent infinite graphs by a finite formalism. This thesis has its main focus in the latter domain.

In the first part of the thesis, we investigate mixed prefix / suffix rewriting (MPSR) systems, which combine prefix and suffix rewriting in a nondeterministic way. We study central algorithmic properties of the graphs that can be generated by such systems, with an emphasis on the reachability problem (as a master problem in model-checking), and we determine the connection between the classes of such graphs and other well-studied graph classes, such as the classes of prefix recognizable and of automatic graphs. Furthermore, we study the class of trace languages of graphs that are generated by MPSR systems, and we show that this class strictly includes the class of context-free languages, and is itself properly included in the class of context-sensitive languages.

In the second part of the thesis, we introduce and investigate tagged infix rewriting (TIR) systems, which extend the MPSR systems, and which use special markers for a restricted form of infix rewriting. We show that in their basic form, where the markers may not be rewritten, TIR and MPSR systems share a number of model-checking properties, and we obtain analogous results concerning their languages.

We also study two variants of TIR systems. For the first, where markers may be removed by rewriting steps, we show that such systems preserve regularity of languages under rewriting, by adapting the saturation method as known for pushdown systems. In the second variant, where markers may be added by rewriting steps, this does not hold; however, we show that an algorithmic reachability analysis is still possible.

Evaluators: Prof. Dr. Dr.h.c. Wolfgang Thomas, Dr. habil. Didier Caucal (Université Paris Est)

Date of oral examination: 9 December 2009
**Personalized eHomes: Mobility, Privacy, and Security**

Ibrahim Armaç

eHomes are intelligent environments providing value-added services to their users. These services realize complex functionalities by combining basic functionalities of various devices and appliances. Reasonable eHome services can be identified in the domains of comfort, security, multimedia, energy consumption and eHealth.

There exist several challenges which need to be addressed when developing and operating eHomes. First, the heterogeneity of various device types and standards must be overcome in order to ensure the interoperability of eHome services. Second, changes which result from various kinds of dynamics must be taken into account at runtime. Third, adequate concepts are required for personalizing eHome services so that their functionalities can be adapted to individual user preferences. Finally, multilateral security must be provided to users and eHomes.

Several tools have been developed in previous dissertations at the Software Engineering group for addressing the heterogeneity problem. These tools enable the reuse of component-based eHome services by a specification, configuration, and deployment process (SCD Process). Moreover, the structure of a service composition, resulting from the SCD Process, can be adapted while the system is running. Thus, an eHome can handle the abovementioned dynamics.

In this thesis, I have worked on two essential aspects of eHomes which have not been considered in previous dissertations.

First, I have investigated how users can be supported in personalizing eHomes in the context of inter-eHome mobility, a special kind of dynamics. This term describes the situation where users often move from one eHome to another one. The aim is to adapt eHome services to the preferences of the mobile users possibly without an additional configuration overhead. For this purpose, I have extended the existing eHome prototype. It now enables two kinds of eHomes personalization. First, I have developed a mobile user model which can be used to store and manage user preferences on a mobile device and provide them to visited eHomes when necessary. As a result, redundant management effort is avoided. Second, mobile users now can take along and execute personal services on their mobile devices. These services can remotely interact with basic services which are executed in the visited eHomes and control the devices required for realizing their functionalities. Hence, the users can benefit from habitual functionalities even in such eHomes which do not offer these functionalities by their own services.

Second, I have worked on the realization of multilateral security in the context of inter-eHome mobility. In doing this, I considered the security objectives of both the users and the eHomes.

For protecting the user privacy, I have developed concepts based on the principles of data minimization and unlikability of user data. For minimizing the data disclosed to eHomes, I have introduced a negotiation-based identity management system. Furthermore, this system enables mobile users to interact with each eHome by another identity. In addition to that, an authentication mechanism based on anonymous credentials avoids the linkability of user data by colluding eHomes.
For protecting eHome services against unauthorized access by both users and services, I have realized a combination of credential- and role-based access control mechanisms. On the one hand, they fulfill accountability requirements. On the other hand, the roles can be automatically adapted to evolving service compositions at runtime of an eHome.

The described concepts have been realized in form of new tools. The applicability and the evaluation of the achieved results have been shown in different test scenarios. For this purpose, I have developed different software demonstrators simulating eHomes.

Concluding, this thesis accommodates personalization to privacy protection, two reluctant requirements, by providing a sound compromise between anonymity and accountability. Due to this, mobile users can benefit from personal services in different eHomes while their privacy is protected. As a result, this work contributes to the acceptance of eHomes in a future mass market.

**Evaluators:** Prof. Dr.-Ing. Manfred Nagl
Prof. Dr. h.c. Otto Spaniol

**Date of oral exam:** 6 July 2010
Design Patterns for Safety-Critical Embedded Systems
Ashraf Armoush

Over the last few years, embedded systems have been increasingly used in safety-critical applications where failure can have serious consequences. The design of these systems is a complex process, which is requiring the integration of common design methods both in hardware and software to fulfill functional and non-functional requirements for these safety-critical applications.

Design patterns, which give abstract solutions to commonly recurring design problems, have been widely used in the software and hardware domain. In this thesis, the concept of design patterns is adopted in the design of safety-critical embedded system. A catalog of design patterns was constructed to support the design of safety-critical embedded systems. This catalog includes a set of hardware and software design patterns which cover common design problems such as handling of random and systematic faults, safety monitoring, and sequence control. Furthermore, the catalog provides a decision support component that supports the decision process of choosing a suitable pattern for a particular problem based on the available resources and the requirements of the applicable patterns.

As non-functional requirements are an important aspect in the design of safety-critical embedded systems, this work focuses on the integration of implications on non-functional properties in the existing design pattern concept. A pattern representation is proposed for safety-critical embedded application design methods by including fields for the implications and side effects of the represented design pattern on the non-functional requirements of the systems. The considered requirements include safety, reliability, modifiability, cost, and execution time.

Safety and reliability represent the main non-functional requirements that should be provided in the design of safety-critical applications. Thus, reliability and safety assessment methods are proposed to show the relative safety and reliability improvement which can be achieved when using the design patterns under consideration. Moreover, a Monte Carlo based simulation method is used to illustrate the proposed assessment method which allows comparing different design patterns with respect to their impact on safety and reliability.

**Evaluators:** Prof. Dr.-Ing. Stefan Kowalewski
                       Prof. Dr. Bernhard Rumpe

**Date of oral exam:** 15 June 2010
Timestamp synchronization of concurrent events

Daniel Becker

Supercomputing is a key technological pillar of modern science and engineering, indispensable for solving critical problems of high complexity. However, to effectively utilize today’s supercomputing systems, scientists and engineers need powerful and robust software development tools. One technique widely used by such tools is event tracing. Recording time-stamped runtime events in event traces is especially helpful to understand the performance behavior of parallel programs, since it enables the post-mortem analysis of communication and synchronization patterns.

The accuracy of such analyses depends on the comparability of timestamps taken on different processors and may be adversely affected by non-synchronized clocks. Inconsistent trace data may not only lead to false conclusions and confuse the user of trace-visualization tools but also may break tools if they rely on the correct event order to function properly. Although linear offset interpolation can restore the consistency of the trace data to some degree, time-dependent drifts and other inaccuracies may still disarrange the original sequence of events.

The already familiar controlled logical clock algorithm accounts for such violations in point-to-point communication. It is, however, not suitable for realistic applications because it ignores collective and shared-memory communication and - as a serial algorithm - offers only limited scalability. To address these shortcomings, the algorithm was (i) extended such that it also restores the event semantics of collective and shared-memory operations and (ii) parallelized to make it suitable for large-scale systems including computational grids. The extended and parallelized version was evaluated in practice by integrating it into the Scalasca trace-analysis framework and applying it to traces of realistic applications taken on single cluster systems and computational grids.

Evaluators:  Prof. Dr. Felix. Wolf
               Prof. Christian H. Bischof, Ph.D
               Prof. Dr. Michael Resch (Universität Stuttgart)

Date of oral exam:  10 December 2010
Machine translation is the task of automatically translating a text from one natural language into another. Due to improved concepts and algorithms, the quality of the generated translation hypotheses has been significantly improved in recent years. Still, the translation quality leaves a lot to be desired when going beyond traditional translation tasks such as newswire articles. We extend the state-of-the-art in phrase-based translation which enables us to build a robust translation system for multi-domain input. Robustness is hereby regarded as the ability to produce high quality translations for arbitrary input texts, e.g. automatic transcriptions of recognized speech or other unstructured, potentially noisy input. In this work, we focus on Arabic-English translation tasks. We study the search problem for phrase-based statistical machine translation in detail and examine the effect of the different models on the translation quality. Moreover, we make an explicit distinction between reordering (coverage) and lexical hypotheses in the pruning process and stress the importance of the coverage pruning to adjust the balance between hypotheses representing different reorderings (coverage hypotheses) and hypotheses with different lexical representations. To trim our translation system for multi-domain input and to improve the robustness built into the decoder, we apply domain adaptation to the language models and rerank the candidate translations using appropriate rescoring models. We also present our work on adjusting the vocabularies of the speech recognizer and the machine translation system in a preprocessing step and on predicting missing punctuation marks for automatically transcribed speech (in the actual translation process). Finally, we investigate different data-driven approaches to the task of transliterating proper names. Often, such names are out-of-vocabulary terms and the intention is to preserve the names by transliteration. The presented machine translation system achieves state-of-the-art performance and has been successfully applied to the large-scale Arabic-English GALE translation evaluations. Furthermore, the system was ranked among the top submissions for the NIST Open Machine Translation Evaluation 2006 and for the series of IWSLT evaluation campaigns.

**Evaluators:** Prof. Dr. Hermann Ney  
Prof. Francisco Casacuberta

**Date of oral exam:** 11 March 2010.

Christian Berger

In projects dealing with autonomous vehicles which are driving in different contexts like highways, urban environments, and rough areas, managing the software's quality for the entire data processing chain of sensor- and actuator-based autonomous systems is increasingly complex. One main reason is the early dependency on all sensors' raw data to setup the data processing chain and to identify subsystems. These sensors' data might be extensive, especially if laser scanners or color camera systems are continuously producing a vast number of raw data. Moreover, due to this dependency the sensors' setup including their respectively specified mounting positions and calibration information is also necessary to gather real input data from real surroundings' situations of the system. This is even more important before actually starting to integrate independently developed subsystems for carrying out tests for the entire data processing chain.

To reduce this dependency and therefore to decouple tasks from the project's critical path, an approach is outlined in this thesis which was developed to support the software engineering for sensor- and actuator-based autonomous systems. This approach relies on customer's requirements and corresponding customer's acceptance criteria as well as the decoupling of the software engineering from the real hardware environment to allow appropriate system simulations.

Based on the customer's requirements, formally specified scenarios using a domain specific language are derived which are used to provide surroundings and suitable situations for a sensor- and actuator-based autonomous system. From these formally specified surroundings, the required input data is derived for different layers of a sensor data processing system to generate actions within the system's context. This input data itself depends on a given sensor model to compute its specific raw data. Amongst others, on the example of laser scanners and camera systems, algorithms using modern graphical processing units are outlined to generate the required raw data even for complex situations.

To realize the aforementioned aspects, a development environment is necessary consisting of tools for modeling and working with instances of a domain specific language. Furthermore, a software framework is required which provides easily usable and mature solutions for common programming requirements like synchronization for concurrent threads or communication in a high-level point of view. For relying on a consistent and homogeneous software framework for implementing the concepts, a highly portable and real-time-capable software framework for distributed applications was realized which was written entirely from scratch in strictly object-oriented C++. Moreover, this software framework also integrates the formally modeled input data derived from the specified requirements and the sensors' models to allow unattended system simulations to support the acceptance tests for subsystems or an entire system.

On the example of autonomous vehicles, the applicability of the approach and the software framework is demonstrated by implementing a vehicle navigation algorithm which uses a given digital map for finding the best route to a desired destination from an arbitrarily chosen starting point. This algorithm was developed considering the test-first-principle and is continuously evaluated by unattended and automatic software tests which are executed on a continuous integration system. Its implementation and its evaluation make use of the aforementioned concepts and algorithms. Therefore, the vehicle's surroundings were formally
modeled together with its necessary sensors using the provided development tools and environment for performing and evaluating unattended system runs before the algorithm was put into operation on the real vehicle.

**Evaluators:**  Prof. Dr. rer. nat. Bernhard Rumpe  
Prof. Dr.-Ing. Thomas Form

**Dato of oral exam:** 19 July 2010
Mobile and fixed telecommunications network operators have been experiencing aggressive competition from Internet content providers that use the operators’ infrastructure for providing subscribers with a wide choice of web-based mobile multimedia services. For keeping pace, operators designed and implemented strategies aimed at enabling the development of Value Added Services whose differentiation relies on their key strengths including call control, messaging, location, presence, etc.

Even though some standardization initiatives enabling the homogeneous exposure of the mentioned functionality are already in place, considerable work still has to be done for easing the interaction with it on the service development side. The presented approach aims at enhancing this interaction by proposing a context management platform that enables the development of Value Added Services from a context awareness perspective.

Within the platform, a Value Added Service is conceptualized as a component implementing application logic mapping context notifications, which are generated by the Context Providers as result of events happening inside and outside the network, into invocations of Service Capabilities, which implement functionality aimed at triggering some actions based on the received context notifications.

Built on top of on well-known telecommunications concepts, the platform is based on a middleware approach for implementing the fundamental context acquisition and management operations, and uses a Publish-Subscribe communication model between the components implementing its key functionalities. Acknowledging the goals already achieved in the field of telecommunications feature exposure, the interfaces between Value Added Services and both Context Providers and Service Capabilities are based on the standardized and open Parlay OSA and Parlay X APIs.

**Evaluators:** Prof. Dr. Otto Spaniol (RWTH Aachen University)  
Prof. Alejandro P. Buchmann, Ph. D. (TU Darmstadt)

**Date of oral exam:** 8 July 2010
There is a wide agreement that traditional Technology Enhanced Learning (TEL) models have failed to cope with the fast-paced change and critical challenges of the new knowledge era. In this thesis, the Learning as a Network (LaaN) theory is introduced as a response to the increasing complexity of the new learning environments. LaaN draws upon connectivism, complexity theory, and double-loop learning. It views knowledge as a personal network and represents a knowledge ecological approach to learning.

Based on the LaaN theory, the 3P Learning Model is discussed as an alternative TEL model that represents a fundamental shift toward a more personalized, social, open, dynamic, emergent and knowledge-pull model for learning, as opposed to the one-size-fits-all, centralized, static, top-down, and knowledge-push paradigms of traditional TEL models.

Finally, the Social Software Supported Learning Framework is presented as a TEL information system that illustrates the 3P learning model in action, by implementing the main ideas underpinning the 3P learning model, based on Web 2.0 concepts and social software technologies.

**Evaluators:** Prof. Dr. rer. pol. Matthias Jarke, RWTH Aachen University  
Prof. Dr. Marcus Specht, Open University Netherlands

**Date of oral exam:** 5 October 2010
System Model-Based Definition of Object-Oriented Modeling Languages with Semantic Variation Points

Hans Grönniger

A successful model-based software development method requires a variable yet precise definition of the modeling languages used. This especially involves the explicit definition of the meaning of the language, i.e., its semantics. Formal semantics contributes to an unambiguous communication between people and may enable a high degree of automation using interoperable tools. This thesis is concerned with the complete, formal definition of object-based modelling languages. It concentrates on the flexible definition of problem-oriented semantics.

For the definition of the semantics of object-based modeling languages the system model is defined as a commonly used semantic domain. The system model abstractly characterizes the structure, behavior, and interaction of objects in an object-based system. The predicative semantic mapping of elements of the syntax of a language into the system model defines a set of object-based systems. The mapping thereby establishes a precise mapping even of incomplete or underspecified models. Based on the system model, semantics of model composition and model refinement can be defined by simple mathematical operations.

According to a general classification of possible variability within a modeling language, the different constituents of a language like syntax, semantic mapping, and semantic domain can be equipped with variants. This enables the tailoring of a language to, for example, a project-specific context. Variants and their interdependency are captured using feature diagrams. A configuration, i.e., the selection of language variants according to the feature diagrams, then denotes the set of effective definitions.

Tool support is introduced using MontiCore, a framework for the development of textual languages, and the theorem prover Isabelle/HOL. A flexible and at the same time machine readable syntax and semantics is thus obtained. Furthermore, the definition and configuration of semantics variants is supported.

Semantics of the UML subset UML/P is defined using the tool support in order to validate the approach. Semantics of class diagrams, object diagrams, state charts, and sequence diagrams is considered. Additionally, simple versions of Java, acting as an action language, and OCL, used as a constraint language, are defined.

The given UML/P semantics variants can be used directly to conduct tool-supported verification in the theorem prover because concrete models can be translated automatically to Isabelle as well. Using the integrated semantics of several UML/P modeling languages, verification is demonstrated with the help of concrete examples. The examples substantiate the practical usability of the approach.

Evaluators: Prof. Dr. rer. nat. Bernhard Rumpe
Prof. Juergen Dingel, Ph.D

Date of oral exam: 16 June 2010
Conventional speech recognition systems are based on Gaussian hidden Markov models (HMMs). Discriminative techniques such as log-linear modeling have been investigated in speech recognition only recently. This thesis establishes a log-linear modeling framework in the context of discriminative training criteria, with examples from continuous speech recognition, part-of-speech tagging, and handwriting recognition. The focus will be on the theoretical and experimental comparison of different training algorithms. Equivalence relations for Gaussian and log-linear models in speech recognition are derived. It is shown how to incorporate a margin term into conventional discriminative training criteria like for example minimum phone error (MPE). This permits to evaluate directly the utility of the margin concept for string recognition. The equivalence relations and the margin-based training criteria lead to a unified view of three major training paradigms, namely Gaussian HMMs, log-linear models, and support vector machines (SVMs). Generalized iterative scaling (GIS) is traditionally used for the optimization of log-linear models with the maximum mutual information (MMI) criterion. This thesis suggests an extension of GIS to log-linear models including hidden variables, and to other training criteria (e.g. MPE). Finally, investigations on convex optimization in speech recognition are presented. Experimental results are provided for a variety of tasks, including the European Parliament plenary sessions task and Mandarin broadcasts.

**Evaluators:** Prof. Dr. Hermann Ney  
Prof. Dr. Dietrich Klakow

**Date of oral exam:** 28 June 2010
Interactive Feature Analysis in Virtual Environments

Bernd Hentschel

The availability of high-performance computers has led to a drastic increase in the size of today's simulation data. Timely analysis of the resulting large, time-dependent data sets has become a major bottleneck for scientific advance.

Feature-based visualization tries to tackle this problem by automatically extracting predefined structures of interest, the so-called features, from the underlying raw data. However, feature-based methods suffer from several disadvantages: first, they require a considerable amount of domain knowledge; second many features are not clearly definable in a binary fashion; finally, domain scientists tend to distrust the black-box nature of automatic feature detection.

In this thesis, we have abandoned the classic notion of automatic feature detection in favor of a user-centered process which allows domain experts to interactively define, extract and analyze arbitrary features. In a first stage, the domain expert is enabled to interactively mark arbitrary subsets of the data for further analysis. This stage is based on the information visualization concept of brushing linked views. Second, marked points are clustered for individual time steps and the resulting clusters are tracked over time. The paths output by this process describe the features’ spatio-temporal evolution. The third stage consists of methods for the analysis of extracted features and largely relies on a quantitative description of features. The analysis is extended to a feature's history. Colloquially, this history contains all the data points, which may have influenced a feature object at a given time. An analysis of the history therefore facilitates insights into temporal cause-and-effect-relationships governing a feature’s evolution.

The entire process is embedded in an immersive virtual environment, i.e. it features stereoscopic viewing and direct 3D interaction. All compute-intensive parts of the process have been offloaded to a remote parallel computer in order to ensure timely updates for an interactive workflow. Throughout the thesis, the applicability of the presented techniques is demonstrated in several real-world case studies which have been carried out in order to validate the proposed methods.

Evaluators:  Prof. Dr. T. Kuhlen
             Prof. Dr. R. Westermann, TU München
             Prof. C. Bischof, PhD

Date of oral exam: 11 December 2009
Activities in management of schemas and schema mappings are usually solved by special-purpose solutions such as coding wrapper components or manually updating view definitions. The goal of model management is to raise the level of abstraction for metadata-intensive activities by providing a set of high-level operators that automate or semi-automate such tasks.

The problems of model management are aggravated by the fact that usually heterogeneous modeling languages, such as the relational data model, XML Schema, or ontologies, are employed within the same organization. Therefore, model management aims at genericness by devising operations that are agnostic about the underlying native metamodels. Current solutions fail to be generic as they are restricted to certain combinations of modeling languages. Therefore, a generic solution for model management problems requires generic languages for modeling and mapping specification as well as algorithms operating on such generic representations.

This work solves some of the problems in generic model management. In particular, the work makes the following contributions: 1. A generic metamodel that allows the detailed representation of schemas imported from various native languages. This is required, for instance, by schema matching algorithms which use the knowledge about schemas to produce a mapping between them. 2. The semantics of our generic metamodel serves as the foundation for a formal and generic schema mapping language which allows data exchange and query rewriting between schemas in different modeling languages. Unlike other languages, our mapping language at the same time supports powerful restructuring of data and is closed under composition. 3. Our solutions for schema matching, mapping composition and other model management operations have been integrated into a holistic generic model management prototype system. 4. Our schema mapping language has been used to develop an object-relational mapping tool and a federated data management system that is agnostic about the native metamodels employed by its data sources.

**Evaluators:** Prof. Dr. Matthias Jarke (RWTH Aachen University)  
Prof. Avigdor Gal, PhD (Technion - Isreal Institute of Technology)  

**Date of oral exam:** 2 November 2010
MontiCore: Agile development of domain-specific languages for Software engineering

Holger Krahn

Domain specific languages (DSLs) are languages in computer science which permit specifying compact solutions in clear-cut functional or technical application areas. Using a domain specific notation simplifies the integration of experts in comparison to conventional software development because the models are easier understood by them. The automatic creation of production code from domain specific models is an effective form of model-driven development.

An agile and efficient development process is hard to establish using existing DSL development methods because of the missing central language reference which includes abstract and concrete syntax and inadequate modularization techniques. Methods and reference architectures are lacking for designing and using complex and model-based tools in structured way for software development.

Thus, in this thesis the modular development of textual DSLs and tools with the MontiCore-framework is described. The most important contributions to research can be summarized as follows:

• Textual domain specific languages can be defined by a compact grammar-based format that defines abstract syntax as well as concrete syntax of a language and can therefore be used as a central documentation for developers and users of a DSL. The emerging abstract syntax is equivalent to well-established meta-modeling-techniques and extends common grammar-based approaches.

• The reuse of language fragments within model-driven development is supported by two modularity mechanisms that combine existing artefacts in a structured way to form new languages: Grammar inheritance supports the specialization and extension of languages. Embedding permits the flexible combination of multiple languages, which can also differ fundamentally in their lexical structure.

• The used grammar format is extensible in a modular way such that additional information can be specified as so-called concepts. Based on them, further infrastructure can be generated from the language definition. The extensibility by concepts is demonstrated by a declarative way to specify links in the abstract syntax and by an attribute grammar system.

• The development of code generators and tools for the analysis of DSLs is simplified considerably by making a reference architecture available. Approved solutions can be used without further development effort. Thus, the quality of the emerging tools is increased in comparison to existing approaches.

• It is demonstrated how compilable templates can be used for an integrated refactoring of templates and a runtime environment. Based on that, a method is defined to develop a generator in a stepwise manner from existing source code. The data model of the generator can be derived automatically.

The abovementioned languages and methods are developed within the framework MontiCore. Their applicability is demonstrated by the development of the framework itself in a bootstrapping-process and by two further case studies.
Evaluators:  Prof. Dr. rer. nat. Bernhard Rumpe
            Prof. Dr. rer. nat. Andy Schürr

Date of oral exam: 18 December 2009
Adaptive Service Discovery in Wireless-Mesh-Networks

Martin Krebs

Service-Discovery-Protocols provide a means to discover resources like printers, scanners, or a music collection in a network, or to make information about them available. Today, a number of approaches for Service-Discovery-Protocols exists for local area networks, the Internet, and mobile ad-hoc Networks. Unfortunately, most of them have been optimised for the respective type of underlying network. However, such approaches are not suitable for wireless-mesh-networks, due to their common lack of adequate adaptivity. For example, flooding messages through wireless-mesh-networks is not very efficient since it does not deploy any stable parts of the network. Centralised approaches are very error-prone since wireless connections may suffer from an unstable connection quality, or may loose connectivity altogether. Both effects would lead to a service discovery to be cancelled.

This thesis presents adaptive and self-configuring approaches that adequately take into account the dynamic structure of a mesh network. To achieve this, protocols are deployed that are capable of adapting their behaviour to local network characteristics. In addition, a virtual backbone is dynamically created from a variable number of super nodes.

Evaluators:  Prof. Dr. Otto Spaniol
            Prof. Dr. Henning Schulzrinne, Columbia University

Date of oral exam: 27 May 2010
The diversity of applications in the Internet and the heterogeneity of today's networked platforms make the development of communication protocols complex and time-consuming. This work introduces mechanisms, models, and tools to reduce the complexity and engineering effort required for protocol development and evaluation. It makes the following three key contributions:

1. Similarities in protocol mechanisms are extracted into modular building blocks to reduce the complexity of communication system development.
2. We introduce a platform abstraction layer to gradually evolve protocol implementations across platforms avoiding frequent reimplementation.
3. Automated instrumentation of models with system properties allows to accurately analyzing the time dependent behavior and power consumption of networked devices.

**Evaluators:** Prof. Dr. Klaus Wehrle, RWTH Aachen University  
Prof. Joseph Anthony, UC Berkeley

**Date of oral exam:** 22 March 2010

Andreas Lorenz

In a world of ambient services, the technology disappears into the surroundings until only the user interface remains perceivable by users. The use of input devices adopted from desktop computing is not feasible for interacting with complex services surrounding the user in highly computerised environments. Powerful mobile computers and high speed wireless networking enable enhanced interaction in a world of ambient services, e.g. by employing a mobile phone, using gestures, or observing body movements. The arising heterogeneity of hardware, software and communication technology combined with an open set of interaction styles narrow the interoperability of the user interface and the service to control.

A common understanding of a solution and a detailed description of the components and their relationships facilitate interoperability. Available patterns for software architectures are rather unspecific, in particular with respect to addressing the physical distribution of components. The thesis describes the design of a general solution to enable input devices to control environmental computing services. It extends the approach of separating the user interface from the application logic by defining virtual or logical input devices physically separated from the services to control. The complexity of development and the required programming effort were reduced by applying the software artefacts presented in the thesis. The achievement of uniformity of the design together with tools and auto-generation of source code are beneficial to the development in independent teams.

Evaluators: Prof. Dr. Matthias Jarke, RWTH Aachen University
Prof. Dr. Jan Borchers, RWTH Aachen University

Day of oral exam: 22 Dezember 2009
Adaptive Multimodal Exploration of Music Collection

Dominik Lübbers

Current online music portals and systems for the management of private music collections mainly concentrate on the support for directed search for music pieces (e.g. on the basis of describing metadata like title, artist, etc.). However, empirical studies have shown that the typical behaviour of customers in classic music retail stores is much more characterized by an undirected browsing in the offered catalogue without being able to articulate a clear information demand.

To improve support for this access paradigm, this thesis describes the conceptualization, implementation and evaluation of a computer game-like exploration environment for music collections, which allows its users to freely and autonomously explore a comprehensibly structured music library.

Such a structure is based on a quantifiable notion of similarity between songs. Therefore, in the first part of this thesis content-based, expert-based, collaborative and text-based approaches for distance calculation are discussed and assessed. To model the multiple facets of music similarity, a subset of these measures, which cover different aspects of music, are combined into a summarizing distance function.

The generation of self-organizing maps allows the topology-preserving arrangement of pieces on a two-dimensional map, on which similar songs are placed close to each other. Furthermore, it allows the detection of cluster boundaries, that separate homogeneous groups of similar pieces. This information can be used to build a three-dimensional virtual landscape, which the user can freely navigate in.

A main contribution of this thesis is the supplementation of this visual presentation by permanent spatialized acoustic playback of the placed pieces, which makes a media break-free communication of the actual exploration subject possible and thereby allows for a more informed navigation of the user in the landscape. To prevent users' acoustic overstimulation we developed and implemented concepts for perception focussing and intelligent selection of songs for playback.

Besides the development of possibilities to customize the environment (e.g. by moving songs or changing the height profile of the terrain), we also let the environment adapt to the user automatically: On the basis of his interaction with the system, a re-weighting of the individual similarity measure components is learned, which explains the structure provided by the user best. The development of this adaptive distance measure which allows to model a personalized similarity notion can be regarded as a further main contribution of this thesis.

A concluding evaluation shows the importance of the developed multimodal presentation for the user's orientation in the virtual environment and proves the performance of the adaptive distance function.

Evaluators: Prof. Dr. Matthias Jarke
Prof. Dr. Thomas Seidl

Date of oral exam: 8 December 2009
Modern automatic spoken dialogue systems cover a wide range of applications. There are systems for hotel reservations, restaurant guides, systems for travel and timetable information, as well as systems for automatic telephone-banking services. Building the different components and combining them enabling a reasonable dialogue is a complex task because during the course of a dialogue, the system has to deal with uncertain information. In this thesis, we use statistical methods to model and combine the system's components. Statistical methods provide a well-founded theory for modeling systems where decisions have to be made under uncertainty. Starting from Bayes' decision rule, we define and evaluate various statistical models for these components, which comprise speech recognition, natural language understanding, and dialogue management. The problem of natural language understanding is described as a special machine translation problem where a source sentence is translated into a formal language target sentence consisting of concepts. For this, we define and evaluate two models. The first model is a generative model based on the source-channel paradigm. Because the word context plays an important role in natural language understanding tasks, we use a phrase-based translation system in order to take local context dependencies into account. The second model is a direct model based on the maximum entropy framework and works similar to a tagger. For the direct model, we define several feature functions that capture dependencies between words and concepts. Both methods have the advantage that only source-target pairs in the form of input-output sentences must be provided for training. Thus, there is no need to generate grammars manually, which significantly reduces the costs of building dialogue systems for new domains. Furthermore, we propose and investigate a framework based on minimum error rate training that results in a tighter coupling between speech recognition and language understanding. This framework allows for an easy integration of multiple knowledge sources by minimizing the overall error criterion. Thus, it is possible to add language understanding features to the speech recognition framework and thus to minimize the word error rate, or to add speech recognition features to the language understanding framework and thus to minimize the slot error rate. Finally, we develop a task-independent dialogue manager using trees as the fundamental data structure. Based on a cost function, the dialogue manager chooses the next dialogue action with minimal costs. The design and the task-independence of the dialogue manager leads to a strict separation of a given application and the operations performed by the dialogue manager, which simplifies porting an existing dialogue system to a new domain. We report results from a field test in which the dialogue manager was able to choose the optimal dialogue action in 90% of the decisions. We investigate techniques for error handling based on confidence measures defined for speech recognition and language understanding. Furthermore, we investigate the overall performance of the dialogue system when confidence measures from speech recognition and natural language understanding are incorporated into the dialogue strategy. Experiments have been carried out on the TelDir database, which is a German in-house telephone directory assistance corpus, and on the Taba database, a German in-house train time scheduling task.

**Evaluators:** Prof. Dr. Hermann Ney  
Prof. Dr. Dr.-Ing. Wolfgang Minker

**Date of oral exam:** 22 September 2009
Discriminative training has become an important means for estimating model parameters in many statistical pattern recognition tasks. While standard learning methods based on the Maximum Likelihood criterion aim at optimizing model parameters only class individually, discriminative approaches benefit from taking all competing classes into account, thus leading to enhanced class separability which is often accompanied by reduced error rates and improved system performance. Motivated by learning algorithms evolved from neural networks, discriminative methods established as training methods for classification problems such as complex as automatic speech recognition. In this thesis, an extended unifying approach for a class of discriminative training criteria is suggested that, in addition to the Maximum Mutual Information (MMI) criterion and the Minimum Classification Error (MCE) criterion, also captures other criteria more recently proposed as, for example, the Minimum Word Error (MWE) criterion and the closely related Minimum Phone Error (MPE) criterion. The new approach allows for investigating a large number of different training criteria within a single framework and thus to yield consistent analytical and experimental results about their training behavior and recognition performance. This thesis also presents the first successful implementation of a large scale, lattice-based MCE training. Experiments conducted on several speech recognition corpora show that the MCE criterion yields recognition results that are similar to or even outperform the performance gains obtained with both the MWE and the MPE criterion. The parameter optimization problem is discussed for Gaussian mixture models where the covariance matrices can be subject to arbitrary tying schemes. The re-estimation equations as well as the choice of the iteration constants for controlling the convergence rate are discussed for the case that full or diagonal covariance matrices are used. In case of full covariance matrices, the problem of choosing the iteration constants in the Extended Baum (EB) algorithm is shown to result in the solution of a quadratic eigenvalue problem. Two novel methods on setting the iteration constants are proposed that provide faster convergence rates across different variance tying schemes. This thesis also suggests a novel framework that models the posterior distribution directly as a log-linear model. The direct model follows the principle of Maximum Entropy and can effectively be trained using the Generalized Iterative Scaling (GIS) algorithm. Both the direct model and its optimization via the GIS algorithm are compared analytically and experimentally with the MMI criterion and the EB algorithm. Finally, this thesis presents a novel algorithm to efficiently compute and represent the exact and unsmoothed error surface over all sentence hypotheses that are encoded in a word lattice if all parameter settings of a log-linear model are considered that lie along an arbitrary line in the parameter space. While the number of sentence hypotheses encoded in a word lattice is exponential in the lattice size, the complexity of the error surface is shown to be always linearly bounded in the number of lattice arcs. This bound is independent of the underlying error metric. Experiments were conducted on several standardized speech recognition tasks that capture different levels of difficulty, ranging from elementary digit recognition (SieTill) over read speech (Wall Street Journal and North American Business news texts) up to broadcast news transcription tasks (Hub-4). Questions pursued in this context address the effect that different variance tying schemes have on the recognition performance and to what extent increasing the model complexity affects the performance gain of the discriminative training procedure. All experiments were carried out in the extended, unifying approach for a large number of different training criteria.
Evaluators: Prof. Dr. Hermann Ney
            Prof. Dr.-Ing. Gerhard Rigoll

Date of oral exam: 9 March 2010.
Wireless Mesh Networks (WMNs) are a special kind of ad hoc networks in which most of the nodes are static. Different from ad hoc networks, a mesh network introduces a hierarchy in the network architecture and provides broadband wireless Internet access to users. Recent studies have shown that nodes in a WMN are equipped with several radio interfaces for better performance. The aggregate capacity of WMNs can be significantly improved by providing each node with several Wireless Network Interface Cards (WNICs) and by using multiple channels. This is in order to minimize interference and to provide high performance. However, multiple WNICs in each node require a channel assignment planning. The channels have to be assigned in such a way that interferences decrease and the performance increases at the same time. Since the number of available channels is limited, it is desired to dynamically allocate channels on demand.

In this research, we address the problem of assigning channels to nodes in WMNs. For this purpose, we introduce the Distributed Cluster Channel Assignment (CCA) algorithm with the objective of reducing network interferences to increase the overall performance of the network. This clustering approach is employed in order to simplify the method of solving the channel assignment problem in terms of complexity. One of the advantages of this approach is that the possibility to reuse the channels in different clusters. In addition, a dynamic channel assignment is proposed for the aforementioned problem. This approach is called Neighborhood Nodes Collaboration to Support QoS (NNCQ). NNCQ is adaptive to the load in WMNs and supports Quality of Service (QoS) routing. The algorithm adds or selects a channel for heavily loaded nodes based on the local information of the neighbor nodes. The selected or added channel minimizes interferences and ensures network connectivity.

This research also addresses the security vulnerabilities in WMNs in general and of channel assignment in particular. Security in channel assignment is an indispensable area of research in wireless networks. However, this area has been overlooked by the researchers and scientists in WMNs. The previously proposed schemes for dynamic channel assignment in WMNs have not really considered the vulnerabilities that can exist inside these networks. We have proposed an efficient, lightweight and secure assignment of channels in WMNs that mitigates the channel assignment attacks. This is inevitable in order to achieve the benefits of Multi-Radio Multi-Channel WMNs.

**Evaluators:** Prof. Dr. Otto Spaniol (RWTH Aachen University)
Prof. Dr. Petri Mähönen (RWTH Aachen University)

**Date of oral exam:** 28 May 2010
Machine translation of spoken language is a challenging task that involves several natural language processing (NLP) software modules. Human speech in one natural language has to be first automatically transcribed by a speech recognition system. Next, the transcription of the spoken utterance can be translated into another natural language by a machine translation system. In addition, it may be necessary to automatically insert sentence boundaries and punctuation marks. In recent years, a tremendous progress in improving the quality of automatic speech translation could be observed. In particular, statistical approaches to both speech recognition and machine translation have proved to be effective on a large number of translation tasks with both small and large vocabularies. Nevertheless, many unsolved problems remain. In particular, the systems involved in speech translation are often developed and optimized independently of each other. The goal of this thesis is to improve speech translation quality by enhancing the interface between various statistical NLP systems involved in the task of speech translation. The whole pipeline is considered: automatic speech recognition (ASR); automatic sentence segmentation and prediction of punctuation marks; machine translation (MT) using several systems which take either single best or multiple ASR hypotheses as input and employ different translation models; combination of the output of different MT systems. The coupling between the various components is reached through combination of model scores and/or hypotheses, development of new and modifications of existing algorithms to handle ambiguous input or to meet the constraints of the downstream components, as well as through optimization of model parameters with the aim of improving the final translation quality. The main focus of the thesis is on a tighter coupling between speech recognition and machine translation. To this end, two phrase-based MT systems based on two different statistical models are extended to process ambiguous ASR output in the form of word lattices. A novel algorithm for lattice-based translation is proposed that allows for exhaustive, but efficient phrase-level reordering in the search. Experimental results show that significant improvements in translation quality can be obtained by avoiding hard decisions in the ASR system and choosing the path in the lattice with the most likely translation according to the combination of recognition and translation model scores. The conditions under which these improvements are to be expected are identified in numerous experiments on several small and large vocabulary MT tasks. Another important part of this work is combination of multiple MT systems. Different MT systems tend to make different errors. To take advantage of this fact, a method for computing a consensus translation from the outputs of several MT systems is proposed. In this approach, a consensus translation is computed on the word level and includes a novel statistical approach for aligning and reordering the translation hypotheses so that a confusion network for weighted majority voting can be created. A consensus translation is expected to contain words and phrases on which several systems agree and which therefore have a high probability of being correct. In the application to speech translation, the goal can be to combine MT systems which translate only the single best ASR output and those systems which can translate word lattices. The proposed system combination method resulted in highly significant improvements in translation quality over the best single system on a multitude of text and speech translation tasks. Many of these improvements were obtained in official and highly competitive evaluation campaigns, in which the quality of the translations was evaluated using both automatic error measures and human judgment.
Evaluators: Prof. Dr. Hermann Ney
             Prof. Dr. Jose B. Marino

Date of oral exam: 10 December 2009. External Evaluator:.

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Combinatorial Optimization and Recognition of Graph Classes with Applications to Related Models

George B. Mertzios

We mainly investigate the structure of some classes of perfect graphs that have been widely studied, due to both their interesting structure and their numerous applications. By exploiting the structure of these graph classes, we provide solutions to some open problems on them (in both the affirmative and negative), along with some new representation models that enable the design of new efficient algorithms.

In particular, we first investigate the classes of interval and proper interval graphs, and especially, path problems on them. These classes of graphs have been extensively studied and they find many applications in several fields and disciplines such as genetics, molecular biology, scheduling, VLSI design, archaeology, and psychology, among others. Although the Hamiltonian path problem is well known to be linearly solvable on interval graphs, the complexity status of the longest path problem, which is the most natural optimization version of the Hamiltonian path problem, was an open question. We present the first polynomial algorithm for this problem with running time \( O(n^4) \). Furthermore, we introduce a matrix representation for both interval and proper interval graphs, called the Normal Interval Representation (NIR) and the Stair Normal Interval Representation (SNIR) matrix, respectively. The whole information of both NIR and SNIR matrices for a graph with \( n \) vertices can be captured in \( O(n) \) space. We illustrate the use of this succinct matrix representation (SNIR) for proper interval graphs to solve in optimal \( O(n) \) time the \( k \)-fixed-endpoint path cover problem, which is another optimization variant of the Hamiltonian path problem.

Next, we investigate the classes of tolerance and bounded tolerance graphs, which generalize in a natural way both interval and permutation graphs. This class of graphs has attracted many research efforts since its introduction by Golumbic and Monma in 1982, as it finds many important applications in bioinformatics, constrained-based temporal reasoning, resource allocation, and scheduling, among others. We present the first non-trivial intersection model for tolerance graphs, given by three-dimensional parallelepipeds. Apart of being important on its own, this new intersection model enables the design of efficient algorithms on tolerance graphs. Namely, given a tolerance graph \( G \) with \( n \) vertices, we present optimal \( O(n \log n) \) time algorithms for the minimum coloring and the maximum clique problems, as well as an improved \( O(n^2) \) time algorithm for the maximum weighted independent set problem on \( G \).

In spite of the extensive study of these classes, the recognition of both tolerance and bounded tolerance graphs have been the most fundamental open problems since their introduction. Therefore, all existing efficient algorithms assumed that the input graph is given along with a tolerance or a bounded tolerance representation, respectively. We prove that both recognition problems are NP-complete, thereby settling a long standing open question. These hardness results are surprising, since it was expected that the recognition of these graph classes is polynomial.

Finally, we investigate a scheduling model, which is closely related to the concept of interval and tolerance graphs. Namely, we deal with the scheduling of weighted jobs with release times and with equal processing time each on a single machine. In our model, the scheduling of the jobs is preemptive, i.e., the processing of a job can be interrupted by another one. Our goal is to find a schedule of the given jobs with the minimum weighted sum of completion times. The complexity status of this problem has been stated as an open question. We present
for this problem the first polynomial algorithm for the case where the number of different weights of the jobs is constant.

**Evaluators:**  Priv.-Doz. Dr. Walter Unger  
Prof. Dr. Berthold Vöcking  
Prof. Dr. Dieter Rautenbach

**Date of oral exam:** 30 November 2009
Efficient Knowledge Discovery in Subspaces of High Dimensional Databases

Emmanuel Müller

In many recent applications such as sensor network analysis, customer segmentation or gene expression analysis tremendous amount of data is gathered. As collecting and storing of data is cheap, users tend to record everything they can. Thus, in today's applications for each object one uses many attributes to provide as much information as possible. However, the valuable knowledge to be learned out of this information is hidden in subsets of the given attributes. Considering any of these subspaces one expands the search space significantly. This poses novel challenges to data mining techniques which aim at extracting this knowledge out of high dimensional databases.

This work has its focus on clustering as one of the main data mining tasks. Clustering is an established technique for grouping objects based on mutual similarity. As traditional clustering approaches are unable to detect clusters hidden in subspaces of high dimensional databases, recent subspace clustering models have been proposed that detect groups of similar objects in any subset of the given attributes. However, as the number of possible subspaces scales exponentially with the number of attributes, development of efficient techniques is crucial for knowledge discovery in subspaces of high dimensional databases.

In this work we propose both novel subspace clustering models aiming at high quality results and efficient processing schemes for these models.

We start with novel subspace cluster definitions ensuring the detection of clusters in arbitrary subspaces. We highlight the general challenges of redundancy in recent subspace clustering models and propose novel non-redundant subspace clustering definitions. In this context, our aim is to reduce result sizes to all and only novel knowledge by optimizing the overall subspace clustering result. According to these models not all subspace clusters are valuable for the final result. Based on this general observation we propose efficient processing schemes. Our novel algorithmic solutions overcome efficiency problems caused by exhaustive search of almost all subspace projections and costly database access. We select only the most promising subspace regions for efficient subspace clustering. Overall, our techniques are scalable to large and high dimensional databases providing only few but high quality subspace clusters.

Furthermore, as a general contribution to the community we provide a systematic evaluation study on a broad set of approaches. We show both efficiency and quality characteristics of major paradigms. As major aspect for sustained scientific research we ensure repeatability and comparability for all of our empirical results. Our evaluation framework is available as open source project and provides a basis for future enhancements in this research area. Thus, this thesis provides not only novel methods for efficient cluster and also outlier detection in subspaces of high dimensional data, but it is a fundamental basis for repeatable comparison of recent data mining approaches.

Evaluators: Prof. Dr. Thomas Seidl, RWTH Aachen
Prof. Dr. Myra Spiliopoulou, Otto von Guericke-Universität Magdeburg

Date of oral exam: 9 June 2010
Aspects of Wardrop Equilibria

Lars Olbrich

Global communication networks like the Internet often lack a central authority that monitors and regulates network traffic. Network users may behave selfishly according to their private interest without regard to the overall system performance. Such highly complex environments prompted a paradigm shift in computer science. Whereas traditional concepts are designed for stand-alone machines and manageable networks, a profound understanding of large-scale communication systems with strategic users requires to combine methods from theoretical computer science with game-theoretic techniques. In this thesis, we study equilibrium situations in Wardrop's traffic model. In Wardrop's model a rate of traffic between each pair of vertices of a network is modeled as network flow, i.e., traffic is allowed to split into arbitrary pieces. The resources are the network edges with latency functions quantifying the time needed to traverse an edge. The latency of an edge depends on the congestion. It increases the more flow traverses that edge. A common interpretation of the Wardrop model is that flow is controlled by an infinite number of agents each of which is responsible to route an infinitesimal amount of traffic between its origin and destination vertex. Each agent plays a pure strategy in choosing one path from its origin to its destination, where the agent's disutility is the sum of edge latencies on this path. A Wardrop equilibrium denotes a strategy profile in which all used paths between a given origin-destination pair have equal and minimal latency. Wardrop equilibria are also Nash equilibria as no agent can decrease its experienced latency by unilaterally deviating to another path. Like Nash equilibria in general, Wardrop equilibria do not optimize any global objective per se. In particular, the total latency of all agents is not minimized at Wardrop equilibrium. Addressing this issue, Roughgarden and Tardos gave tight bounds on the price of anarchy measuring the worst-possible inefficiency of equilibria with respect to the incurred latency. Further, the famous Braess's paradox states that adding edges to a network may in fact worsen the unique equilibrium. The primary goal of this thesis is to provide a deeper understanding of Wardrop equilibria. We identify several problems whose solution captures the essence of Wardrop equilibria. First, we study natural and innovative means to reduce the price of anarchy. Secondly, we analyze the stability of equilibria regarding modifications of the network environment. Finally, we propose a distributed algorithm for computing approximate equilibria. The inefficiency of equilibria motivates our first line of research. In Wardrop's model, imposing marginal cost taxes on every edge completely eliminates the inefficiency of selfish routing. We concentrate on optimal taxes for the crucial and more realistic case in which only a given subset of the edges can be taxed. We establish NP-hardness of this optimization problem in general networks. On the positive side, we provide a polynomial time algorithm for computing optimal taxes in parallel link networks with linear latency functions. We also propose a novel approach to improve the performance of selfish flow in networks by additionally routing flow, called auxiliary flow. We focus on the computational complexity for the optimal utilization of auxiliary flow and present strong inapproximability results. In particular, the minimal amount of auxiliary flow needed to induce an optimal flow as the outcome of selfish behavior cannot be approximated by any subexponential factor. Further, we study the sensitivity of Wardrop equilibria. From both the practical and the theoretical perspective it is a natural and intriguing question, how equilibria respond to slight modifications of either the network topology or the traffic flow. We show positive and negative results on the stability of flow pattern and flow characteristics at equilibrium. As it is fundamental for the above studies that selfish behavior in network routing games yields an equilibrium, it is not clear how the set of agents can attain an equilibrium in the first place. In previous work it was shown that an
infinite set of selfish agents can approach Wardrop equilibria quickly by following a simple round-based load-adaptive rerouting policy relying on very mild assumptions only. We convert this policy into an efficient, distributed algorithm for computing approximate Wardrop equilibria for a slightly different setting in which the flow is controlled by a finite number of agents only each of which aims at balancing the entire flow of one commodity. We show that an approximate equilibrium in which only a small fraction of the agents sustains latency significantly above average is reached in expected polynomial time.

**Evaluators:** Prof. Dr. Berthold Vöcking  
Prof. Dr. Ekkehard Wendler  

**Date of oral exam:** 22 February 2010
Anonymous Communication in the Age of the Internet
Andriy Panchenko

Privacy on the Internet is becoming a concern as an already significant and ever growing part of our daily activities is carried out online. While cryptography can be used to protect the integrity and confidentiality of contents of communication, everyone along the route on which a packet is traveling can still observe the addresses of the respective communication parties. This often is enough to uniquely identify persons participating in a communication. Anonymous communication is used to hide relationships between the communicating parties. These relationships as well as patterns of communication can often be as revealing as their content. Hence, anonymity is a key technology needed to retain privacy in communications.

We first present the design and evaluation of a novel lightweight anonymization protocol based purely on open standards. It significantly outperforms other existing approaches for anonymization while only slightly sacrificing the level of provided protection. We next propose and analyze an innovative approach for scalable distribution of information about anonymization networks. It has security properties similar to a centralized directory, but scales gracefully and does not require to trust any third party. We use analytical models and simulations to validate our approach. We then consider performance issues of anonymization networks. To this end we develop and evaluate path selection metrics for performance-improved onion routing. The results show that applying our methods, users can obtain a significant increase in performance without harming their anonymity. Alternatively, users can get a dramatic performance boost with little sacrifice in anonymity. We provide a practical approach to empirically analyze the strength of anonymity different methods of path selection provide in comparison to each other. Finally, we investigate several attacks against anonymous communication systems. Most notably, we present the traffic analysis attack against encrypted HTTP streams sent through different anonymizers with surprising results showing the effectiveness and ease of website identification in encrypted channels transferred through the commonly used anonymizers. Moreover, we show under which condition and how innocent-looking application layer data can be used to speed up traditional attacks that are targeted at the network layer identification of a users' peer partners. We also propose and briefly discuss different countermeasures hampering these attacks.

**Evaluators:** Prof. Dr. Otto Spaniol (RWTH Aachen University)  
Prof. Dr. Ulrike Meyer (RWTH Aachen University)  
Prof. Dr. Thomas Engel (University of LuxembourG)

**Date of oral exam:** 9 July 2010
Software support for adaptive eHome Systems

Daniel Retkowitz

eHomes are environments in which complex cross-device functionalities are provided by services. So far such functionalities are not common in home environments even though a lot of application areas exist, e.g. in the fields of security and comfort or for medical surveillance and support of elderly persons.

For the development of eHomes a lot of challenges have to be overcome. Main aspects are the consideration of mobility and dynamics in eHomes that apply to both inhabitants and devices as well as the heterogeneity of services that results from the large number of available standards.

The dissertation provides a contribution in different areas and is specific to the application area of eHomes so that a specific support of the characteristics of eHomes is achieved.

The developed approach supports the composition and adaptation of services in eHomes while considering the challenges mentioned above. The structure of a service composition can be adapted while the system is running. This way changes which result from mobility and dynamics are taken into account at runtime.

For managing context information, service dependencies, and the current composition a global graph model and a model driven design process are employed which allows an easy access of all relevant data.

An important contribution is the runtime mechanism for dynamic adapter generation based on a semantic service description allowing to overcome syntactic incompatibilities. This way the interoperability of semantically matching services in a heterogeneous environment is achieved.

Finally the development of tools which support both the service development and the runtime of the eHome system are an important part of the work.

Evaluators: Prof. Dr.-Ing. Manfred Nagl
Prof. Dr. rer. nat. Kurt Geihs
Prof. Dr. rer. nat. Bernhard Rumpe

Date of oral exam: 13 January 2010
World libraries: towards efficiently sharing large data volumes in open untrusted environments while preserving privacy

Stefan Richter

Public libraries have served an invaluable function for a long time. Yet in an age of digital media, traditional methods of publishing and distributing information become increasingly marginalized. This thesis poses the question if and how information technology can be employed to find functional alternatives, conforming to the needs of society that have been changed by information technology itself. To this end we introduce the concept of world libraries: Massively distributed systems that allow for the efficient sharing of large data volumes in open, untrusted environments while preserving privacy. To begin with, we discuss our definition as it relates to similar but different notions, then defend its utility with philosophical, economical, and legal arguments. We go on to examine anonymous file sharing systems with regard to their applicability for world libraries. We identify reasons why these systems have failed to achieve popularity so far, as well as promising principles and structures for successful world library implementations. Of these, distributed hash tables (DHTs) turn out to be particularly important. That is why we study their security and privacy properties in detail. Using both analytical models and simulation, weaknesses in earlier approaches are shown, leading us to the discovery of the first practical DHT that scalably defends against active adversaries. The fourth chapter is dedicated to general bounds on anonymity. Anonymity techniques are important tools for the preservation of privacy. We present novel attacks that endanger the anonymity provided by these tools under very general circumstances, giving analytical lower bounds to the success probability of such attacks measured in the number of adversarial observations. These results limit the applicability of anonymity techniques in world library implementations and other privacy enhancing technologies. Finally, we summarize our findings and their impact on world library design.

Evaluators: Prof. Dr. Peter Rossmanith (RWTH Aachen University)
Prof. Dr. Dr. h.c. Otto Spaniol (RWTH Aachen University)

Date of oral exam: 12 November 2009
Metric-based evaluation of software repositories for process assessment

Holger Schackmann

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 that is routinely collected in software repositories like change request management systems.

The goal of the methods and tools developed in this thesis is to make better use of the data collected in software repositories for process assessment. The core of the presented solution is the declarative language ITMS for the specification of metrics on issue tracking systems. This language facilitates a compact and precise description of metrics on a high abstraction level. The presented reference implementation of the language can be flexibly adapted to different software repositories. Moreover the metrics specified in ITMS are easily maintainable, such that an iterative procedure for development and validation of metrics can be applied.

To ease the systematic interpretation of measurement results, a meta-model for quality models will be presented. Such a quality model represents the relation between subjective quality characteristics and the measurements. These concepts are demonstrated in a quality model editor and evaluation tool. The evaluation tool supports the classification of measurement results based on empirical comparison data. This facilitates a pragmatic and realistic interpretation of the measurement results.

Applicability and scalability of the developed methods and tools are demonstrated with case studies in the context of industrial software development as well as in the context of open source software.

Evaluator: Prof. Dr. rer. nat. Horst Lichter, RWTH Aachen University
Evaluator: Prof. Dr. rer. nat. Kurt Schneider, Leibniz Universität Hannover

Date of oral exam: 6 May 2009
On the Complexity of Equilibria in Games with Succinct Representation

Alexander Skopalik

Algorithmic game theory studies computational and algorithmic questions arising from the behavior of players in strategic situations. The computational aspects of game theory became subject to closer scrutiny in the last two decades. One reason for this is certainly the advent of large scale communication networks -- most prominently the Internet. Modern technology allows to monitor, evaluate, and influence the behavior of interacting agents in large systems. One may think of many (future) applications including distribution of goods and services in auctions, allocation of resources, routing of data packages, or regulation of vehicle traffic. One of the main contributions of game theory is the ability to predict how these games will be played. The most commonly used solution concepts are equilibrium concepts that describe which strategies will be adopted by players.

One of the central challenges in algorithmic game theory is to characterize the computational complexity of such equilibria. Results in this direction yield important indicators if game-theoretic solution concepts are plausible outcomes of competitive environments in practice. Furthermore, computational complexity is of practical importance if one desires to predict or influence the outcome of a strategic situation in a large-scale environment. In this work, we answer fundamental complexity theoretic questions about several equilibrium concepts. We investigate the complexity of problems regarding the existence, recognition, and computation of Nash equilibria, strong equilibria, and sink equilibria. Probably the most prominent solution concept in (non-cooperative) game theory is the Nash equilibrium -- a strategy profile, from which no player can profitably unilaterally deviate. A refinement of Nash equilibria is the concept of strong equilibrium -- a strategy profile, from which no coalition wants to jointly deviate. We also study the dynamics that emerge when players iteratively play best responses. That is, in each time step one of the players chooses his optimal strategy given that strategies of the other players are fixed. We identify games in which this process converges to an equilibrium and study the duration of this process. For games in which the best response dynamics does not converge, the concept of sink equilibrium was proposed. Intuitively, a sink equilibrium is the set of strategy profiles on which the aforementioned best response dynamics eventually ends up without leaving this set again. A sink equilibrium is guaranteed to exist in every finite game. We study the complexity of two basic questions related to sink equilibria -- whether a given strategy profile belongs to a sink equilibrium and whether a game has a sink equilibrium that consists of more than one strategy profile.

We study these equilibrium concepts in games that have a succinct representation. Unlike games in normal form, in which the utilities or payoffs for the players are given explicitly for every possible strategy profile of the game, we consider games that have a certain underlying combinatorial structure which allows for a compact description of the game: That is, the description size of the game grows only polynomial with natural parameters such as the number of players or the number of strategies. A well studied class of succinct games are congestion games. They are an elegant model to address the effects of resource usage and congestion with strategic agents and have been used frequently to model competitive network routing scenarios. We also consider two generalizations of the class of congestion games, namely weighted and player-specific congestion games, and a variation in form of bottleneck congestion games. In addition, we study the class of anonymous games with a constant number of actions. Here, a player's payoff does not depend on the identities of others players, which allows to represent the game in polynomial space. Finally, we question the assumption of selfish players and consider a scenario in which players are partly altruistic. We study the
existence and the complexity of equilibria in congestion games with such players. Some of our results can be extended to a class of general potential games and social cost functions, and we study a number of prominent examples.

**Evaluators:** Prof. Dr. Berthold Vöcking  
Prof. Dr. Burkhard Monien

**Date of oral exam:** 31 August 2010
Energy-Efficient Design for Portable Storages on Battery-Powered Computers
Thitinan Tantidham

This thesis focuses on energy efficiency design for different storage characteristics, e.g. between an internal-storage drive of a laptop computer and a portable-storage device. It studies the characteristics of battery packs and their lifetime by observing multiple systems. Furthermore, battery discharge models have been analyzed based on system utilization in terms of CPU utilization, frequency, and voltage considering CMOS power consumption basis and using regression method analysis. The accuracy of the model depends on regression coefficients, the measurement techniques due to instability of battery discharge rate and capacity, and the profile workloads. The proposed models are flexible to be applied to different systems with the available or unavailable value of the present rate provided by the smart battery. They can be used to estimate the remaining battery lifetime by giving the system utilization information. By developing time series models like moving average techniques, they can be used to estimate the battery lifetime together with the present rate given by the smart battery.

Furthermore, the portable storage system architecture and characteristics of portable flash and magnetic disk storages are investigated. I/O workloads of portable storages can be classified into two categories: file transfer and data-access operation. A file transfer represents data backup applications or any long data transfer between a portable and a local storage drive. A data-access operation is intended for a portable application, an accessed file, or a database file, which requires a small number of I/O operations. The evaluation methodologies in the file system level for these two workloads have been observed by measurements, without description of hardware characteristics. The results reveal that flash storages provide better energy efficiency on a read file transfer in small file sizes as well as a random read access and a synchronous write access for small request sizes than disk storages do. Since flash storage has higher cost per bit than hard-disks and a finite number of erase-write cycles, they are better for allocating read-only files. In contrast, the disk storages outperform the flash storages for write operations, especially on a large file transfer, but their power consumption and performance highly depend on the spinning rate.

Finally, the framework for power-aware data allocation management between a portable and a hard disk drive in the context of energy efficiency has been proposed. This framework supports two phases of power supply: AC or battery. In an AC power phase, storage maintenance operations, such as data defragmentation, virus scanning, software installation, backup, and file allocation, should be performed. As the file access patterns, by means of read-to-write ratio, random-to-sequential ratio, and I/O request size, are dependent on the applications and dynamic upon user access behaviours, the graphs with a mixture of different access patterns support the file-allocation making-decision schemes. In a battery-power phase, in order to maintain data service continuation during laptop’s battery exhaustion, data synchronization and backup from the local storage to the portable storage is periodically scheduled upon the specified failure rate, the remaining battery capacity, the file size, and the portable storage characteristics.

**Evaluators:** Prof. Dr. Otto Spaniol (RWTH Aachen University)
Assoc. Prof. Dr. Supachai Tangwongsan, Mahidol University

**Date of oral exam:** 25 June 2010
Stochastic Multiplayer Games: Theory and Algorithms
Michael Ummels

Stochastic games provide a versatile model for reactive systems that are affected by random events. Intuitively, a play of such a game evolves by moving a token along the edges of a directed graph. Each vertex of the graph is either controlled by one of the players, or it is a stochastic vertex. Whenever the token arrives at a non-stochastic vertex, the player who controls this vertex must move the token to a successor vertex; when the token arrives at a stochastic vertex, a fixed probability distribution determines the next vertex. At the end of a play, every player receives a payoff. In our case, the possible payoffs of a single play for one player are just 0 and 1: each player either wins or loses a play. However, due to the presence of stochastic vertices, a player's expected payoff, i.e. her probability of winning, can be an arbitrary number between 0 and 1.

This dissertation develops the algorithmic theory of stochastic multiplayer games. In particular, we analyse the computational complexity of finding Nash equilibria in these games. On the conceptual side, we argue that the computational complexity of equilibria should not only be measured by the complexity of finding an arbitrary equilibrium, but also by the complexity of finding equilibria with certain payoffs. Specifically, we single out the following decision problem, which we call NE, as a yardstick for the complexity of equilibria: Given a game as well as an upper and a lower threshold on the payoff, decide whether the game has an equilibrium whose payoff lies in-between the given thresholds.

The main result of this thesis is that NE is undecidable, regardless whether one looks for an equilibrium in pure or randomised strategies. In practice, equilibria in simpler strategies are more desirable than equilibria in arbitrary pure or randomised strategies, whose behaviour may depend on the whole sequence of vertices seen so far. In particular, strategies that only depend on the current vertex, so-called stationary strategies (which might again be pure or randomised) are very appealing. We prove that, for many typical payoff functions, NE with respect to stationary strategies is both NP-hard and contained in PSPACE, whereas NE with respect to pure stationary strategies is NP-complete.

Our analysis is completed by providing algorithms for several fragments of NE. For instance, we show that NE becomes decidable when one searches for an equilibrium where the expected payoff for each player is either 0 or 1, or when one searches for an equilibrium where all but one player receive expected payoff 1. Our algorithms are accompanied by hardness proofs, which provide (almost always matching) lower bounds on the complexities of the problems we consider.

Evaluators: Prof. Dr. Erich Grädel  
Prof. Dr. Wolfgang Thomas  
Dr. Marcin Jurdzinski

Date of oral exam: 27 January 2010
Efficient and effective methods of making data accessible to its consumers -- be they humans or algorithms -- are crucial for turning ever-growing data dumps into data mines.

Of particular importance to the user are access methods that allow for query-based searching of databases. However, for vast collections of complex data objects such as digital image libraries and music databases, querying methods that necessitate an accurate, algebraic description of what the user is looking for cannot cover all search needs. For instance, a prototypical object might be known to the user and yet he or she may be unable to describe which qualities make the object prototypical. Similarity search systems based on the query-by-example paradigm can help the user in such situations by retrieving objects from the database that exhibit a high degree of similarity to the prototypical query object. For this purpose, the system must decide algorithmically which objects are to be deemed similar to each other.

After giving an introduction and reviewing preliminaries in parts I and II, the following three parts of this thesis address novel techniques regarding the efficiency, effectiveness, and applicability of a particularly intuitive and flexible class of distance measures where the distance (i.e., dissimilarity) between two objects is modeled as the minimum amount of work that is required for transforming the feature representation of one object into the feature representation of the other. As the cost of transforming a feature into another can be chosen depending on the features at hand, these transformation-based distance measures are highly adaptable and do not assume that the underlying features are perceptually independent.

Evaluators: Prof. Dr. Thomas Seidl, RWTH Aachen
Prof. Dr. Andreas Henrich, Otto-Friedrich-Universität Bamberg

Date of oral exam: 12 October 2010
**Navigation in Time-Varying Scientific Data**

Marc Wolter

Most of today's scientific data sets are time-varying because they simulate the evolution of a dynamic system or a specific phenomenon. Examples include blood flow simulations in artificial blood pumps and geothermal heat flow forecasts 100 years into the future. Simulations spanning thousands of discrete time steps are common these days; simulations with a much higher resolution exist. The navigation in the temporal dimension of this scientific data is an essential part of the data analysis process, both for investigation and integration of insight. However, for this growing problem size, two basic challenges arise: First, due to the large amount of discrete time steps, a simulation expert needs a user interface that supports all navigation tasks emerging in the analysis process (“interaction problem”). Second, generating an animation from time-varying visualizations produces an enormous computational load due to the sheer amount of discrete time steps, which impedes interactive visualization ("computation problem").

This thesis introduces taxonomies and techniques that address both problems in order to enable an interactive analysis of large, time-varying data. Because Virtual Reality (VR) has shown to be an effective tool in the analysis of complex, spatio-temporal phenomena, we focus our techniques on analysis scenarios within virtual environments.

In order to contribute to the full analysis process, a set of heterogeneous techniques including direct 3D interaction, multi-objective optimization, and parallel scheduling techniques is introduced. To build up a formal foundation, we elaborated a time model to describe time in scientific visualizations. In addition to this formal foundation, we introduce a taxonomy of common user tasks related to temporal navigation. Using these two foundations, we address the interaction problem by a novel 3D user interface that relies on direct spatial manipulation techniques for temporal navigation.

In order to ease the computational problem, we follow a two-step approach: we first subsample the available discrete data and then compute visualizations on the remaining data concurrently. In addition, we propose novel scheduling techniques that attempt to answer certain analysis tasks faster by incorporating the user's interaction into the computational process.

**Evaluators:** Prof. Dr. T. Kuhlen  
Prof. O. Staadt, Uni Rostock  
Prof. C. Bischof, PhD

**Date of oral exam:** 17 March 2010
Finite Automata on Unranked Trees: Extensions by Arithmetical and Equality Constraints
Karianto Wong

The notion of unranked trees has attracted much interest in current research, especially due to their application as formal models of XML documents. In particular, several automata and logic formalisms on unranked trees have been considered (again) in the literature, and many results that had previously been shown for the ranked-tree setting have turned out to hold for the unranked-tree setting as well. In this thesis, we study two kinds of extensions of finite automata on unranked trees, namely, the extension by arithmetical constraints and the extension by subtree-equality constraints.

In the first part of the thesis we introduce a framework of automata on unranked trees that unifies two different approaches to incorporating arithmetical constraints known from the literature, namely the global-constraint approach of Klaedtke and Rueß (2003) and the local-constraint approach of Seidl et al. (2003). We investigate the relationship between the two types of arithmetical constraints with respect to language recognition, and we show that the emptiness problem for this automaton model is decidable.

In the second part of this thesis, we introduce automata on unranked trees that are equipped with equality and disequality constraints between direct subtrees, thereby extending the corresponding automaton model in the ranked-tree setting, which was introduced by Bogaert and Tison (1982). In the definition of the automaton model, we propose using formulas of monadic second-order logic to capture the possibility of comparing unboundedly many direct subtrees for equality, a feature that arises naturally in light of the unrankedness. Our main result is that the emptiness problem for this automaton model is decidable. Based upon this result, furthermore, we introduce a logic over data words (that is, words over an infinite alphabet) for which the satisfiability problem is decidable.

Evaluators: Priv.-Doz. Dr. Christof Löding,
Prof. Dr. Dr.h.c. Wolfgang Thomas,
Prof. Dr. Thomas Schwentick

Date of oral examination: 22 June 2010
Management of dynamic business processes based on static process management systems

René Wörzberger

Process management systems support business processes. They supply process participants, i.e., clerks or software services in an insurance company, with the right data at the right point in time.

However, complex business processes cannot be entirely planned before execution. Unexpected events demand for deviations from the plan during process execution. This inherent property of business and design processes is named “dynamics”.

Common process management systems cannot properly cope with dynamics as they require a static model of the respective business process before its execution and do not allow for deviations from that model during process execution. This restriction often leads to highly complex process models, which are hard to maintain yet fail to cover every reasonable process run. If a business process deviates from the process model, the process management system is detached from the process and cannot support it any more.

This work describes a process management system which particularly supports dynamics in business processes. Instead of deviating of an executed process model, a process participant can structurally modify a process model and thereby adapt it to the unforeseen situation.

In contrast to related works, the described system has not been realized from scratch. Instead it extends the widespread commercial process management system IBM WebSphere Process Server (WPS), which is particularly used by Generali Deutschland Informatik Services GmbH (GDIS) – our partner in industry.

The following achievements have been made:

The work extends the incomplete modeling system of WPS. Process definition models, which are expressed in the standard language WS-BPEL, are complemented by process instance models that carry additional information about the current execution state of a process as well as information about the process’ history. Process knowledge models contain abstract regulations about runs of processes. This includes regulations about permitted activity sequences, activity frequencies and mutual exclusions of activities in certain processes. The process knowledge models’ syntax and semantic have been formally defined using meta models and temporal logic formulas which are applied to graph rewriting systems. A process model editor has been developed that supports editing of all three kinds of process models.

The semantics of process definition models and process instance models constitutes the formal foundation for the implementation of a dynamic layer that extends the WPS. The dynamics layer simulates dynamic changes which cannot be directly applied to the WPS. The simulation is hidden from process participants who perceive dynamic changes as real structural changes to process instance models within the process model editor.

Dynamic changes in the process model editor are restricted by technical and professional constraints. A syntax-based checking tool ensures that these constraints are not violated by some dynamic change. In contrast to related works, checks of technical and professional constraints are based on a single, holistic approach, which utilizes the Object Constraint Language (OCL). Thus, all kinds of process models can be explicitly checked for (inner) technical correctness and process definition and instance models for professional compliance with regard to some process knowledge model.
Explicit checks are complemented by checks against implicit process knowledge. Implicit process knowledge is knowledge about activity frequencies and orderings. Another checking tool leverages this implicit knowledge by revealing inconsistencies among process definition and instance models. These inconsistencies are detected in graph transitions systems which constitute the simultaneous run of two process instance or definition models.

**Evaluators:** Prof. Dr.-Ing. Manfred Nagl
Prof. Dr. Gregor Engels
Prof. Dr. rer. nat. Bernhard Rumpe

**Date of oral exam:** 11 January 2010
In the last decade, while statistical machine translation has advanced significantly, there is still much room for further improvements relating to many natural language processing tasks such as word segmentation, word alignment and parsing. Human language is composed of sequences of meaningful units. These sequences can be words, phrases, sentences or even articles serving as basic elements in communication and components for computational modeling. However, in monolingual text some sequences are not naturally separated by delimiters, and in bilingual text both sequence boundaries and their corresponding translations can be unlabeled. This work addresses solutions of sequence segmentation and alignment for statistical machine translation, including the following topics: Chinese word segmentation: Different from the explicit word segmentation in trivial approaches, I introduce integrated Chinese word segmentation, where segmentation and alignment of words are trained jointly, and the decoding is performed on the lattice composed of alternative word segmentations. I show that direct translation on Chinese characters can achieve even better translation performance than translation on Chinese words; Phrase training: Currently phrases are extracted in a heuristic way. I propose a mixture phrase pair model which is trained discriminatively allowing to combine multiple extraction processes and various resources, especially the underlying word alignment models discarded in the standard approach; Parallel sentence exploitation: Training corpus acquisition is crucial for a data-driven translation system. I propose a maximum-entropy model where document pairs are partitioned recursively into sentence pairs using 'binary segmentation' without any requirement on sentence boundary markers. Domain adaptation: A hierarchical clustering algorithm is applied to classify the training data into distinct domains. Domain specific language models and translation models are then combined to build a domain dependent system, and domain priors are estimated with a minimum error rate training. Experimental results on state-of-the-art, large-scale Chinese-English tasks show that the training speed can be increased with a factor of four and each above mentioned method leads to an enhancement of the translation quality up to 6% relatively.

**Evaluators:** Prof. Dr. Hermann Ney  
Prof. Dekai Wu

**Date of oral exam:** 10 September 2010
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
  Janina Jansen
  Christian Königs
  Jan Remmenga

- Student Workers
  René Birekoven
  Sebastian Kaufmann
  Kevin Möllering
  Behnam Nikzad
  Heiner Oßwald
  Sascha Walther
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, mailserver, and webserver. Students, faculty, and staff have free unlimited access to the computer labs operated by the RBI.

The computer labs are used in computer science courses and for student and faculty research projects. Especially for novice users a user helpdesk is offered during business hours. The labs are provided with 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

The RBI operates five labs in the basement of the E1 and E2 building. The labs are particularly intended for practical courses and student research projects. A user helpdesk is located next to the labs in both locations and provides support for lab users and installation support for students. The labs offer a total number of 52 networked computers based on Intel and AMD CPUs and running the Debian GNU/Linux operating system, additional workplaces for teamworking and laptop users, and beamers and flip charts for presentations.

Most GNU tools and many other free- and shareware tools are installed on the lab computers. 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.

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 based on Sun Fire X2100 machines and RAID-Systems with a total hard disk capacity of 30 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 customizations.
- A dedicated mailserver 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. 100BaseT and 1000BaseT twisted pair cables 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 is obtained by switching technology. Simple Ethernet HUBs with a transfer rate of 10 Mbit/s were replaced by Fast- and GigabitEthernet switches using transfer rates of 100 and 1000 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.

**Services**

**User Helpdesk and Opening Hours**

The user helpdesk is located in room 4U16a in the basement of building E1 and additionally in room 6U10a in the basement of building E2. 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:

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<tr>
<td>fri:</td>
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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 database server and software of the computer science library and the workstations for the library users. The database contains the entire stock of books and journals of the library. The RBI develops and supports dedicated software for cataloging and querying the database.
Computer Science Library
RWTH Aachen

Staff

• **Head:**
  Dipl.-Bibl. Renate Eschenbach-Thomas

• **Team:**
  Mehrnaz Alirezaie (until 30.04.10)
  Dennis Go (since 21.06.10)
  Florentine Gruhn
  Richard Hoffmann (until 30.06.10)
  Eva Onkels (since 22.02.10)
  Tatjana Repenko
  Nina Scharenberg
  René Scherer
  David Weninger (since 14.06.10)
  Birgit Willms (since 01.06.10)
  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: 8.30 a.m. – 7.30 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
What you can find in our library

• More than 36,000 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” until 2005; only selected titles after that. Additionally we have complete digital access to all LNCS-Volumes since 1997
• More than 300 journals
• Always up to date: Magazines like Aachener Nachrichten, PC Magazin, National Geographic, 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
• 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

Highlights

In the past twelve months, several events took place that marked important developments for our library:

1. New magazine: Additional room for storage was assigned to the library in September 2010: We can use the “magazine” of the underground floor that was previously used by the University library and is now free. This move will allow us to create a lot of new working places for our students, transforming the library into a center of learning (and not just reading). Also the display of books will be organized in a much more efficient and attractive way, since many old (and very rarely used) volumes can be shifted to the underground magazine. The process of reorganizing the library will take several months.

2. New books: The library of the Computing Center (Rechen- und Kommunikationszentrum) is being integrated into the stock of the Computer Science library. This transfer of books
from Seffenter Weg to Ahornstrasse extends our stock considerably and will be finished around the end of 2010.

3. New equipment: The entry door of the library was changed – it is now a glass door that offers a glimpse and invites visitors to enter. Such “atmospheric” changes are vital for realizing a pleasant learning environment. Also an improvement for the reading garden was achieved: We got a sun sail for the hotter days, and a direct water supply for the gardening tasks was installed.

4. A Party: On the social level, we took the occasion of the “German library week” in November 2009 to open our book flea market with a reception, where “Waffeln and Glühwein” were offered. Many students, assistants, and professors came by and had an enjoyable afternoon.
5. Bookcrossing: Since 2009, our library joined the “bookcrossing” scheme: On a shelf in the corridor leading to the library, everyone can take books of interest, and leave books that are given away for the “next readers”. The shelf is thus a place for book exchange – completely voluntary and without any costs.
Overview

All students of mathematics, physics and computer science at RWTH Aachen form the Fachschaft (student union) Mathematik/Physik/Informatik. Its active members work hard to represent the students' interests toward the university. We do so in the examination boards, study fee committee and other bodies with student representation.

To a big part the past year's work in the examination boards revolved around the implementation of the RWTH's new examination regulation framework. This framework is a new set of general guidelines and rules that all subjects' examination regulations at RWTH need to follow. Therefore, this required many changes to our own regulations; thankfully the combined efforts of professors and student members lead to new regulations that provide some considerable advantages for students.

This is by far not the only body in which we collaborate constructively with the department of computer science. For instance, a teaching committee was founded to further enhance the quality of our lectures.

Aside from committee work, there are numerous offers directed explicitly at the assistance of our students. More precisely, we offer daily office hours in our premises at Kármánstr., as well as office hours in the computer science building at least once a week. There, students can seek advice regarding various issues concerning their studies. Furthermore, we provide material for exam preparation, which is used extensively.

Since we pay special attention to the needs of first year students, the Fachschaft possesses a separate consortium that organizes numerous activities to familiarize new students with the daily routine at university. We especially take care of international students, for instance in the international Master programmes.

Moreover, we support our students by videotaping several lectures in agreement with the respective lecturer, organize social events (for instance a Linux installfest), and inform the students through several publications.

In addition to our explicit work for the student body, we stand up for several university-wide improvements. In collaboration with other student unions, we enable students to use the rooms in the Mogam building for study. We also try to create new working spaces for students in the computer science building. Together with the department for computer science, we encouraged the renovation of the lecture halls in the computer science building.

Another domain that we are concerned with is public relations. Hence we took part in arranging the „Studifest“; an event serving to present the RWTH Aachen to the public, and provided an information stand to introduce our fields of study to interested passers-by. And, of course, we supported the „Tag der Informatik“ organized by the computer science department.
All these activities are made possible by numerous students who work voluntarily for the student council, where the main responsibility is carried by the collective elected by the student body, namely the following students:

André Goliath
Andrius Bentkus
Anne Zilles
Anton Maier
Björn Guth
Christine Peters
Christoph Rackwitz
Daniel Schmitz
Daniel Weigand
David Dursthoff
Elisa Friebel
Elmar Borchard
Eugen Beck
Felix Kampmann
Felix Reidl
Fernando Sanchez Villaamil
Florian Führer
Frauke Schattner
Georg Chechelnizki
Gereon Kremer
Heiner Oßwald
Hendrik Siegler
Holger Weber
Hossein Shafagh
Inga Herber
Jakob Breier
Jan Bergner
Jan Bußmann
Jolande Fooken
Jonas Gallenkämper
Julian Meichsner
Katja Rübel
Lisa Markhof
Lukas Middendorf
Marcel Straub
Marlin Frickenschmidt
Martin Henze
Martin Lang
Matthias Heinrichs
Matthias Rauber
Niklas Fischer
Nina Thomas
Nobuyoshi Kuramoto
Patrick Hallen
Patrick Loemker
Richard Schubert
Sabrina Kielmann
Sebastian Wüsten
Sebastian Petzak
Sebastian Schmitz
Simon Jakubowski
Stefan Schubert
Svenja Schalthöfer
Timo Falck
Tobias Schäfer
Valentina Gerber
Volker Enzesberger

We are looking forward to another year of constructive collaboration with the computer science department!
Co-operations
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.

UMIC is funding three Endowed Professorships that belong to the Computer Science Department. These include the post of Prof. Ulrike Meyer, and those of the two junior professors James Gross and Bastian Leibe.

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.

This year saw several changes in the management personnel.

- Prof. Jarke succeeded Prof. Spaniol as Vice Speaker.
- Prof. Kobbelt succeeded Prof. Jarke as Area Coordinator ‘Mobile Applications & Services’
- Prof. Wehrle succeeded Prof. Kobbelt as Vice Area Coordinator ‘Mobile Applications & Services’

**Current Projects**

- Mobile Stream Data Mining (Information Management in Wearable and Environmental Computing)
- Context-Aware Semantic Multimedia Services for Mobile Communities
- Adaptive Self-Organizing Protocols for Wireless Mesh Networks
- Extended Communication Primitives for UMIC Applications
- Mobile and Wearable P2P Information Management in HealthNet Applications
- Organic Interfaces: Metaphor-free interaction techniques for mobile devices
- Interactive Image-Based 3D Scene Modeling for Mobile Multimedia Applications
- Energy Efficient Audio Communication and Conferencing
- Precise Localization and Pose Estimation for Mobile Devices
- A Flexible and Versatile Software Architecture for Modular Protocol Development and Cross-Layer Adaptation
- UMIC Audiovisual Communication and Conferencing
- Adaptive Error Protection for Scalable Video Coding.
The UMIC Workshop on Future Mobile Applications (UMICWS)

UMICWS was held on 26 February 2010 at the UMIC Research Centre. It was jointly organized by the Chair of Information Systems & Databases (Informatik 5) and the Fraunhofer Institute for Applied Information Technology (FIT). It provided a forum for academics and practitioners to share knowledge and experience, explore future scenarios, directions and application domains of innovative research, and discuss the challenges and solutions for developing new mobile systems and applications. Over researchers from UMIC and other institutions participated in the workshop, including some from the German Research Centre for Artificial Intelligence (DFKI), and from the Dutch Open. Prototypes were presented, and there were lively discussion on the presented research findings. The event helped establish a research community across universities and research institutions, for further knowledge sharing and long-term collaboration.

UMIC Guest Lecture

On 29 January, Dr. Russel Hainen, from the Toshiba Research Labs Europe (TRL), gave a guest lecture entitled ‘Formal Methods and Femto-cells’.

TRL in Bristol is at the forefront of research into wireless telecommunications and plays a leading role in numerous global standards and projects in the industry. Dr. Haines is TRL’s Chief Standardisation Officer. He presented an overview of the lab and some of the work that goes on there, with particular focus on the new hot topics of femto-cells and self-organising networks. He also talked about some of his recent and ongoing research in this area, including the use of formal methods in reconfigurable devices.

UMIC Distinguished Lecture

This year’s Distinguished Lecture was given on 1 February by Prof. Dr. Giovanni de Micheli of the Ecole Polytechnique Fédérale de Lausanne (EPFL). Prof. de Micheli is Director of the Institute of Electrical Engineering and of the Integrated Systems Centre at EPFL. His presentation was entitled ‘System-Level Design Technologies for Heterogeneous Embedded Systems’.

He discussed how smart micro/nano systems will foster a revolution in health and environmental management, with the final objective of improving security and quality of life. At the same time, he argued, they will create a large market of components and systems, and a renewed perspective for electronic design and manufacturing companies. Such systems will be the fundamental building blocks of wearable and ambient systems, to gather and integrate heterogeneous data in real time and to operate and communicate in a wireless and ultra low power mode. According to Prof. de Micheli, the design of these systems will be enabled by the hybridization of manufacturing technologies which enables us to attain unprecedented levels performance as well as to integrate electronic and fluidic circuits with sensors and actuators. To accomplish this ambitious goal, new technologies and architectures must be matched and tailored to the operational environment by solving novel and challenging design and optimization problems, through the creation of novel design methodologies and tools. These aspects are studied (among many others) at the Swiss federal program ‘Nano-Tera.ch’ that is lead by Prof. de Micheli.
UMIC Open Day 2010

The UMIC cluster of excellence (Ultra High-Speed Mobile Information and Communication) held its Open Day on 21 April. Students and visitors from academia, companies and the interested public attended the event (in addition to RWTH staff).

This year, the focus was on new wireless applications developed by UMIC. In addition to some more formally presented demonstrators visitors had the opportunity test the application devices in ‘real-life’ – they could walk through the building guided by an electronic handheld assistant. Here, Corona was a very popular application. It allows its users to be part of an emperor coronation ceremony. The position and viewing angle of visitors is measured by sensors. A connected sound system with earphones gives you the feeling to be in the middle of the scene.

But there was a multitude of other applications and demonstrations, ranging from exploring the physical layer of wireless transmission to the direct handling and operation of new devices. Exhibits were shown all over the building attracting a large number of visitors from different areas. The UMIC open day formed another well recognized opportunity to popularize recent research progress.

UMIC Day

The 2010 UMIC Day was held on 19 October, at RWTH’s SuperC building. The scientific programme comprised the Keynote Speech by Magnus Frodigh, on ‘Cost Efficient Mobile Broadband to Handle Exponential Traffic Growth’. Dr. Frodigh is the Director of Ericsson’s Research Wireless Access Networks Group. Four talks by Jun. Profs. associated with UMIC discussed such diverse topics as Bio-Inspired Condensation of Information (Dr. Anke Schmeink), Schedulability in OFDMA Networks (Dr. James Gross), Energy-efficient MPSoC Design (Dr. Anupam Chattopadhyay), and Mobile Vision Applications (Dr. Bastian Leibe). In addition, numerous demonstrators were on display.

The less scientific part of the event starred off with the aptly named ‘Mobile Performance’, by members of the ‘Aachener Tanzsportclub Blau-Silber’. This was followed by an informal get together with a buffet.
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Aachen Institute for Advanced Study in Computational Engineering Science (AICES)

AICES is a 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 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 20 doctoral fellows pursue their doctoral degrees funded through AICES scholarships and recruitment of additional fellows is still ongoing. Currently, five of the 18 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
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Virtual Institute – High Productivity Supercomputing (VI-HPS)

The Virtual Institute - High Productivity Supercomputing is a joint initiative of Forschungszentrum Jülich, German Research School for Simulation Sciences, RWTH Aachen University, TU Dresden, University of Tennessee, TU Munich, and University of 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. During the past year, three tuning workshops with hands-on sessions were organized in Munich, Amsterdam, and the King Abdullah University of Science and Technology in Saudi Arabia. In addition, two conference tutorials also with hands-on exercises were held at the IEEE Conference on Cluster Computing in Heraklion, Greece and at the ACM/IEEE Conference on Supercomputing (SC10) in New Orleans, USA.

More information
www.vi-hps.org

Contact
Prof. Dr. Felix Wolf
German Research School for Simulation Sciences
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52062 Aachen
Germany
e-mail: f.wolf@grs-sim.de
German Research School for Simulation Sciences

The German Research School for Simulation Sciences is a joint venture of Forschungszentrum Jülich and RWTH Aachen University, combining the specific strengths of the two founders in the fields of science, engineering, and high-performance computing in a unique synergistic way. Located in dedicated modern facilities on the Aachen and Jülich campuses and equipped with privileged access to world-class computing and visualization resources, the school is committed to research and education in the applications and methods of HPC-based computer simulation in science and engineering. As an essential element of its mission, the school provides a Master's and a doctoral program designed to train the next generation of computational scientists and engineers.

The Laboratory for Parallel Programming in Aachen led by Prof. Wolf, one of the school's four research divisions, is affiliated with the computer science department of RWTH Aachen University and specializes in tools that support simulation scientists in exploiting parallelism at massive scales.

More information

www.parallel.grs-sim.de

Contact

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e-mail: f.wolf@grs-sim.de
Bonn-Aachen International Center for Information Technology

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. B-IT aims at the internationalization of elite study programs in Applied Informatics. Prof. Matthias Jarke serves as Founding Director together with Prof. A.B. Cremers, Bonn, and Prof. K. Witt, FH Bonn-Rhein-Sieg, Prof. Otto Spaniol is Study Coordinator of the Media Informatics program (from October 2010: Prof. Jan Borchers), Dr. Jürgen Rapp its study advisor. In fall 2010, the re-accreditation audit for the B-IT Master Programs is conducted, not just with the German ASSIN agency but – for the first time in Germany – also with the European agency EQANIE.

English-Language International Master Programs

Supported by the €57 mio. B-IT Foundation and supplementary NRW-state and federal funds, BIT offers highly selective English-language master programs in Media Informatics, Life Science Informatics, and Autonomous Systems. B-IT master programs include a significant share of research lab courses in the participating Fraunhofer institutes of Applied Information Technology FIT, Intelligent Analysis and Information Systems IAIS, and Scientific Computing and Algorithms SCAI. A second goal of B-IT is a kind of honor class support for the undergraduate computer science curricula at Bonn and RWTH Aachen University.

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. In 2010, the new Erasmus-Mundus scholarship program India4EU strengthened the cooperation with top Indian universities, such as IIT Delhi. B-IT students have been unusually successful in obtaining attractive competitive scholarships. The 180 B-IT students come from over 40 countries.

All study programs are operating at full capacity. The Media Informatics program managed by RWTH Aachen accepts about 30-35 students annually after a strict pre-selection which leads to a success rate of student close to 90%. The placement record of B-IT remains excellent. Master graduates have been accepted as doctoral candidates in many leading universities and research institutes worldwide, including places such as the ETH Zürich, the...
Universities of Cambridge and Oxford as well as Stanford. Meanwhile some of the early B-IT graduates have already finished their doctoral degrees.

B-IT Research School

Since late 2008, the B-IT Research School offers doctoral training in eight areas of applied information technology and its formal fundamentals. Key training concepts include:

• the teambuilding within research areas across the organizational boundaries of the B-IT partners, to achieve a critical mass similar to the large top universities worldwide;
• a system of compact specialized courses for each area enabling not just holders of doctoral scholarships but also “normal” research assistants with heavy teaching and project duties to participate; in 2009, half a dozen initial compact courses, plus several contributions to larger summer schools, were organized;
• stress on quality, diversity, and international recruiting through a selective scholarship system, incentive travel funds, and personalized research training plans commensurate with the funding situation and other individual aspects and interests.

In three rounds of applications from October 2008 to April 2010, a total of 29 doctoral scholarships to candidates from 11 countries were awarded from over 500 applications all over the world. Six of the scholars are graduates from the B-IT master programs.

Welcome party of the new B-IT students in September 2010
Graduiertenkollegs – Research Training Groups

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” (short: GK) 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 RWTH Aachen University there are two GKs in the area of computer science:

- GRK 643 “Software for Mobile Communication Systems”, speaker Prof. Spaniol
- GRK 1298 “AlgoSyn”, speaker Prof. Thomas.

Helen Bolke-Hermanns links the two GRKs together: she is responsible for management and coordination.

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 grant holders 2010 are the following:

• Dipl.-Inform. Kai Dominik Bollue, Institute of Automatic Control, Prof. Dr. Abel
• Namit Chaturveri, M.Sc, Chair Informatik 7, Prof. Dr. Thomas
• Dipl.-Inform. Diana Fischer, Chair Informatik 7 Lab, Prof. Dr. Grädel
• Dipl.-Inform. Dominique Gückel, Chair Informatik 11, Prof. Dr. Kowalewski
• Dipl.-Inform. Paul Hänsch, Chair Informatik 11, Prof. Dr. Kowalewski
• Dipl.-Inform. Michael Holtmann, Chair Informatik 7, Prof. Dr. Thomas
• Dipl.-Inform. Ulrich Loup, Hybrid Systems Group, Prof. Dr. Abraham
• Alexandru Mereacre, M.Sc., Chair Informatik 2, Prof. Dr. Katoen
• Dipl.-Inform. Stefan Schulz, Chair Informatik 7, Prof. Dr. Thomas
• Dipl.-Inform. Michaela Slaats, Chair Informatik 7, Prof. Dr. Thomas
• Dipl.-Inform. Jacob Spönemann, Institute of Transport Science and Chair of Railway Engineering and Transport Economics, Prof. Dr. Wendler
• Dipl.-Inform. Oliver Ringert, Chair Informatik 3, Prof. Dr. Rumpe
• Dipl.-Inform. Sabrina von Styp-Rekowski, Chair Informatik 2, Prof. Dr. Katoen
• Dipl.-Inform. Melanie Winkler, Chair Informatik 1, Prof. Dr. Vöcking

Dr. Lars Olbrich enriched the “Graduiertenkolleg” with his research work as postdoc.
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.

For a full version of the proposal (in German language) please see: http://www-i4.informatik.rwth-aachen.de/Kolleg

After ten years of successful work with 45 scholarship holders and 10 supervisors the Graduiertenkolleg “Software for mobile Communication Systems” is now in its final stage. The grant holders 2010 were:

- M. Sc. Vaishak Belle, Chair Informatik 4 Lab, Prof. Dr. Lakemeyer
- M. Sc. Zeeshan Ahmad, Chair Theoretische Informationstechnik, Prof. Dr. Mathar
- Dipl.-Inform. Arnd Hannemann, Chair Informatik 4, Prof. Dr. Spaniol
- Dipl.-Inform. Tobias Heer, Chair Informatik 4 Lab, Prof. Dr. Wehrle
- Dipl.-Inform. Ulrich Meis, Chair Informatik 4, Prof. Dr. Spaniol
- Dipl.-Inform. Cem Mengi, Chair Informatik 3, Prof. Dr. Nagl
- M. Sc. Andriy Pancheko, Chair Informatik 4, Prof. Dr. Spaniol
- M. Sc. Manh Cuong Pham, Chair Informatik 5, Prof. Dr. Jarke
- Dipl.-Inform. Torsten Sattler, Chair Informatik 8, Prof. Dr. Kobbelt
- Dipl.-Inform. Benjamin Schleinzer, Chair Informatik 4, Prof. Dr. Spaniol
- Dipl.-Inform. Florian Schmidt, Chair Informatik 4 Lab, Prof. Dr. Wehrle
- Dipl.-Inform. Elias Weingärtner, Chair Informatik 4 Lab, Prof. Dr. Wehrle
- M. SC. Xiang Xu, Chair Theoretische Informationstechnik, Prof. Dr. Mathar
A very special event took place in SuperC 27. – 28. September 2010 where representatives of DFG, former members of Graduiertenkolleg “Software for mobile Communication Systems” and members of the predecessor GK “Computer Science and Technology” got together for 2—day-workshop and exchange of experience.

20 years Graduiertenkolleg: The DFG published a special brochure with the history of this successful type of funding.

Prof. Dr. Spaniol was asked to give an interview about his experience of the last years, read more about his interesting explanations under:

The German University of Technology in Oman (GUtech) is a new privately funded University in Muscat, Oman, set up since 2007 with assistance and quality assurance by RWTH Aachen University. Former RWTH Rector Prof. Burkhart Rauhut serves as Founding Rector of GUtech. GUtech currently offers four Bachelor of Science programs in fields of particular strategic interest to the Sultanate of Oman, an Arabic country with significant oil reserves, one of the most interesting geologies in the world, a historically important geo-strategic location at the straits of Hormuz with corresponding seafaring traditions and logistical needs, and a thriving high-class tourism development. All four Bachelor programs – applied geosciences, urban planning and architecture, sustainable tourism and regional development, and IT for Engineering and Management – have been defined by adapting corresponding programs from RWTH Aachen to regional needs and preconditions; a Foundation Year and stiff entrance exams ensure quality of student intake. After successful and unconditional accreditation by the AQUIN agency in early 2009, they are the first accredited bachelor programs in the country, two of them also being the only ones of their kind on the Arabian peninsula.

In cooperation with the Business Informatics group (Prof. Michael Bastian), the Informatics department at RWTH Aachen – coordinated by Prof. Matthias Jarke as Inaugural Dean -- has assisted the set-up of the bachelor program in Information Technology for Engineering and Management in several ways. The basic course structure follows the Bachelor of Informatics at RWTH Aachen University. The minor field of study has been fixed to be Business Administration, and specialization courses can be linked to locally important application domains such as the oil, gas, and minerals sector or the field of logistics. Moreover, the program is expanded by significant course work on language and cultural skills, because from the beginning, all courses are taught in English (rather than the local Arabic) and the student population needs to understand both the local culture and the Western one. This was one of the reasons why the bachelor is scheduled for four years rather than three.

Besides taking responsibility for the curriculum development in cooperation with the GUtech university management, RWTH faculty and senior researchers also taught some of the first-year courses in Muscat and will continue to offer fly-in compact courses in specialized fields. In 2009-2010, this concerned e.g. Prof. Dr. Manfred Nagl (Informatik 3). GUtech IT students in good standing are also offered the opportunity to visit RWTH Aachen at least twice in their study program, in the first year to get acquainted with the technology and culture, at the end of the third year for a lab course internship in one of the Informatics research groups.

Strategically even more important, several faculty from the department participated in the GUtech search committees for permanent faculty at GUtech. In 2008, three excellent assistant and associate professors were hired:

- Nahla Barakat, with industry experience from Philips, long teaching experience in the region, and a Ph.D. in data mining from the University of Queensland, Australia
• Lucia Cloth, a former RWTH student who obtained her doctorate and held a postdoc position at the University of Twente, Netherlands;

• Bernhard Heim, researcher at the Max-Planck institute of Mathematics in Bonn and former IT manager at Deutsche Bahn, with a doctorate from Heidelberg and the habilitation from the University of Mannheim.

Two further hiring processes are underway.

The initial IT student population has started very small in 2008, with only four students, but has been growing to 6 in 2009, and 12 students in 2010. 17 students have joined the foundation year for a bachelor start in 2011. Omani companies showed themselves impressed by the quality of the early students who by now have been performed their first internships.

The quality management support offered by RWTH Aachen University, and the exchange visits, are funded by a major grant of the German international exchange service DAAD. In October 2009, an external review of this project characterized it as outstanding within the set of currently forty similar programs DAAD is supporting worldwide.

In fall of 2010, a further major step was accomplished by moving acquiring an additional GUtech building near Muscat Airport.
Overview

TGGS is a joint institution established by RWTH Aachen University and her Thai partner KMUTNB (King Mon kut’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

TGGS offers both MSc and PhD programmes.

The International TGGS M.Sc. Programmes originate from the international M.Sc. courses (taught in English) offered at RWTH Aachen University. They are similar in content, but adapted to the Thai educational system in terms of credits and in the number of modules. The TGGS courses have been developed to better meet the industrial needs in Thailand through practical training in industry (mandatory project-oriented internships and industry-oriented Master theses). The direct participation of RWTH professors, contributing by block lectures in Bangkok, and by building up industry links, makes sure that the teaching also contains elements of advanced engineering practice and research. For outstanding students, opportunities are provided to experience an internship in Germany and to write the Master thesis in Germany as well, under the supervision of RWTH professors. All TGGS courses include a module of ‘Management and Economics for Engineers’.

The TGGS Ph.D. Programmes provide opportunities for Ph.D. work under the joint supervision of a German and Thai supervisor (German RWTH professor with a Thai professor acting as the co-supervisor). Part of this programme is a one-year research stay at RWTH Aachen
University. For high-level Ph.D. work, to a large extent conducted on industry-oriented research projects, RWTH Aachen provides excellent boundary conditions in terms of experienced research supervisors, advanced technology equipment and project funding. The Ph.D. degree obtained at TGGS is a Thai degree within the framework of CHE, the Commission of Higher Education.

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)
Forum Information Technology at RWTH Aachen University

The Interdisciplinary Forums at RWTH Aachen University are a medium and a platform for the development of interdisciplinary research and education at RWTH Aachen University. They serve as a communication network and constitute a marketplace for creative ideas. At the same time, they are a catalyst for highly interdisciplinary topics which can only be deduced in an interdisciplinary cooperation and with a transdisciplinary perspective.

The Forum Information Technology aims to be a nationally and internationally visible marketplace for the intermediation of the competences of the RWTH Aachen University institutes in the fields of Information Science, Information Technology, Computational Engineering and the respective fields of application.

Mission

The Forum Information Technology connects research and education in the fields of Information Science/Information Technology/Computational Engineering at RWTH Aachen University and pursues the goal of initiating interdisciplinary projects. It serves as a partner- and project marketplace for its members. Moreover, it supports the exchange of information and ideas, initiates cooperations and joint projects and establishes an appropriate public image.

The forum promotes the collaboration of its members with external research and development institutions, government agencies, organizations, politics and economy (especially REGINA e.V.). It plays a role in political consulting, in the development of research programs of the European Union and in the advancement of the university education.

By means of the realization of information days for students, student advisory, lecture series and innovative teaching and learning techniques (e.g. eLearning), concerns of recent and future students will be considered individually and exceptionally.

Organization

Board

- Prof. Dr.rer.nat. Otto Spaniol (Chairman of the board until Juli 2nd 2010)
- Prof. Dr.rer.nat. Bernhard Rumpe (Chairman of the board since Juli 3rd 2010)
- Prof. Dr.-Ing. Gerd Ascheid
- Prof. Marek Behr PhD (Member since April 19th 2010)
- Prof. Dr.rer.nat. Sabina Jeschke (Member since April 19th 2010)
- Prof. Dr.rer.nat Torsten Kuhlen (Member since April 19th 2010)
- Prof. Dr.-Ing. Jens-Rainer Ohm
- Prof. Dr. rer. pol. Kai Reimers
- Prof. Dr.phil. Martina Ziefle (Member since April 19th 2010)
- Prof. Dr.-Ing. Dipl.-Wirt.Ing. Thomas Gries, University Representative of the Interdisciplinary Forums
- Prof. Dr.med. Rolf Rossaint, Vice Rector for Structural Development and Research
- Prof. Dr.-Ing. Dirk Abel (Member until April 19th 2010)
- Prof. Dr.-Ing. Christian Brecher (Member until April 19th 2010)
Due to the fact that Otto Spaniol is professor emeritus since mid 2010 a replacement in his function as chairman of the Forum Information Technology became necessary. This position has been exercised by Prof. Spaniol for many years with grand dedication and success.

First from 1988 onwards in his function as foundation chairman and then after the renewed acceptance of the chairman function from 2004 onwards, Prof. Spaniol has greatly contributed to the establishment of computer science as a technical discipline due to his dedicated commitment. Moreover, he has promoted the focus on the interdisciplinary character of Informatics, Information Technology and Computational Engineering. That way, and under his direction, the Forum Information Technology has developed exemplarily, embedded in RWTH Aachen University and also in a regional as well as transregional network. At this point, we would like to take the opportunity to thank Prof. Spaniol cordially for his work and express our great acknowledgement.

On the decision of the forum’s board, Prof. Bernhard Rumpe is the new speaker of the Forum Information Technology from July 3rd 2010 onwards.
Since January 2009, Bernhard Rumpe is professor for Software Engineering at RWTH Aachen University (Chair for Informatics 3) after having been professor at TU Braunschweig, scientist at TU Munich and after accomplishing research residences at the Institute for Software Integrated Systems (ISIS) in Vanderbilt/USA and at the French National Institute for Research in Computer Science and Control (INRIA)/Institut de Recherche en Informatique et Systèmes Aléatoires (IRISA) in Rennes/France. His research foci are on the development and industrial implementation of technologies, methods and tools necessary for the efficient and sustainable design software in the required quality. Since nowadays software is mostly embedded in an overall system, the gearing of software development and complex product engineering processes and product lines play an important role. To this end, innovative techniques of software architecture, requirements analysis and modeling are adopted.

On the occasion of the celebratory colloquium of Prof. Spaniol on September 27\textsuperscript{th} 2010, the Forum Information Technology had the opportunity to thank the former chairman for his accomplishments in interdisciplinary networking and for development of the forum. As reminiscence, his successor as chairman Bernhard Rumpe and the Manager of the forum Gero Bornefeld presented him – in line with the general topic of the forum – with a binary wall clock.

**Lecture Series Forum Information Technology**

The periodic lecture series of the Forum Information Technology addresses current topics of high interest in the RWTH community and attracts highly reputed scientists to come to Aachen to give a lecture which regularly takes place in the SuperC Building of RWTH Aachen University. More information on the single lectures can be found on the web site of the Forum [www.fi.rwth-aachen.de](http://www.fi.rwth-aachen.de) ("Interdisziplinäre Lehre").
**Winter Semester 2009/2010**

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<tr>
<th>Topic</th>
<th>Speaker/Institution</th>
<th>Date</th>
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<tr>
<td>Supercomputing in Jülich, Germany and Europe</td>
<td>Prof. Dr. Dr. Thomas Lippert, Head of Jülich Supercomputing Centre, Forschungszentrum Jülich</td>
<td>08.02.2010</td>
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<tr>
<td>System-Level Design Technologies for Heterogeneous Embedded Systems</td>
<td>Prof. Dr. Giovanni de Micheli, Integrated Systems Laboratory, EPF Lausanne</td>
<td>01.02.2010</td>
</tr>
<tr>
<td>Innovations in the design of user interfaces</td>
<td>Peter Möckel, Head of Telekom Laboratories</td>
<td>18.01.2010</td>
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<tr>
<td>Web 2.0 – from buzzword to all-embracing internet reality</td>
<td>Prof. Dr. Gottfried Vossen, Department of Information Systems, University of Münster</td>
<td>30.09.2009</td>
</tr>
<tr>
<td>The future of mobility in metropolises</td>
<td>Prof. Dr. Andreas Knie, Innovation Centre for Mobility and Societal Change (InnoZ)</td>
<td>11.09.2009</td>
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**Summer Semester 2010**

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<th>Topic</th>
<th>Speaker/Institution</th>
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<tr>
<td>New perspectives in video encoding</td>
<td>Prof. Dr.-Ing. Jens-Rainer Ohm, Communication Engineering, RWTH Aachen University</td>
<td>12.07.2010</td>
</tr>
<tr>
<td>Serious Gaming</td>
<td>Prof. Dr. Maic Masuch, Entertainment Computing Group, University Duisburg-Essen</td>
<td>07.06.2010</td>
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<tr>
<td>The Collective Mind Method – project success by metrification of soft skills</td>
<td>Dr. Alfred Oswald, Institute for Social Technologies, Aachen</td>
<td>03.05.2010</td>
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**Scientific Speed Dating on Simulation**

One of the forums’ major tasks is to bring researchers from different professional backgrounds together, to establish a dialogue and therewith foster impulses for interdisciplinary cooperations. These networks have to grow and expand over a long period in order to truly overcome discipline and communication boundaries and to work together effectively. It is a logical consequence that it can only be of great advantage to start this process already at the beginning of the scientific career.

This networking process is fostered by the forums and the innovative format Scientific Speed Dating, which has been carried out for the first time in December 2009 by the Forum Information Technology. At the forums’ invitation, 50 young researchers and scientists of RWTH Aachen University came together, all of them dealing with the topic of simulation in
the framework of their respective projects or dissertations. The event was supported by facilities of RWTH Aachen University which face this topic institutionally, as for example the graduate school AICES. Due to the participants’ positive feedback, further events of this kind shall follow.

In the Scientific Speed Dating, participants are brought together in four phases: In the plenum, the participants present themselves for about one and a half minutes, using a presentation slide with brief references to their respective institute, subject-specific background and current research topic. The next phase is the vis-à-vis situation indicated by the title of the event (see picture). Here, it is useful to create a link to the first presentation and to mutually explain current activities, results, problems etc. As a by-product, common questions and issues shall be filtered out and collected on a notice board. This process has to be realized within five minutes, since after that the conversational partner changes. The conclusion to the official part consists of the discussion of key issues from the vis-à-vis phase in small groups. Finally, phase four is designed as an informal get-together.

**Cooperation with the Gesellschaft für Informatik e.V. (GI)**

Based on a new cooperation between the Forum Information Technology and the Gesellschaft für Informatik (GI), since mid 2009 the manager of the forum is at the same time speaker of the Regional Group Aachen of the GI. With this he is integrated in the Germany-wide network of the GI Regional Groups. In the course of the cooperation the members of the GI Regional Group Aachen will be invited to public activities of the forum (e.g. Lecture Series). This will improve visibility of the forum and also attract more people to the forum’s events.

**Virtual Reality Center Aachen**

**Ten years VRCA**

When in the late 90’s single RWTH institutes started to work on or with Virtual Reality, it very quickly became clear that high quality research on VR technology and methods requires teamwork within and across disciplines. Also, in order to develop VR solutions that should have the potential to serve as a powerful tool in the scientists’ work, a close collaboration between VR researchers and academic as well as industrial users is mandatory.

As a consequence, in the year 2000, RWTH Aachen University founded the Virtual Reality Center Aachen (VRCA) as an interdisciplinary, non-commercial competence network in order to bundle, coordinate, and expand the Virtual and Augmented Reality (VR/AR) activities at the University and in the region of Aachen. Currently, more than 40 RWTH institutes from 6 faculties as well as 19 companies and external research institutions are organized in the VRCA.

Not only the large number of VRCA members, but in particular the large number of projects presented in this progress report emphasize the research vitality and demonstrate the strategic importance of VR/AR in sciences. Joint projects that cross disciplinary boundaries create an atmosphere where complementary skills supplement each other in an ideal fashion.
This broad interdisciplinary character was instrumental in making the VRCA successful, both at a local and international scale. For example, in the context of the excellence initiative of the German federal and state governments, Virtual Reality plays a vital role in two RWTH Clusters of Excellence, the RWTH Graduate School “Aachen Institute for Advanced Study in Computational Engineering Science“ (AICES), where a high-resolution PowerWall has been installed to empower young researchers, as well as the Jülich Aachen Research Alliance (JARA), where an immersive visualization network (ivNET) aims to create a new quality of collaboration between researchers at RWTH and the Forschungszentrum Jülich.

The installation of a high quality CAVE display in the new building of the Center for Computing and Communication will be the next highlight, which will allow for an immersive and precise visualization of extremely complex simulations.

Prof. Christian Bischof (Speaker VRCA), Prof. Torsten Kuhlen (CEO VRCA)

**VRCA – Progress Report Vol. 4**

In May 2009 the fourth volume of the VRCA Progress Report was published. This progress report impressively demonstrates the importance of advanced visualization, Virtual and Augmented Reality for a Technical University like the RWTH - both as a research area as well as a tool in science and engineering.

It is most notable that Virtual and Augmented Reality are not just topics located in a single faculty. Instead, with Computer Science, Architecture, Civil Engineering, Mechanical Engineering, Georesources and Materials Engineering, Electrical Engineering and Information Technology, Arts and Humanities, and finally Medicine, eight out of the nine RWTH faculties contribute significantly with research or teaching activities to this fascinating field. As such, the success story of the VRCA is also an achievement of the Forum Information Technology, which promoted and supported the VRCA activities from the very beginning. Only through close interdisciplinary collaboration between RWTH institutes and beyond, the remarkable results of the more than 50 VRCA research projects and activities documented in this progress report could be achieved.

Download of the progress report: [www.fi.rwth-aachen.de](http://www.fi.rwth-aachen.de) ("Publikationen")

**Special Interest Group eHealth**

With the Special Interest Group (SIG) „eHealth“ the Forum Information Technology in cooperation with the Forum Life Sciences and HumTec eHealth program has launched an initiative in October 2009 that shall serve as open platform for the topic eHealth an RWTH Aachen University. About 50 scientists expressed their interest in joining this platform. Two workshops were held to get to know each other’s work and identify possible topics to work on together. The participants of the workshops pointed out that this alone was of high value. Many initiatives did not know about each other beforehand and learned that they can benefit from each other. The next step for the group is to synchronize their work with the university-wide initiative “Medicine & Technology” which has started afterwards but has a much broader scale.

**Special Interest Group Robotics**

In September 2010 the Forum Information Technology started a Special Interest Group (SIG) on the highly interdisciplinary topic Robotics. Until now about 35 scientists have joined the group and a kick-off workshop has taken place. Starting point for the workshop was a short presentation of all participants to get to know each other’s research. As a result the participants worked out a matrix of roboter concepts and roboter applications and filled it with
possible research topics. This matrix will be used as a basis for search of possible joint projects in the next workshop taking place in November 2010.

**Study: Conquering Complexity through Modeling and Simulation**

From 2007 to 2009, the Interdisciplinary Forums functioned as associates in the so-called Foresight Process of the Federal Ministry of Education and Research (BMBF) which was coordinated by the Fraunhofer Institute for Systems and Innovation Research (ISI). The results are now available online at [www.bmbf-foresight.de](http://www.bmbf-foresight.de). The study “Conquering Complexity through Modeling and Simulation”, conducted by Prof. Marek Behr (Chair for Computational Analysis of Technical Systems) and Prof. Christian Bischof (Chair for Scientific Computing), represents one important part of Aachen’s contribution to the Foresight Process. The study’s most important results will be presented here, and the entire text of the study can be downloaded at [www.forenaachen.de](http://www.forenaachen.de) under “Publikationen” (publications).

Modeling and simulation supported by high-performance computers has become a cornerstone of engineering and scientific practice. Computational Engineering plays a central role in process and product design, production planning, and operations. Computational science has joined the analytical and experimental approaches as a third pillar of scientific inquiry. The potential of this new field is far from being fully exploited; many challenges arise as wider range of scales is considered, models are sought for increasing range of physical problems, and uncertainties and statistical aspects are taken into account. Most importantly, simulation is often used as a drop-in replacement for experiments; its most promising aspect – its ability to consider any part of the system as target of analysis, including factors that are invariable in a typical experiment – is seldom used. Another challenge arises as the computing architectures diversify and evolve towards harder-to-use multi-core multi-component systems, affecting greatly algorithm design and even model selection.

**Evolving Paths**

In order to better tackle the challenges in modeling and simulation, research and education structures need to be, and are being adapted worldwide. As an example of a large public university significantly adapting its organization, RWTH Aachen University may be considered (cp. the other articles in this newsletter); the changes over the last decade – including new research centers and graduate schools, alliance with a neighboring federal research center, investment in computational and visualization resources, and multiple new study programs tailored to particular audiences – can be described as extensive.

The modeling and simulation discipline is likely to evolve in the coming decades to take advantage of its inherent ability to rigorously guide the tasks that have been so far the sole domain of human intuition – model discovery and discrimination to account for heretofore not quantified physical phenomena; pinpointing of scale interaction mechanisms; and virtual design including identification of optimal parameters which determine an ideal product or an ideal process. Independently, progress in a number of “grand challenge” problems can be expected as more and more sophisticated computational methods are applied more extensively. These problems range from climate change, to advanced materials design and nanotechnology, to global energy supply, to diverse fields of inquiry in the life sciences, such as aging or human cardiovascular system.

**Findings and Recommendations**

Though widely accepted as third pillar of scientific inquiry, Computational Science is in a great state of flux, on one hand driven by advances in computing power and modeling
expressiveness, on the other hand hampered by traditional scientific organizational models that are not geared towards nurturing multi-disciplinary research efforts. But one thing is clear: Only if advances occur in modeling (the traditional responsibility of a domain scientist), numerics (the traditional realm of applied mathematics) and software engineering (a core field of computer science), significant progress will be realized.

With that as a reminder, we will now touch upon issues that we consider crucial if simulation science is to fully realize its potential.

Secondary Education
Mathematics and experiments are well-established in secondary education, while simulation plays virtually no role at all. This is largely due to the fact that teachers, at least in Germany, are educated along classical disciplinary lines, and have no training in the use of “virtual laboratories”. While real lab-time is scarce, students could access virtual laboratories at their will, and, through suitable collaborative paradigms, easily collaborate with their fellow students. Given the computational power easily and cheaply available in compute clouds, students thus could do experiments that would really engage them. However, appropriate pedagogical concepts for the use of such virtual environments must become part of educational curricula.

University Education
Curricula in computational engineering and science are typically composed of existing course offerings from established degree programs, which were designed with a different clientele in mind. At the moment, such curricula seem to attract very bright students who relish the resulting challenge. However, it is clear that programs which are less of a hodge-podge and more of a coherent whole must be provided in order to successfully educate more students, and to make sure that the participating departments benefit from the interdisciplinary knowledge transfer inherent in such curricula.

Career Paths
Collaborations outside one’s own discipline often are a challenge, both intellectually as well as organizationally, as different fields have different canonical ways of looking at the world, and also different cultures. Universities and funding agencies need to recognize the merits of multi-disciplinary collaboration and actively promote it.

Modeling
Currently, models based on differential equations are at the basis of most simulations. However, new modeling paradigms, perhaps inherently accounting for uncertainty, or derived from large data sets via interpolation, classification or machine-learning approaches, are emerging. This is particularly true of traditionally non-numerical, empirically driven fields such as the humanities.

New Fields
Natural science and engineering have been the main drivers behind computational approaches, but other fields are entering the picture. In the social sciences human behavior is more and more not speculated upon or inferred from small samples, but predicted based on large amounts of “digital traces” we all leave behind.

Visual Interaction
The understanding of large data sets, grasping the interaction of different scales, or the comparison of different models or data sets are all tasks that enormously benefit from visual
representation or, even better, real-time immersive interaction in a virtual environment. These approaches need to be pushed forward to fully employ human capabilities of understanding.

**Data**

Tremendous amounts of data are gathered through sensor networks, or computed via supercomputers. However, the organizational (not technical) challenges of caring for such data are not well understood. Data maintenance, data catalogues, and data warehouses are all issues that are of enormous importance in the long term.

**Computers**

The good news is that computing power will be available. Exascale computers are already being planned, general purpose GPUs will act as desk-side vector supercomputers, and the cloud promises virtually unlimited computing power for those willing to foot the bill. As energy efficiency becomes more of an issue for computer vendors, so will the cost of data movement dominate computational efficiency – computation speed alone increasingly will not matter much.

**Software**

This is the bad news. The landscape of computing will continue to diversify, not only at the high end but also at the low end. As a result, there will be an interplay between which algorithms run well on which platform, and software engineering techniques will play an even larger enabling role in turning ideas into tools. In this context, application scientists need to realize that software is more than a program. A program “runs”, but software is validated, extensible, maintainable, and documented, to name just a few attributes. In this context, we foresee a significant impact of new programming paradigms, such as Microsoft’s forthcoming entry into the technical computing market with the Matlab-like M# language and (unusual for technical computing products) its complete software ecosystem.

To venture a guess as to what extent these issues will be addressed in the next decade seems premature. However, it is fair to say that a concerted approach is needed, addressing all aforementioned facets rather than individual challenges.

*Download of the study: [www.fi.rwth-aachen.de](http://www.fi.rwth-aachen.de) (→"Publikationen")*

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REGINA e.V. – Competence Network
Information Technology Aachen

• over 100 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) and CSB (application domain-specific software for the food industry).

**Board**

- Dr. H. Röllinger, SOPTIM AG (chairman)
- Dipl.-Math. R. Geisen Alabon GmbH (chairman)
- Dipl.-Ing. M. Wallrath, Ascom Deutschland GmbH (chairman)
- Dr. R. Oertel, Head of Department 4.0., Technology Transfer & Research Funding, RWTH Aachen
- Dipl.-Ing. M. Bayer, Chamber of Industry and Commerce Aachen
- Dr.-Ing. J. Mansfeld, DSA GmbH (former chairman)
- Prof. Dr. St. Kowalewski, Chair of CS 11, Software for embedded systems, RWTH Aachen

**Activities in 2009-2010**

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 2009/2010:

- Management Get-togethers: Professional Software Development by the Use of UML, Amendment to the German Data Protection Law, Online Marketing B2C-B2B, iPhone Apps, Cloud Computing- hype or chance?, Specialised Personnel Shortage - How to Deal with this Problem?
- Round-table Discussion: Flexible Work: Every day, Every time, Everyplace
• Coaching by experienced managers & researchers
• Recruiting Support
• Social Events

**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.

**Career**

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.

**REGINA - Career Portal: www.karriere.ac**
Karriere.ac is an internet-based job placement exchange for high tech jobs in the Aachen region. REGINA member companies run a chance to offer their vacancies costless.

**Career by Click! →**
1 Application – 100 Recipients
Applicants send their applications to REGINA and we forward them to our member-companies. In this way applicants reach with only one application more than 100 recipients.

**Night of the Companies**
If you have finished university and are looking for a new job then catch the bus and visit your prospect employers. Once a year, in November, we organize for students and graduates the so called Night of the Companies. There are 5 bus lines which carry the participants to companies in the region of Aachen and give them the opportunity to get to know interesting job offers. Further information: www.nachtdunternehmen.de

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The mission of the Fraunhofer Institute for Applied Information Technology FIT, located in Birlinghoven Castle, Sankt Augustin, and at RWTH Aachen University, 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. About 130 researchers, technical and administrative personal, and student assistants work in the institute. Third-party funding in 2009 was about €6.4 mio.

Since January 2010, FIT Executive Director Prof. Dr. Matthias Jarke also serves as Chairman of the ICT Group and Member of the Presidency of the Fraunhofer Society. With ca. 4,100 employees and a budget of over € 210 mio. across its 17 member institutes (about 70% externally funded), the Fraunhofer ICT Group is the largest European research organization in the field of Information and Communication Technologies. In addition to Prof. Jarke, three of the four department leaders in Fraunhofer FIT also hold faculty positions at RWTH Aachen University: Thomas Berlage, Wolfgang Prinz, and Thomas Rose.

FIT pursues its mission in four major research areas which are complemented by special business fields and competence centers (see www.fit.fraunhofer.de for details).

FIT.CSCW (Prof. Wolfgang Prinz, PhD) investigates the field of Cooperation Support Systems. Technological development has been changing collaboration within and between organizations significantly. When complex, interdisciplinary jobs must be done effectively and efficiently, knowledge workers today need to be able to cooperate flexibly, ad-hoc and across organizational boundaries. Developing integrated system support for this type of cooperation was the mission of the international ECOSPACE project that was coordinated by FIT and involved more than 20 European partners and a budget of over 12 million €. The project ended in December 2009 and yielded integrated solutions to reduce information and communication overload. ECOSPACE developed a reference architecture for integrating different cooperation tools based on a service-oriented approach (SOA). It used Semantic Web technologies for the selection of suitable services and linked together a broad range of services and applications. Thus, for the first time, different groupware systems have been seamlessly integrated. Together, the results improve contextual and presence awareness, make available information on user behavior when using the cooperation tools and offer a broad range of Web 2.0 tools in a consistent, interoperable cooperation platform.

Social media, smart-phones and surface computing strongly influence today’s use and development of cooperation systems. While social network services have many millions of private users, companies hesitate to use the technology. Several of our projects deal with this discrepancy. Based on a study of the salient characteristics of prominent Web 2.0 applications we developed recommendations on how to adapt these cooperation platforms to the use
within organizations. Companies could thus integrate the characteristic features of social platforms into their application systems and processes, thus providing their staff with better tools for communication and cooperation. A methodology to study cooperativity, which measures the cooperation in an organization, indicates the room – and need – for improvements. Our initial experience indicates that these tools improve the way people communicate and help to reduce the flood of emails bogging down many organizations.

IdeaPitch is novel application brings together desktop computers, iPhones and the multi-touch table Microsoft Surface for communicating, generating and structuring ideas. IdeaPitch lets its users exchange short notes with a simple gesture. It provides a novel, intuitive form of interaction for brainstorming sessions and documents the results for future use. Another Microsoft Surface application, NETme, supports social networking among visitors to events like conferences that requires advance registration. With the registration visitors can enter – besides the usual information like name, address and affiliation – their user names in social networks (XING, Facebook, Twitter, buzz etc.), upload a photo and add information on their professional interests. At the conference the visitors receive badges with a 2D barcode that identifies them to the NETme system. They can use the Microsoft Surface with NETme, explore the social networks, and contact other visitors that are of interest to them.

FIT.LIFE (Prof. Dr. Thomas Berlage) investigates the field of Life Science Informatics, addressing navigational support for micro-surgery, system environments for large-scale bioinformatics research, and assistive devices for users with special needs. The MobiGuide BMBF project represents a flagship of the activities and integrates multiple lines of research. The goal of this project is to address the needs of prostate surgery, in particular, the detection and assessment of remaining tumor cells. Together with Karl Storz GmbH, a laparoscopic instrument will be extended with a micro-fluidic diagnostic device that captures and analyzes cells from several positions on the surgical site. Those cells will be analyzed with respect to multiple parameters to be integrated into an overall assessment of the surgical situation to aid in the benefit/risk decision how to proceed. Surgical navigation, pathological analysis, micro-molecular diagnosis and visualization are integrated into a medical device.

Further research is conducted on image analysis in tissue, particular the characterization of tumors, and the therapeutically modeling. Another line of research develops miniature diagnostic devices for point-of-care and personal diagnostics.

With the TopoScan platform, the group has developed a modular platform for optical scanning devices. This platform is being refined and several applications are under development. From this platform, specialized automated instruments can be derived that incorporate significant software-driven functionalities, such as content-based autofocus and region-of-interest selection and assay-adaptive scanning strategies. Data management and
service integration capabilities are also included. The functionality can be tailored for individual application to domain-specific languages.

FIT.ICON (Prof. Dr. Reinhard Oppermann, Univ. Koblenz-Landau) develops context-adaptive and mobile systems for eLearning and mobile work. Jointly with Informatik 5, they are main partners in the ROLE EU project in Personalized Technology-Enhanced Learning; other large eLearning projects include the AILB project which develops novel tools to enhance the basic professional competencies for hearing-impaired young workers; the latter is a joint project with the DESIRE research team at RWTH Aachen University led by Prof. Dr. Ludwig Jäger. In 2009, two large European integrated projects were successfully completed, addressing metadata for architectural learning (MACE) and middleware for mobile, networked device integration (HYDRA). FIT is coordinator of a new 12 m€ EU integrated project called ebbits which extends HYDRA results to Enable Business-Based Internet of Things and Services in cooperation with SAP AG and eight other business and science partners, and a large partner in the 19 m€ BRIDGE project which investigates the suitability of multi-agent systems for coordination tasks in large-scale emergency management.

FIT.PRO (Prof. Dr. Thomas Rose) develops process management solutions for domains that can be characterized by the complexity of their decision processes, especially emergency management. Methods and tools for process capture and business models for operating services, including related data integration and data warehousing questions, are a major topic. Mobile data integration applications such as car-to-car information management settings (see report on CoCar project in report by Informatik 5) are also pursued.

In the new BMBF project InfoStrom (www.infostrom.org) we cooperate with companies such as RWE, PSI and SAP to develop tools for the informal capture of knowhow about processes that help to deal with the break-down of the electric power supply network. Since private and public organizations have to cooperate, transparency of processes is decisive.

EU Project Profitex (www.project-profitex.eu) develops advanced navigation and communication support systems for fire services. For engineering these systems we pursue a simulation-based design methodology developed within the precursor wearIT@work project to study the use of partially simulated prototypes under realistic operational conditions. Requirements elicitation and field trials will be conducted with several fire services across Europe. In EU project Socionical (www.socionical.eu) we are analysing complex socio-technical systems by means of complexity science and various simulation methods. In particular we are exploring the impact of ambient intelligence technologies on rescue forces in case of large-scale emergencies, e.g. how can mobile phones be used to gather information on a crisis. In EU project Vicon (www.vicon-project.eu) we study the use of virtual simulations to support product design, and develop tools that provide users with age-related impairments to operate virtual prototypes of household appliances such as laundry machines and phones.

Complementing the four research areas, three FIT competence centers support the German government with microeconomic simulations for the impact analysis of proposed new laws, and the industry and public sector with advanced usability studies as well as methods and tools for enabling web compliance checking and inclusive accessibility to the internet.
Foundation of Synavision GmbH

The energy workgroup at Software Engineering, RWTH Aachen University has founded the spin-off company synavision GmbH with partners at Institute of Building Services and Energy Design, University of Technology Braunschweig.

The interdisciplinary team of software engineers and energy experts focuses on developing and industrially applying software based tools and modeling techniques for increasing energy efficiency of buildings and facilities in industry. Ideas at recent research projects are refined and software products are developed.

The business idea is to develop a formal domain specific language for building and facility specifications and corresponding software tools. The language adapts ideas from computer science, like constraints or state modeling, as well as modeling logical architectures to the needs of domain experts in energy and building management. The tool supports mass data collection from building operation, innovative visualization technologies and an automated analysis of mass data related to the formal specification. Generation of reporting websites, user-defined text reports and a customizable ticket system help energy experts and facility managers to handle the complexity of today’s buildings and facilities.

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**Computer Science Technical Reports 2010**

Electronic copies of all Technical Reports may be obtained through

http://www.informatik.rwth-aachen.de/Forschung/aib.php

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