Annual Report 2009

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. The booklet which you are holding in your hands does that for the academic year of October 2008 to September 2009. You will find ample information not only about our research and teaching activities and successes, but also about social life and important developments in the department. As the current speaker of the Computer Science Department, I am happy to observe that we are able, again, to report on a very successful year which both started and ended with remarkable and important events.

The year started with the award of honorary doctorates to Prof. Jan van Leeuwen and Prof. Reinhard Wilhelm on October 24, 2008. It was the first event of this kind in the more than 35 years long history of the department. Appropriately, the occasion was celebrated with a very well received scientific colloquium and a memorable reception. Details and impressions can be found in the Faculty Life Section of this report.

The year ended with the graduation of our first Bachelors in Computer Science. Having introduced the Bachelor program in the winter term 2006, we can now proudly congratulate the first graduates of the pioneering generation. 28 students were able to finish within 6 semesters or slightly more and will be awarded their certificates on the 2009 Computer Science Day (“Tag der Informatik”). Most of them are continuing to study Computer Science in Aachen and entered our Master program.

During the year, several further occasions are worth mentioning. Most notably, Prof. Manfred Nagl retired at the end of July. To mark this occasion, a scientific colloquium was held in his honor on June 26, 2009. Three of his former students who are now professors at other universities presented three major aspects of current software engineering research and, by that, demonstrated the strong impact which Prof. Nagl’s achievements have had in his field. The colloquium was followed by a reception which will be well remembered.

Although retired, Prof. Nagl is still supporting the department, e.g., in the German Informatics Faculty Conference (“Fakultätenstag Informatik”) which he chaired until 2008 and for which he is still serving as Deputy Chairman. Until 2008, Prof. Nagl was also Chairman of the Union of Faculty Conferences in Mechanical Engineering, Electrical Engineering, Civil Engineering, and Informatics (“4ING”) and is now Member of the Board.

Prof. Nagl’s successor, Prof. Bernhard Rumpe, started at the beginning of 2009. After a mildly chaotic renovation of his premises, he was able to move with his associates into the designated rooms in October. A further change of faculty personnel was the appointment of Prof. Felix Wolf to the newly established professorship “Parallel Programming” in the German Research School in Simulation Science.

Five of our colleagues received (partly multiple) offers from other universities, a fact which is documenting the quality we were able to attract to Aachen. In three cases, Prof. Borchers, Prof. Kuhlen and Prof. Naumann, we were able to beat the foreign offer; in the other two cases, the negotiations are still ongoing.

In the reporting period, our faculty colleagues and researchers received numerous awards and distinctions. It is impossible to list all of them here. Therefore, I will mention only the most important ones, omitting for example the numerous best paper and similar awards:

- Prof. Paolo Bientinesi received the Karl-Arnold-Award of the Academy of Science of Northrhine-Westphalia.
- Dr. Lukasz Kaiser received the E.W. Beth Dissertation Prize awarded by the Association for Logic, Language, and Information (FoLLI).
• Prof. Gerhard Lakemeyer was appointed Fellow of the European Coordination Committee of Artificial Intelligence (ECCAI).
• At the Annual Convention in Lübeck on September 30, 2009, Prof. Nagl was appointed Fellow of the German Informatics Society.
• Prof. Klaus Wehrle was appointed as member of the German Academy of Science and Engineering (acatech).

With respect to teaching on graduate level, we can report that the B-IT Research School commenced its operations with 18 doctoral students receiving a stipend. The MSc program in Control Engineering Science (Automatisierungstechnik) which is jointly offered by the Faculty of Mechanical Engineering, the Faculty of Georesources and Materials Engineering, and our Department welcomed its first students in October 2008. Finally, the IT study program at GUtech in Oman, which was developed by colleagues from our department lead by Prof. Matthias Jarke, successfully went through accreditation and was evaluated with excellent results by the DAAD.

After this list of appetizers, I would like to invite you to browse through the following pages 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, I thank Kai Jakobs for all the work he took over when compiling this report.

Aachen, November 2009

Stefan Kowalewski

Speaker, Computer Science Department
Faculty Life
New Professors

Actually, this should be singular. In 2009, we appointed just one new professor ……

Bernhard Rumpe

In January 2009 Bernhard Rumpe started as full professor at the Chair ‘Software Engineering’ (Informatik 3) at RWTH Aachen University, where he succeeded Manfred Nagl in August 2009. He began his scientific life at the Munich University of Technology, where he received a “summa cum laude” grade, for his Diploma (1992) and this Ph.D. (1996). He also received the Siemens Award for the best CS Diploma at TU Munich; and got his Ph.D. thesis nominated for the Dissertation Award of the German ‘Gesellschaft für Informatik’.

While at the Munich University of Technology, where he was awarded a three year fellowship by the ‘Bayerisches Staatsministerium für Wissenschaft, Forschung und Kunst’ (Bavarian Ministry for Science, Research, and the Arts), he finished his Habilitation in 2003, and in parallel received his first call to the Braunschweig University of Technology where he started as full professor and Head of the Institute for Software Systems Engineering for five years.

He also held two guest professorships at research institute IRISA/INRIA at Universite Rennes 1 in 2003 and at the ISIS institute at Vanderbilt University, Nashville, Tennessee in 2008.

Bernhard is Editor-In-Chief of the International Journal of Software and System Modeling (Sosym) from Springer, and Co-Founder and Steering-Committee-Member of the GI Competence Group ‘Modelling’. He has been co-organiser of several conferences and many workshops and seminars at Schloss Dagstuhl, and frequent Program Committee member.

His scientific interests can be boiled down to the question, how to develop the correct software quickly. This goal consequently breaks down into a portfolio of research questions that he is currently handling, starting with adequate management of requirements, planning to develop customer-specific software in variants and product lines, stable definition of software architectures, efficient code generation and development, semi-automatic and automatic quality assurance through tests and agile evolution of existing software. He proposes to use models and modelling techniques in various variants to simplify these development tasks, for a sustainable quality of software products.

He also cares about the application of appropriate techniques in several domains, based on the observation that different domains do have very different, domain-specific problems. Web, e.g. does need timely solutions, while the automotive domain needs to get their new functionalities integrated with less costs and high quality. Therefore, he is eager to demonstrate the operability of his research, by applying it to monitoring services in the energy and home office domain, to autonomous vehicle development (with a great success at the Darpa Urban Challenge in 2007), to web based government systems and specifically to software development tools, such as the MontiCore family of tools and services.
Honorary Doctorates

Thirty years ago, the first doctorates were awarded in Computer Science at RWTH. Twenty years ago, the Forum Informatik was founded. To commemorate these events, the Computer Science Department awarded its first ever Honorary Doctorates to two outstanding scientists on 24 October.

The recipients were Prof. Dr. Jan van Leeuwen (Utrecht) and Prof. Dr. Reinhard Wilhelm (Saarbrücken). Jan van Leeuwen was honoured for his pioneering contributions to algorithmics, and for his exemplary services to the development of the computer science discipline in Europe. Reinhard Wilhelm received his honorary doctorate for his fundamental contributions to the analysis of real-time systems and programming languages, and for his decade-long role as the Scientific Director of Schloss Dagstuhl.

A scientific colloquium preceded the ceremony. Here, Thomas Ottmann (Freiburg) and Kim G. Larsen (Aalborg) illustrated the research fields of the two laureates. The ceremony was led by RWTH’s Rector Ernst Schmachtenberg, and attended by the faculty and numerous guests.
Zunächst ein Wort an unsere niederländischen Gäste: Ik vraag U vriendelijk om begrip, dat ik diese toespraak niet in het Nederlands - en ook niet in het Latijn - houd, maar in een taal, die mij iets beter ligt.

Wenn man sich in den Werken der Dichter nach dem Anliegen unserer Feierstunde - Wissenschaft und Doktorgrade - umschaut, dann findet man nur sehr wenig Einschlägiges; Wissenschaftler spielen dort eher eine Nebenrolle. Eine prominente Ausnahme ist natürlich Goethes Faust — dieses Stück beginnt mit dem Monolog eines frustrierten Wissenschaftlers, und es wird auch über Doktoren gesprochen. In der ersten Fassung, dem sog. „Urfaust“, lässt Goethe den Faust folgendes sagen:

„Heiße Doktor, heiße Professor gar, und ziehe schon an die zehen Jahr
Herauf herab und quer und krumm meine Schüler an der Nas herum."


Natürlich werde ich auf die herausragenden wissenschaftlichen Beiträge unserer Ehrendoktoren (erst in 20 Minuten sind sie Ehrendoktoren) eingehen, und wir werden feststellen, dass diese Beiträge in zwei komplementäre Bereiche der Informatik fallen.


Eine Voraussetzung dafür war, dass es prägende Persönlichkeiten gab, die für dieses Fach die nötige eigenständige Lehr- und Forschungs-Infrastruktur schufen. Dazu zählt vieles: die Konzeption von Curricula, die Gründung und Führung von Publikationsorganen wie Zeitschriften, und die Schaffung eigener Foren für die wissenschaftliche Diskussion. Jan van Leeuwen und Reinhard Wilhelm sind zwei Wissenschaftler, die für die Informatik hier Entscheidendes bewegt haben und weiter bewegen. Gemeinsam ist beiden auch, dass sie das in einer freundlichen, humorvollen und unaufdringlichen Art tun, ohne viel Aufhebens, aber mit einer staunenswerten Ener-
gie und Beharrlichkeit.

Beginnen wir mit Jan van Leeuwen. Es war Anfang der siebziger Jahre, als seine ersten Arbeiten erschienen und er seine Dissertation an der Universität Utrecht verfasste, zum Thema „Rule-labeled programs“, eine - wie es im Titel ergänzend heißt - „Study of a generalization of context-free grammars and some classes of formal languages“.


Nach der Promotion ging Jan van Leeuwen für mehrere Jahre an verschiedene Universitäten in die USA (Berkeley, State University of New York at Buffalo, Penn State), um dann 1977 nach Utrecht zurückzukehren, erst als Associate Professor, dann Full Professor, und dann in all den Ämtern, die eine Fakultät so zu bieten hat, darunter mehrfach das des Dekans. Nebenbei war er an seiner Universität auch der Gründer des Faches Informatik.


Die wissenschaftlichen Arbeiten Jan van Leeuwens fallen in eine weite Palette von Gebieten im Bereich dessen, was wir heute Algorithmik nennen, wozu die Entwicklung und der Analyse von Algorithmen, algebraische Komplexitätstheorie und das riesige Gebiet der Netzwerkalgorithmen (auch Graphalgorithmen genannt) fallen.

Jan van Leeuwen ist einer der geistigen Väter der Algorithmik, und - wie noch sehen werden - er hat Entscheidendes dazu beigetragen, dass es diesen Begriff überhaupt gibt.

Man muss dabei zwei Ebenen unterscheiden: die Forschungsergebnisse, und dann die Gründung und die Betreuung von Tagungsserien und Publikationsorganen.

Zum ersten Aspekt nur ein ganz kleines Beispiel, die Dynamisierung statischer Datenstrukturen. Statische Datenstrukturen unterstützen keine schrankenlosen Veränderungen ihrer Inhalte und sind damit für dynamische Situationen ungeeignet. Statt nun im Einzelfall eine statische Datenstruktur für dynamische Situationen neu zu erfinden oder vielleicht anzupassen, entwickelt Jan van Leeuwen ein allgemeines Schema, das noch nicht einmal auf die innere Operationsweise der statischen Struktur eingeht, effizient umsetzbar ist und viele Einzelanstrengungen obsolet macht. Die Grundidee, die diesen Durchbruch gestattet, nutzt den Begriff des redundanten Zahlensys-
tems, und mit langem Atem und hoher Kreativität wird der Ansatz zum Funktionieren gebracht. Es sei hier darauf verzichtet, nun weiter ins Detail zu gehen.

Die zweite Ebene betrifft die Prägung des Feldes der Algorithmik durch Konferenzen und Publikationsmedien. Ein Beispiel ist der „Workshop on Graph-Theoretical Aspects of Computer Science“, den Jan van Leeuwen mit anderen, darunter Kollege Nagl aus Aachen, zu einem höchst erfolgreichen Forum gestaltete, das in diesem Jahr bereits zum 34. Mal stattfand.


In jüngerer Zeit kam sogar noch ein weiteres Aktionsfeld dazu: Aktivitäten auf europäischer Ebene, um das Studien- und Forschungsfach Informatik international abzusichern und weiterzu- entwickeln. Jan van Leeuwen ist einer der Initiatoren für die Institution „Informatics Europe“, eine Art europäischer Fakultätentag für Informatik. Hier ist er derzeit stellvertretender Vorsitzender und leistet segensreiche Dienste, um die politischen Rahmenbedingungen (ich habe ja den Bologna-Prozess schon einmal erwähnt) so mitzustalten, dass die schlimme Unglücke möglichst verhindert werden.

Zusammenfassend habe ich zu meinen Ausführungen über Jan van Leeuwen keine Aussage, sondern eher eine Frage: Wie kann eine Einzelperson allein überhaupt so viel leisten?
Kommen wir zu unserem zweiten Ehrendoktoranden Reinhard Wilhelm.


Hier sehen Sie ein Foto zur Promotion von Reinhard Wilhelm – das Umfeld trägt hier keine Ta- lare mehr, aber immerhin gibt es wie auch heutzutage in Aachen einen individuell gefertigten Doktorhut.

Nach einem Aufenthalt in Stanford wurde Reinhard Wilhelm an die Universität Saarbrücken berufen, und er übernahm dort den Lehrstuhl für Programmiersprachen und Übersetzerbau.


In seinen frühen Arbeiten zum Übersetzerbau war Reinhard Wilhelm einer der führenden Wissenschaftler in der Methodologie der Compilerkonstruktion mit Attributgrammatiken, und er war es, der die Praktikabilität dieses Ansatz als erster durch eine Implementierung nachgewiesen hat. Es schlossen sich eine ganze Reihe weiterer Untersuchungen an, in denen er eine weite Palette von Techniken integrierte (Tabellenkompression, Graphreduktion, Code-Optimierung, virtuelle Maschinen) – und hier reicht die Zeit nicht, dies im einzelnen zu erläutern.


In den vergangenen zwölf Jahren machte Reinhard Wilhelm mit innovativen Beiträgen im Felde der Programmanalyse auf sich aufmerksam. Hier erzielte er Durchbrüche in zwei Bereichen. Zunächst gelang es ihm (in Arbeiten zusammen mit Reps und Sagiv) die Methode der statischen Analyse auf eine neue Ebene zu heben durch die Begründung der „Shape-Analyse“ – dies ist ein Ansatz zur Verifikation von Programmen über dynamischen Datenstrukturen mit dem Einsatz
mehrwertiger Logik. Diese Arbeiten haben eine neue Methodologie begründet und binnen kurzer Zeit eine enorme Rate an Zitationen erreicht.


In diesem Seminarzentrum mit einer wunderbaren Bibliothek finden Woche für Woche Seminare statt, bei denen sich jeweils um die 40 Wissenschaftler zu Vorträgen und Diskussionen über ein spezifisches Thema treffen – wie zum Beispiel „Verifikation von Echtzeitsystemen“. Organisiert wird das Seminar jeweils von ungefähr drei führenden Fachvertretern, die zuvor einen Antrag auf Durchführung des Seminars einreichen müssen mit einer Vorschlagsliste für die einzuladen- den Forscherinnen und Forscher, und die dann das Mandat zur Leitung des Seminars erhalten. Alle administrativen Vorgänge, das Versenden der Einladungen, Unterbringung und Essen, werden aber von Schloss Dagstuhl übernommen. Es sind also geradezu paradiesische Verhältnisse.

Die Idee ist dabei, intensiven Gedankenaustausch und Kooperationen auf höchstem Niveau zu fördern, indem man Forscher höchster Qualität weitaus vom Schuss zusammen unterbringt, ohne Fernsehen und sonstige Ablenkungen, so dass sie sich eigentlich nur miteinander unterhalten können.

dieser Maßnahme war, dass sie nicht eingezogen wurden. Die Operation diente also dazu, dass eine ganze Riege junger Mathematiker die letzten Kriegsmonate überlebte und eine prägende Rolle nach dem Krieg übernehmen konnte. Die Operation gelang, und nach dem Krieg wurde diese Villa in ein Seminarzentrum umgewandelt.

Wenn Sie dieses Bild sehen, können Sie nicht mehr erkennen, wie Dagstuhl angefangen hat und was sein Leiter Reinhard Wilhelm alles leisten und regeln musste, damit dieses Zentrum diesen baulichen Zustand erreichte und – viel wichtiger noch – zum weltweit führenden Forschungsforum wurde, das heute der Leibniz-Gesellschaft gehört.


Aber Reinhard Wilhelm hat auch alle anderen Aspekte des Instituts entscheidend geprägt. Es gibt eine zugleich entspannte und fordernde Arbeitsatmosphäre, hervorragende Weine (die man natürlich selber zahlt), und es gibt viel zeitgenössische Kunst.


Ich hoffe, dass ich Ihnen, meine Damen und Herren, nahe bringen konnte, warum wir die Kollegen Jan van Leeuwen und Reinhard Wilhelm als Wissenschaftler höchster Reputation und als in
jeder Hinsicht vorbildliche Vertreter unseres Faches für den Ehrendoktortitel der RWTH Aachen vorgeschlagen haben. Wir, die Informatikerinnen und Informatiker der RWTH Aachen, freuen uns, dass Fakultät und Senat mit einstimmigen Voten diesem Vorschlag gefolgt sind.

An beide Ehrendoktoranden, in sehr naher Zukunft auch Ehrendoktoren, noch eine letzte Bemerkung.

Jan und Reinhard, Ihr gehört vom heutigen Tage an irgendwie zu uns, und die Aachener Informatik ist stolz und glücklich über diese Ergänzung. Keine Angst: Wir werden Euch nicht in den Professoriumsverteiler infprof at informatik dot rwth-aachen dot de aufnehmen und mit der La wine der üblichen Alltagsfragen belästigen. Aber es wird doch Einladungen zu besonderen Veranstaltungen, hoffentlich regelmäßiger Kontakte, und hin und wieder vielleicht auch die Bitte um einen Rat geben, und wir hoffen sehr, dass uns unsere beiden ersten Ehrendoktoren in diesem Sinne verbunden bleiben werden.
Ceremony for Emeritus Prof. Dr.-Ing. M. Nagl

In the year under report Prof. Nagl became an emeritus professor and handed over the Department of Computer Science 3 to Prof. Dr. Bernhard Rumpe. For this reason, the Department of Computer Science invited to a ceremony in the Aula 2 at 26th of June. Several notables of the RWTH Aachen University, representatives of several organizations from industry and research, professors of several universities and academic descendants of Prof. Nagl took part in the event. Altogether, around 240 guests attended the ceremony.

The program started with several welcoming speeches. Rector Prof. Schmachtenberg emphasized Prof. Nagl’s achievements in research, in particular the Collaborative Research Center 476 IMPROVE. Prof. Nagl proved to have much professional and social competence by successfully managing such a huge interdisciplinary project.

The second welcoming speech was given by the dean of the Faculty of Mathematics, Computer Science and Natural Sciences. Since the appointment of Prof. Nagl as professor for software engineering, the Department of Computer Science at RWTH made a spectacular development, e.g. the number of professors increased from 5 to over 20 today. Prof. Nagl had a big share in this development. Over the years, he took over many key positions in the faculty. In particular he was a long-term member of the budgeting commission, and as such advocated for the needs of the department. Without his contribution, the lasting development of the Department of Computer Science would not have been possible. Furthermore, Prof. Nagl initiated cooperations with other faculties, which also led to the CRC 476 IMPROVE. The research merits of Prof. Nagl are proven by the large number of diploma theses and dissertations which were completed. From his PhD students, 14 became professors. Prof. Nagl was also very active regarding the acquisition of third-party for different projects. As a consequence of his successful work, he received a call from the University of Zurich in 1992 which he declined.

The speaker of the Department of Computer Science, Prof. Kowalewski gave a coarse overview over Prof. Nagl’s work as a member of the department. Prof. Nagl built up the discipline of software engineering in Aachen. He took over many positions like that of speaker of the department, and carried out his work with a high accuracy. Many initiatives for the Forum Informatik led to a high visibility of the department in the whole University. Prof. Nagl was also one of the initiators of the Regional Industry Club Aachen, REGINA, of which he is one of the few honorary members today. He is one of the authors of the Dagstuhl Initiative Software Engineering which published a position paper about the perspectives of the
discipline. Finally, Prof. Nagl was very active in the Fakultätentag Informatik and intensified its political influence.

The president of 4ING, Prof. Müller from TU Munich, shortly introduced the organization and in particular its work regarding the education in technical subjects at German Universities. Prof. Nagl was one of the founders of 4ING and was chairman from 2007 to 2008. He was the right person at the right time at the right place.

After the welcoming speeches, some personal surprises were presented: A personal poem written and recited by Prof. Spaniol, and a Festschrift, presented by Prof. Westfechtel, written by academic descendants but also colleagues of Prof. Nagl being published by Springer Verlag.

The laudation to Prof. Nagl was given by Prof. Thomas. He focused on the one hand on the career of Prof. Nagl and on the other hand on his personality. The stages of Prof. Nagl’s career led him from his studies over his work at Siemens to his dissertation and habilitation in the group of Prof. Schneider at the University of Erlangen. There, he was working on graph rewriting systems and on a methodology for their realization. After two professorships, he finally moved to Aachen, where he was urgently needed as a representative for the Practical Computer Science. However, due to his affinity to graph theoretic topics, he also remained connected to the theoretical computer science through his whole career. In the field of software engineering, he wrote pioneering books about the programming language Ada and about software architectures.

After Prof. Nagl’s affiliation to the RWTH Aachen, the computer science department improved significantly. He initiated the Aachener Informatik-Berichte and the annual reports of the department (the one you are currently reading). Over the years, Prof. Nagl raised many scholarships from companies which were given to exceptional students. Regarding his personality, Prof. Nagl could be described with properties of the software systems he has built over the years: highly complex, well-structured, very robust, extremely reliable, efficient, dynamic and adaptive. He has the ability to develop visions and to elaborate and finally realize them with a strong endurance until all obstacles have been resolved. In the Department of Computer Science, Prof. Nagl has always been a team player, often in the role of a trainer pushing his team to peak performance.

In three presentations, academic descendants of Prof. Nagl examined the influence and impact of his research on three different areas of software engineering. Prof. Schäfer from the University Paderborn presented current developments in the area of development processes and their support by software tools, and he pointed out, how fundamental concepts from the IPSEN project found their way to the current research. Prof. Lewerentz from the BTU Cottbus presented new approaches for the visualization and analysis of complex software architectures, and he highlighted the connections to Prof. Nagl’s fundamental results in this area. Prof. Schürr from the TU Darmstadt gave a presentation about model-driven software development and how graph rewriting systems can be applied for this purpose.
After the technical presentations, Prof. Kowalewski presented the present of the Department of Computer Science. Former and the current assistants presented their presents among which was a genealogical tree of all academic descendants of Prof. Nagl. Prof. Spaniol gave a cabaret performance about the work in the CRC 476 IMPROVE.

In his response, Prof. Nagl expressed his thanks to the speakers and the guests. He tried to relativize the compliments by saying that he had a lot of luck in his life. However, when opportunities come along in life, one should take them up. Prof. Nagl shortly described the different stations of his professional career in his personal view. He said thanks to the representatives of the present groups and organisations and his former and present assistants. Finally, he closed with the promise to stay active in the department and the University.
Open Day – 22. ‘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 I (Algorithms and Complexity).

The welcome address was given by Vice Dean Prof. Dr. Ulrich Simon and by the spokesman of the Computer Science Department, Prof. Dr. Stefan Kowalewski.

In 2008, the Department was lucky enough to welcome a number of new professors. They introduced themselves to a wider audience through scientific presentations. These included

- ‘Mobile Network Performance’, by Prof. Dr. James Gross.
- Code Generation for High-Performance Architectures, by Prof. Paolo Bientinesi, PhD.
- Mobile Multimedia Processing, by Prof. Dr. Bastian Leibe.
- Security in Mobile Communication Networks, by Prof. Dr. Ulrike Meyer.

These presentations were followed by the Keynote address, this year delivered by Prof. Dr. Orna Grumberg, of the Technion at Haifa, Israel. Her talk was entitled “Compositional Verification and 3-Valued Abstraction Join Forces”.

Following the scientific part of the day, the once again highly entertaining final rounds of the annual ‘Sun-SAR Softwarepreis’ were played out. Traditionally, participants in this contest have to implement clever strategies for a particular strategic game. This year, it was ‘The
Crazy Pyramid’. Six teams competed in the preliminaries. Eventually, ‘SunnyBoy’ won, with last year’s winner team ‘BearBot’ as runner-up, and ‘TombRaider’ making third place.

The final session of the afternoon programme started with a formal speech, given by Prof. Dr. em. Klaus Indermark. This was followed by the ceremonial presentation of the diploma/master certificates to this year’s graduates. The ‘Aachener HochschulSalonOrchester ACHSO’, with their conductor D. Havenith, contributed the musical part of the ceremony with pieces by Strauss, Winkler, and Michiels.

Following the official part of the day was the traditional evening banquet, which attended roughly five hundred people including the graduates and their families, many current students and alumni, most of the CS department staff and many visitors from industry and academia.
Each year, towards the end of the summer term, the Computer Science Department organises a summer party for the ceremonial presentation of diploma certificates to the graduates of the past six or so months. Once again, the events took place at Computer Science Centre (and its adjoining parking lot). Each event started with an introductory talk that was followed by a more humorous ceremonial talk. The official part ended with the presentation of the diploma certificates; over 50 students received their certificates at each summer party.

Said official ceremony was followed by the – less formal – party proper. A small buffet and plenty of drinks were on offer. The typical crowd of about 500 – 600 people attended the events, including the graduates and their families, current students, most of the staff of the computer science department, and several guests from other departments.
‘Mens sana in corpore sano’ could have been the slogan of the InfoCup tournaments. Here, teams of the individual Computer Science Chairs compete in the sportive, but less scientific discipline of ‘Indoor Soccer’.

The 2009 event was the third in a row. Ten – highly motivated – teams participated. Accordingly, the preliminaries comprised two groups with five team each. Each match lasted 10 minutes. i3 and LuFG i4 dominates their group, as did i4 (they lost the last match, though). Just like in 2007, the future champion survived largely by luck ………..

The semi-final matches lasted for 12 minutes. All matches were exciting; LuFG i4 lost to their ‘mother’, as did i3 to i5. Eventually, i5 secured the championship through a 2:0 win over i4. The team of i4 beat LuFGi9 in the petite finale.
Thus, the top 4 were:

1. i5
2. i4
3. i3
4. LuFG i4

On the other end of the spectrum the team of the student council was second to none, with 0 goal and 0 points – a nice testimonial to the excellent post-graduate training at RWTH.

The sportive activities were – inevitably – followed by a party that set a new record regarding the number of people in the i4 seminar room and on the terrace.
Bright Minds in Computer Science –
Helle Köpfe in der Informatik

Starting four 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 2006. An external steering committee selected 16 children who attend the new program called Helle Köpfe in der Informatik. During six course meetings, faculty members of the department introduce the talented pupils to basic topics of computer science.

They particularly stress the insight that computer science exceeds just working with computers by far.

Both rounds in summer 2007 and 2008 addressed the following topics:

• Why is it possible to scratch a CD? (Peter Rossmanith)
• Searching and Sorting (Thomas Seidl)
• The needle in the haystack (Joost-Pieter Katoen/Thomas Noll)
• How does the Internet work? (Klaus Wehrle)
• Kara, the programmable ladybug (Horst Lichter)

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

The experiences made so were very positive, and the program will be continued in the next years.
Four hundred years ago, Galileo Galilei made a number of discoveries when he pointed his telescope to the sky. The telescope has been an invaluable tool for exploring the distant and exciting universe.

Johannes Kepler published his "Astronomia nova" in the same year 1609, an epoch-making book about the Solar System. Kepler was first in correctly describing the motion of the planets on their orbits around the Sun.

The International Year of Astronomy 2009 has been called by the UNESCO in remembrance of the progress made by Kepler and Galilei and of the importance astronomy has had for mankind in general.

Due to this event Prof. Oberschelp wrote a play about astronomy called “CASSINI”.

CASSINI was staged at RWTH Wissenschaftsnacht, 13/11/2009 in Karrman Auditorium.

In addition Prof. Oberschelp and Prof. Spaniol took responsibility for Informatik-Spektrum ‘Extraheft zur Astronomie’ published end of the year with articles from Prof. Oberschelp and Helen Bolke-Hermanns (“Irdische Klänge für kosmische Intelligenzen”)
The 8th International Conference on Web-based learning (ICWL 2009) was held on August 19-21, 2009 in Germany's westernmost located and truly European city Aachen. ICWL 2009 was jointly organized by the Hong Kong Web Society, Informatik 5 (Information Systems, Prof. M. Jarke) at RWTH Aachen University, and Max-Planck-Institute for Computer Science.

Authors that submitted to the ICWL 2009 conference came from more than 30 countries with remarkably many submissions from across Europe. ICWL is an annual international conference series on Web-based learning that has so far been held in Asia, Australia and Europe. This series represents the cooperation of European and Asian researchers to advance the field of Web-based learning. A lot of joint research papers and joint projects have emerged from the successful track record of ICWL.

Altogether, a total of 106 valid submissions have been received. After a rigorous reviewing process, we decided to accept a total of 38 papers as full papers, representing an acceptance rate of 36%. In addition, we accepted another 14 papers as short papers. Moreover, we included three invited papers of renowned researchers into the conference proceedings. As a novelty, for the first time we had four co-located workshops with the conference. Having immediately attracted four workshops we interpreted this as an indicator of the significance and visibility of this conference series within the Web-based learning community.

The conference organizers were able to invite renowned Web-based learning experts to give keynote talks and invited paper talks: Erik Duval from Katholieke Universiteit Leuven,
Wolfgang Nejdl from L3S Lab and University Hannover, Ulrik Schröder from RWTH Aachen University, Won Kim from Kyungwon University, and Helen Ashman from University of South Australia.

Prof. Jarke handed presents to the invited Speaker Prof. Erik Duval from Katholieke Universiteit Leuven, after he gave a talk on “Learning in Times of Abundance: The Snowflake Effect”
Networking 2009

The IFIP TC6 flagship conference ‘Networking 2009’ (this time organised in Aachen – Germany; 11 – 15 May 2009) was a really great event. According to participants, the conference offered a perfect mixture of German thoroughness and of French joy of life [try to imagine for a second what would have happened if we had combined German quality of life with French thoroughness … and English cooking … and Italian mechanical engineering … and Swiss love making … you’re getting the idea …].

Of course, it helped that we could use the top floor of RWTH’s latest landmark building – the Super-C.

The quality of the presentations was astonishingly high. Most likely, this was the consequence of a very strict selection procedure not only during the review process, but also at the programme committee meeting where manuscripts of questionable quality – probably including many that would have easily been accepted at other conferences – were eliminated mercilessly. Moreover, the number of no-show authors was minimal, and in all cases the absence of the presenters was down to very valid reasons.

The Chairs of the technical programme committee (Luigi Fratta, Italy; Henning Schulzrinne, USA; Yutaka Takahashi, Japan) had done a perfect job. Unfortunately, however, Yutaka couldn’t make it to the conference thanks to a rather questionable ruling of Kyoto university: they did (and still do) not allow travelling to countries where a single(!) case of swine flu had been reported. A side comment to this strange rule: members of Kyoto university are allowed to travel to Luxemburg or Tahiti, but not to China, India, USA, or Germany. Apparently, Kyoto’s knowledge of probability theory is rather limited.

A special highlight of the conference were the three invited talks by Paul Francis on “A Dirty Slate Approach to Scaling BGP”, by Paul Kuehn on “Development of Global Communications”, and by Mario Gerla on “Vehicular Urban Sensing”.
In conjunction with the main conference, three one-day workshops were organised on: “Traffic Monitoring and Analysis”, “Internet Charging and QoS Technologies”, and “Mobile and Wireless Networks Security”

At Networking 2009, we tried several new conference features for the first time (well, at least in the ‘Networking’ environment). Among others, these included the OMM (One Minute Madness) sessions; much appreciated by everyone. In OMM, every presenter of a manuscript tries to advertise his/her paper on one slide in just one minute (in 45 seconds in our case, to be precise). As was to be expected, these advertisements differed very much between presenters. In any case, the sessions were good fun, and we can proudly state that several other conference organisers spontaneously announced to adopt this format at their own events.

Despite all this, the absolute highlight of Networking 2009 was the social event, held in the evening of 12 May. It started off with a concert in the 1200 years old Aachen Cathedral. The singer, Heike Schuhmacher, is the sister-in-law of the system administrator of the i4 chair at RWTH Aachen University. This was followed by a dinner at the Coronation Hall at the venerable Aachen Town Hall. At this occasion, Dr. Peter Reichl, ftw Vienna (an ‘Informatik 4’ alumnus) presented Italian songs at least as good as Luciano Pavarotti.

And, most spectacularly, we had arranged a performance by three artistic cyclists of ‘his’ cycling club – Iris Jungbluth (women singles), and Nicole Fürch and Angie Koepsel (women doubles); Nicole and Angie just missed the German championship by a very small margin. You can imagine that their show was absolutely stunning. I mention this to highlight that computer scientists are not necessarily just blinkered specialists ….

The video can be watched via http://www.networking-2009.org/multimedia/impressions.html.

In conclusion, Networking 2009 in Aachen was a wonderful event that will be fondly remembered by all participants for a very, very long time.

“And Networking” is “Before Networking” (adapted from Sepp Herberger, the German football national team coach in 1954) – the next event of the series will be held 10 – 14 May in Madras (Chennai), India.
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.

Degree: Diploma

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

Registered students: 1320 (total number in fall term 2009)

Female rate: approx. 11.25 %

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

Registered students: 590 (total number in fall term 2008)

Female rate: approx. 12.5 %

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.

Degree: Magister/Magistra Artium

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

Required Qualifications

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

Overall Structure

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

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

Stage II

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

Professional Areas

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

The subject of computer science at school

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

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

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

An overview of the curriculum

Within the computer science curriculum, the first two years are concerned with basic foundations. The following courses have to be passed (each of them accompanied by practical exercises): Introduction to Programming, Computer Structures, Data Structures and Algorithms, System Programming, and Automata and Formal Languages. In addition, a software practicum and a 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 acquaintance with abstract methods and constructions as they are learned and trained in mathematics. Moreover, the ability to communicate with others (and of course, in particular with children) is a necessary condition for future success as a teacher.
The International Master Programme
Software Systems Engineering

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

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

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

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

Since September 2004, Software Systems Engineering is also part of the Erasmus Mundus programme European Master in Informatics, which is offered together with the University of Edinburgh and the University of Trento. Participating students receive a two-year scholarship and spend the middle two semesters at one of the partner universities. At the end of the programme, they receive a double degree.
Media Informatics Master 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
Department of Computer Science 4
Media Informatics Team
52056 Aachen, Germany
E-Mail: msc-mi@b-it-center.de
Webpage: [http://mi.b-it-center.de/](http://mi.b-it-center.de/)
The *Girls’ Day* is organized nationwide once a year to provide an opportunity for 10- to 16-year-old female pupils to gain insight into professions in technical areas and in the domain of science. In 2009, a workshop was jointly organized by several computer science institutes and was attended by twelve pupils.

The full-day workshop consisted of two parts: In the morning, the workshop was organized as an interactive walk through computer science where several institutes presented selected research projects. In the afternoon, the girls were involved more actively by programming a little robot by themselves.

Starting with a game to get to know each other and a short introduction to studying computer science at RWTH Aachen University, the Media Computing Group presented the SLAP project, an interactive table which uses real controls like knobs or keyboards to interact with the computer. The girls had the chance to experiment with this device themselves. Afterwards, the RatPack project of the Distributed Systems Group, which uses programmable sensor nodes to analyze social networks of rats, was illustratively presented to the girls. The Computer Graphics Group showed a dynamic fluid simulation allowing the girls to interact with the flow by inserting obstacles or manipulating flow characteristics. A three-dimensional visualization of the city of Aachen closed the projects presentations. All demonstrations were followed by the girls with high interest.

In the second part of the workshop, the basic elements of programming a computer were playfully introduced to the girls by programming a little robot using Lego Mindstorms. After a brief introduction of the graphical programming interface, the girls were able to implement simple programs to accomplish basic tasks like moving the robot for a prescribed distance. With increasing experience, the tasks grew in their complexity and at the end of the day, the robots performed complex task like following a curved line on the floor or safely navigating around obstacles. At several instances, the girls reported the tasks they had chosen together with the problems arising and their strategies how they finally solved the problems.

The combination of research presentations and actively participating in the workshop by programming a robot was greatly appreciated by the girls in a closing discussion.
# Courses Taught in 2009

## Undergraduate Courses – Summer Term

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**Undergraduate Courses – Winter Term**

**Prüfung Einführung in High-Performance Computing**

Bücker  

Kl

**Programmierung**  
Bischof, Heinen, Lülfesmann, Otto,  
VT (4)

**Programmierung (Globalübung)**  
Bischof, Heinen, Lülfesmann, Otto,  
Ü (2)

**Programmierung (Übung - Tutorial)**  
Bischof, Heinen, Lülfesmann, Otto,  
ÜT (2)

**Klausur Programmierung**  
Bischof,  
KIT

**Einsicht Klausur Programmierung**  
Bischof

**Klausur Programmierung (Wdhlg.)**  
Bischof,  
KIT

**Einführung in die Technische Informatik**  
Kowalewski, Barakat, Diab, Franke  
VT (4)

**Einführung in die Technische Informatik**  
Kowalewski, Barakat, Diab  
Ü (2)

**Klausur Einführung in die Technische Informatik**  
Kowalewski,  
KI

**Klausur Einführung in die Technische Informatik (Wdhlg.)**  
Kowalewski,  
KI

**Analysis für Informatiker**  
Jongen  
V (4)

**Analysis für Informatiker**  
Jongen, Günzel, Shikhman  
ÜT (2)

**Analysis für Informatiker (Diskussion in Gruppen)**  
Jongen, Günzel, Shikhman  
ÜT (1)

**Klausur Analysis für Informatiker (1. Klausur)**  
Jongen,  
KIT

**Klausur Analysis für Informatiker (2. Klausur)**  
Jongen  
KIT

**Diskrete Strukturen**  
Hanke, Hiß  
V (2)

**Diskrete Strukturen**  
Hanke, Hiß  
Ü (1)

**Klausur Diskrete Strukturen**  
Hanke, Hiß  
KI

**Klausur Diskrete Strukturen (Wdhlg.)**  
Hanke, Hiß  
KI

**Schein Klausur Einführung in die Technische Informatik**  
Kowalewski, Barakat, Diab  
KIT (0)

**Betriebssysteme und Systemsoftware**  
Spaniol, Thißen, Krempels  
V (4)

**Betriebssysteme und Systemsoftware**  
Spaniol, Krempels, Kritzner, Sasnauskas, Thißen  
Ü (2)

**Betriebssysteme und Systemsoftware (Übungsgruppe 1)**  
Thißen, Spaniol, Krempels, Kritzner, Sasnauskas  
Ü (2)

**Klausur Betriebssysteme und Systemsoftware**  
Spaniol,  
T

**Klausur Betriebssysteme und Systemsoftware (Wdhlg.)**  
Spaniol  
KI

**Berechenbarkeit und Komplexität**  
Vöcking, Skopalik, Keßelheim  
V (3)

**Berechenbarkeit und Komplexität**  
Vöcking  
Ü

**Klausur Berechenbarkeit u. Komplexität**  
Vöcking  
KIT

**Klausur Berechenbarkeit und Komplexität (Wdhlg.)**  
Vöcking  
KI

**Numerisches Rechnen**  
Esser  
V (3)

**Numerisches Rechnen (Vorkurs)**  
Esser  
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### Graphics (Wiederholungsklausur)

- **Designing Interactive Systems I - Nachschreibeklausur**
  - Borchers, Herkenrath, Lichtschlag, Mennicken
  - Kl (V4/Ü2 (V4/Ü1))

- **Designing Interactive Systems I - Klausur (8 Credits)**
  - Borchers, Herkenrath, Lichtschlag, Mennicken
  - Kl (V4/Ü2 (V4/Ü1))

- **Web Technologien (WebTech 1)**
  - Schroeder, Herding, Brauner
  - KT (3+2)

- **Einführung in iPhone Anwendungsprogrammierung**
  - Borchers, Diehl, Heller
  - VT (V2Ü3)

- **Einführung in iPhone Anwendungsprogrammierung (Übung)**
  - Borchers, Diehl, Heller
  - Ü (V2Ü3)

- **Einführung in iPhone Anwendungsprogrammierung - Klausur (6 Credits)**
  - Borchers, Diehl, Heller
  - Kl (V2Ü3)

- **Einführung in iPhone Anwendungsprogrammierung - Naschreibeklausur (6 Credits)**
  - Borchers, Diehl, Heller
  - Kl

- **Designing Interactive Systems I - Klausur (6 Credits)**
  - Borchers, Herkenrath, Lichtschlag, Mennicken
  - Kl (V4/Ü2 (V4/Ü1))

- **Einführung in iPhone Anwendungsprogrammierung - Klausur (3 Credits)**
  - Borchers, Diehl, Heller
  - Kl (V2)

- **Einführung in iPhone Anwendungsprogrammierung - Naschreibeklausur (3 Credits)**
  - Borchers, Diehl, Heller
  - Kl

- **Seminar: Logik, Komplexität, Spiele**
  - Grädel
  - ST (2)

- **Languages for Scientific Computing I**
  - Bientinesi
  - VPT (V3/ÜE1)

- **Verhandlungsstrategie - Theorie und Praxis**
  - Mohnen
  - E (2)

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### Postgraduate Courses – Summer Term

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<td>Seminar: Aktuelle Themen der Virtuellen Realität</td>
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<td>IT-Sicherheit 2</td>
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<td>Communication Systems Engineering 2 - Simulation, Evaluation and Analysis</td>
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<td>Prozesse und Methoden beim Testen von Software</td>
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<td>Machine Learning</td>
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**Postgraduate Courses – Winter Term**

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<td>Compilerbau</td>
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<td>Espinosa Carlin, Thißen, Spaniol</td>
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<td>Komplexitätstheorie und Quantum Computing</td>
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<tr>
<td>Bachelor-/Masterprüfung</td>
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<tr>
<td>Master-Mentorenprogramm: Software &amp; Kommunikation</td>
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<tr>
<td>Modellbasierte Softwareentwicklung</td>
<td>Rumpe, Kurpick</td>
<td>VÜT (2+3)</td>
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<tr>
<td>Modellbasierte Softwareentwicklung (Wdh.)</td>
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<tr>
<td>Planung und Entwicklung eines interaktiven Gebäudeinformationssystems</td>
<td>Borchers, Rumpe, Wehrle, Ringert, Weingärtner</td>
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<tr>
<td>Komponentenbasierte Softwareentwicklung am Beispiel von Android</td>
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<tr>
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Technologies for Wireless Mesh Networks
   Spaniol, Thißen, Zimmermann, Krebs, Hannemann  S (2)
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   Wehrle, Götz, Kunz  VÜT (3+1)
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   Wehrle, Götz, Kunz  Ü (3+1)
Schriftliche Klausur zu Massively Distributed Systems I (Peer-to-Peer Systems and Applications)
   Wehrle, Götz, Kunz  KI (3+1)
Schriftliche Nachholklausur zu Massively Distributed Systems I (Peer-to-Peer Systems and Applications)
   Wehrle, Götz, Kunz  KI (3+1)
Formale Methoden für eingebettete Systeme
   Schlich, Brauer, Kamin  VÜT (3+1)
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   Kowalewski, Schlich, Brauer, Kamin  KI
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   Kowalewski, Gückel, Brauer, Kamin  ST (2)
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   Jarke, Quix, Li, Chatti  VÜT (V3/Ü2)
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Klausur Implementierung von Datenbanken (Wiederholung)
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Klausur Web Science II
   Jarke, Klamma, Petrushyna  VT (V2/Ü1)
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Introduction to Artificial Intelligence
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   Lakemeyer, Beck, Claßen  VÜT (V3/Ü2)
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<tr>
<td>Web Technologies (WebTech 1)</td>
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<tr>
<td>Security in Mobile Communications</td>
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<td>Examination Security in Mobile Communications</td>
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<tr>
<td>IT Security 1 - Network Security</td>
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<td>Cryptography I</td>
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<td>Master-Mentorship Program: Applied Informatics</td>
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<td>Pattern Recognition and Neural Networks</td>
<td>Ney, Schröter</td>
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<td>Examination Pattern Recognition and Neural Networks</td>
<td>Ney, Schröter, Ratajczak, Wiesler</td>
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<td>Automatic Speech Recognition</td>
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<td>Basic Techniques in Computer Graphics</td>
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<td>Basic Techniques in Computer Graphics</td>
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<td>Computer Graphics, Geometry Processing, and Computer Vision</td>
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<td>Designing Interactive Systems I</td>
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<td>Designing Interactive Systems I - Klausur (6 Credits)</td>
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<td>Virtuelle Realität</td>
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Computer Science Colloquium – Talks

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

15.09.2009: Multi-Table Stream Mining
Frau Prof. Dr. Myra Spiliopoulou, Otto-von-Guericke-Universität Magdeburg

23.07.2009: Präferenzenbasiertes Lernen von Ähnlichkeitsanfragen auf der Grundlage der Quantenlogik
Prof. Dr. Ingo Schmitt, Technische Universität Cottbus

02.07.2009: Enhancing Utilities of Frequent Patterns
Vivekanand Gopalkrishnan, Ph.D., Nanyang Technological University Singapore

09.07.2009: DBLP und bibliometrische Evaluationen?
Dr. Michael Ley, Universität Trier

19.06.2009: Privacy-aware outsourcing of metric data
Frau Dr. Ira Assent, Aalborg University, Dänemark

05.06.2009: Thorn: Robust, Concurrent, Extensible Scripting on the JVM
John Field, IBM T.J. Watson Research Center

08.06.2009: IEEE 802 - Standards and Processes
Jim Carlo, J. Carlo Consulting LLC

30.04.2009: Optimal Solutions for Spatially Continuous Labelling Problems
Prof. Dr. Daniel Cremers, University of Bonn

23.04.2009: Computable Analysis and Dynamic Systems
Dr. Pieter Collins, CWI Amsterdam

Dr. Clemens Greleck, University of Amsterdam, University of Hertfordshire

16.04.2009: Implementation of Distributed Loop Scheduling Schemes on the TeraGrid
Prof. Dr. Anthony T. Chronopoulos, University of Texas at San Antonio

16.04.2009: Towards Motor Skill Learning in Robotics
Jan Peters, Ph.D., MPI for Biological Cybernetics

29.01.2009: Verminderung der Abbrecherquote: Zwei Modelle für den Studienbeginn – Erfahrungen an der TU Darmstadt
Prof. Dr.-Ing. M. J. Hampe, Verfahrenstechnik, TU Darmstadt
Prof. Dr. K. Weihe, Fachbereich Informatik, TU Darmstadt

05.02.2009: Database as a Service
Prof. Dr. Alfons Kemper, Ph.D., TU München

22.01.2009: Algorithms for Large-Scale Matching Problems
Prof. Nikos Mamoulis, Ph.D., University of Hong Kong

Dr. Kai Jakobs, RWTH Aachen
08.12.2008:  *Proving Termination with Size Change Graphs: Theory, Practice & (Boolean) Satisfaction*
Prof. Dr. Michael Codish, Ben-Gurion University, Beer-Sheva, Israel

04.12.2008:  *Algorithmisch handhabbare kontextfreie Spezifikationen*
Dr. Christof Löding, RWTH Aachen
# Diploma and Master Theses

## Diploma theses

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<td>Susanne</td>
<td>Aghassi</td>
<td>Technische Unterstützung der verteilten, kollaborativen Bearbeitung von vorlesungsbegleitenden Projekt- und Übungsaufgaben (Technical Support of Collaborative Work on Weekly Assignments in Higher Education)</td>
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<tr>
<td>Bettina</td>
<td>Akkapurathu</td>
<td>Integriertes Profiling von Datenbankanwendungen (Integrated Profiling of Database Applications)</td>
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<tr>
<td>Michael</td>
<td>Arens</td>
<td>Animationstransfer zwischen Figuren basierend auf kompatibler Segmentierung (Character Animation Transfer Based on Compatible Segmentation)</td>
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<tr>
<td>Senol</td>
<td>Arikan</td>
<td>Entwicklung einer Systemarchitektur und Middleware zum dezentralen Datenmanagement in wandelbaren Produktnetzwerken (Development of a System Architecture and Middleware for Decentral Management of Data within Flexible Production Networks)</td>
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<tr>
<td>Christoph</td>
<td>Außem</td>
<td>Visualisierung multidimensionaler Projektstatusdaten im Anlagenbau (Visualization of Multidimensional Project Status Data in Plant Engineering)</td>
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<tr>
<td>Corinna</td>
<td>Baldauf</td>
<td>Flexibles, Probabilistisches Clustering zur Verfolgung von Konzeptänderungen in Datenströmen (Flexible Probabilistic Clustering for Concept Drift Detection in Streaming Data)</td>
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<tr>
<td>Marion</td>
<td>Beckers</td>
<td>Strukturen der Pushdown-Hierarchie und Prädikate natürlicher Zahlen (Structures of the Pushdown Hierarchy and Predicates of Natural Numbers)</td>
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<td>Hicham</td>
<td>Benkirane</td>
<td>Konzeption und Implementierung einer VOIP-Lösung für den Einsatz im untertägigen Bergbau (Design and Implementation of a VOIP Solution for the Application in Underground Mining)</td>
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<tr>
<td>Andreas</td>
<td>Besting</td>
<td>Waveletbasierte Methoden zur physiologischen Frequenz- und Synchronisationsanalyse (Wavelet-based Methods for Analysis of Frequency and Synchronization in Physiological Data)</td>
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<td>Canan</td>
<td>Bicer</td>
<td>Erstellung einer ENUM-Architektur für die Daimler AG (Modelling of an ENUM Architecture for the Daimler AG)</td>
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<td>René</td>
<td>Bohne</td>
<td>Luminet: ein organisches, interaktives Beleuchtungsnetzwerk (Luminet: an Organic Interactive Illumination Network)</td>
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<td>René</td>
<td>Boulnois</td>
<td>Effiziente Konsistenzprüfung in objektrelationalen Datenbanken für elektronische Kommunikationssysteme (Efficient Consistency Checking in Object Relational Databases for Electronic Communication Systems)</td>
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<td>Omar</td>
<td>Bouraga</td>
<td>Wissensbasierte NC-Prozessplanung auf Basis vorangegangener Bearbeitungsfälle (Knowledge-based Planning of NC Processes on the Basis of Previous Cases)</td>
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<td>Philipp</td>
<td>Brauner</td>
<td>Konzeption, Entwicklung und Analayse eines greifbaren Turtles in Hinblick auf die Steigerung der Computerselbstwirksamkeit von Schülerinnen und Schülern (Design, Implementation and Analysis of a Tangible Turtle with Special Consideration of Increased Computer Self-Efficacy of School Students)</td>
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<td>Ruth</td>
<td>Breuer</td>
<td>Untersuchung zur Akteur-Netzwerk Struktur in 35.000 Schulen (Actor-Network Analysis of 35.000 Schools)</td>
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<tr>
<td>Christian</td>
<td>Brockly</td>
<td>Auswertung von direkter Manipulation für Videonavigation innerhalb von Szenen (Evaluation of direct manipulation techniques for in-scene video navigation)</td>
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<td>André</td>
<td>Brosig</td>
<td>Automatische Extraktion von Epiphysen-Regionen aus Handradiographien (Automatic Extraction of Epiphyseal Regions from Hand-Radiographs)</td>
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<td>Marcel</td>
<td>Campen</td>
<td>Ein Framework für Geometrieverarbeitung basierend auf hybriden Oberflächendarstellungen (A Framework für Geometry Processing based on Hybrid Surface Representations)</td>
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<td>Tobias</td>
<td>Campmann</td>
<td>Dynamisch erzeugte Reparaturaktionen für die Wiederherstellung der Konsistenz zwischen Dokumenten (Dynamically Generated Repair Actions for Restoring Consistency between Documents)</td>
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<td>Daniel</td>
<td>Derieth</td>
<td>Konzepte zur datenreduktion großer Prozessdatenbanken (Concept for Data Reduction of Large Process Data Bases)</td>
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<td>Yue</td>
<td>Di</td>
<td>Modellierung und Erkennung von Formteilen anhand von 3D-Fourierdeskriptoren (Shape Modelling and Recognition Using 3D Fourier Descriptors)</td>
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<td>Dieter</td>
<td>Drobny</td>
<td>Ein sensorgestütztes System zur Unterstützung von Tanzanfängern (A Sensor Based System to Support Dance Beginners)</td>
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<td>Ramona</td>
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<td>Entwurf und Entwicklung einer modularen Simulations- und Testumgebung für Steuergeräte in Automobilanwendungen (Design and Implementation of a Modular Simulation- and Test-Environment for Electronic Control Units in Automotive Applications)</td>
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<td>Ismail</td>
<td>Durmaz</td>
<td>Konzeption und Implementierung einer Datenflussverwaltung in einem Relais-fähigen Multi-Mode MAC-Protokoll (Conception and Implementation of a Flow Management in a Relay Capable Multi-Mode MAC Protocol)</td>
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<td>André</td>
<td>Egners</td>
<td>Implementierung und Evaluierung von versteckten Diensten basierend auf offenen Standards (Implementation and Evaluation of Hidden Services Based on Open Standards)</td>
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<tr>
<td>Fabian</td>
<td>Emmes</td>
<td>Automatische Terminierungsanalyse von Kontextsensitiven Termersetzungssystemen (Automated Termination Analysis of Context-Sensitive Term Rewrite Systems)</td>
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<tr>
<td>Martin</td>
<td>Eul</td>
<td>Entwicklung und Analyse informationsgetriebener Mechanismen zur Optimierung dynamischer Flughafen-Anzeigesysteme (Development and Analysis of Data-driven Mechanisms to Optimize Dynamic Flight Information Display-Systems)</td>
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<td>Daniel</td>
<td>Ewert</td>
<td>Entwicklung einer Softwarearchitektur eines kognitiven Interaktionssystems zur Planung und Steuerung eines Montageprozesses (Development of a Softwarearchitecture for a Cognitive Interaction System for Planning and Controling an Assembly Process)</td>
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<tr>
<td>Ines</td>
<td>Färber</td>
<td>Mining orthogonaler Konzepte in hochdimensionalen Datenbanken (Mining Orthogonal Concepts in High-Dimensional Databases)</td>
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<tr>
<td>Alina</td>
<td>Forster</td>
<td>Design und Implementierung einer Simulation zum Testen von Regler- und Kollisionswarnalgorithmen und kritischen Fahrsituationen (Design and Implementation of a Simulation to Test Control and Collision Warning Algorithms and Critical Driving Situations)</td>
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<tr>
<td>Michael</td>
<td>Förster</td>
<td>Verifikation von Datenabhängigkeiten in Ableitungscode (Verification of Data Dependencies in Derivatives Codes)</td>
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<td>Dominik</td>
<td>Franke</td>
<td>Verifikation der Java Echtzeitfähigkeit für den Einsatz in zeitkritischen Systemen (Verification of the Java Real-Time Capability for Deployment in Time-Critical Systems)</td>
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<tr>
<td>Sebastian</td>
<td>Franken</td>
<td>Konzeption und Evaluation einer web-basierten Faceted Browsing Anwendung für ein Groupware-System (Conception and Evaluation of a web-based Faceted Browsing Application for a Groupware System)</td>
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<tr>
<td>Wladimir</td>
<td>Fridman</td>
<td>Kontextfreie Sprachen und das Church'sche Problem der Controller-Synthese (Context-Free Languages and Church's Problem of Controller Synthesis)</td>
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<td>Sergej</td>
<td>Fries</td>
<td>Mehrklassenbäume für Anytime Bayes Klassifikation (Multi-Class Trees for Anytime Bayes Classification)</td>
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<tr>
<td>Juri</td>
<td>Ganitkevitch</td>
<td>Lexikalische Wort-Trigger für statistische maschinelle Übersetzung (Lexical Triggers for Statistical Machine Translation)</td>
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<tr>
<td>Yan</td>
<td>Gao</td>
<td>Web 2.0 Learning Communities für chinesische, klassische Poesie (Web 2.0 Learning Communities for Chinese Classical Poetry)</td>
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<tr>
<td>Tobias</td>
<td>Gaß</td>
<td>Verformungen und Diskriminative Modelle für Bilderkennung (Deformations and Discriminative Models for Image Recognition)</td>
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<tr>
<td>Richard</td>
<td>Gay</td>
<td>Interrupt-Basierte verdeckte Kanäle aus der Perspektive eines Angreifers (Interrupt-Related Covert Channels from an Attacker's Perspective)</td>
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<tr>
<td>Borys</td>
<td>Gendler</td>
<td>Reengineering von Compilern zu einem Beispiel (Reengineering of Compilers - An Example)</td>
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<tr>
<td>Sascha</td>
<td>Geulen</td>
<td>Online Interferenze Scheduling (Online Interference Scheduling)</td>
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<tr>
<td>Nils</td>
<td>Gräf</td>
<td>Mandantenfähige SharePoint Server in Hostingumgebungen (Multi-Client Capable SharePoint Server in Hosting Environments)</td>
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<tr>
<td>Felix</td>
<td>Gremse</td>
<td>Robuste Navigation in geschlossenen Räumen (Robust Navigation in Indoor Environments)</td>
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<tr>
<td>Ralf</td>
<td>Grossmann</td>
<td>Heapabstraktion durch partielle Graphreduktion mittels Graphgrammatiken (Heap Abstraction by Partial Graph Reduction Using Graph Grammers)</td>
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<tr>
<td>Katja</td>
<td>Gruber</td>
<td>Sichten auf visuelle Graphspezifikationen (Views on Visual Graph Specifications)</td>
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<td>Demitrius</td>
<td>Haak</td>
<td>Kombinination zweier Ansätze zur Konfiguration von variantenreichen Simulinkmodellen (Concination of two Approaches for Configuring Simulink Models Rich in Variants)</td>
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<tr>
<td>Christoph</td>
<td>Halmes</td>
<td>Performanzanalyse von Trouble Ticket und Workorder Systemen (Performance Analysis of Trouble Ticket and Work Order Systems)</td>
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<tr>
<td>Stefan</td>
<td>Hamacher</td>
<td>Förderung explorativen Lernens durch ein XML-Framework zur strukturierten Erfassung und webbasierten Präsentation von Wissensgebieten (Facilitation of Explorative Learning with an XML-Framework for Structured Capture and Web-Based Presentation of Knowledge Areas)</td>
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<tr>
<td>Ji-Hyoung</td>
<td>Han</td>
<td>Eine deklarative Semantik für eine Untermenge von PDDL (A Declarative Semantics for a Subset of PDDL)</td>
</tr>
<tr>
<td>Paul</td>
<td>Hänsch</td>
<td>Lösung unendlicher Spiele mit parametrisierten Spezifikationen (Solving Infinite Games with Parameterized Specifications)</td>
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<tr>
<td>Florian</td>
<td>Heller</td>
<td>Umsetzung eines interaktiven Erlebnisses in visuell unantastbaren Räumen mit Hilfe von kontinuierlichen virtuellen Audio-Räumen (Realizing an Interactive Experience in Visually Untouchable Rooms Using Continuous Virtual Audio Spaces)</td>
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<tr>
<td>Sven</td>
<td>Hendriks</td>
<td>Integration einer effizienten Systemdiagnose in einen automatischen Versuchsträger mit Drive-by-Wire Architektur (Integration of an Efficient System Diagnosis into an Automotive Experimental Vehicle with a Drive-by-Wire Architecture)</td>
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<tr>
<td>Gerrit</td>
<td>Hentschel</td>
<td>Anatomische Modellierung der Atemwege für eine automatisierte Segmentierung und Beschriftung (Anatomical Modelling of the Airway Tree for Automated Segmentation and Labelling)</td>
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<tr>
<td>Kai</td>
<td>Herings</td>
<td>Entwicklung einer generischen Zuweiseanbindung niedergelassener Ärzte an die Krankenhaus-Middleware (Development of a Generic Hospital Referral System)</td>
</tr>
<tr>
<td>Anke</td>
<td>Hilgers</td>
<td>Neue Anwendungsbereiche für taktiles Feedback (Exploring New Domains for Tactile Feedback)</td>
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<tr>
<td>Sarah</td>
<td>Horsten</td>
<td>Untersuchungen an Sboxen für kompakte Implementierungen in symmetrischen Chiffren (Analysis of Sboxes for Compact Implementations in Symmetric Ciphers)</td>
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<td>Changhong</td>
<td>Huang</td>
<td>Vergleich von Mechanismen zur Replikation in strukturierten Peer-to-Peer Systemen (Comparison of Replication Mechanism in Structured Peer-to-Peer Systems)</td>
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<td>René</td>
<td>Hummen</td>
<td>Sichere Identitätsbasierte Funktionen für Netzwerkstrukturalemente mit dem Host Indentity Protokol (Secure Identity-based Middlebox Functions using the Host Identity Protocol)</td>
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<tr>
<td>Stefan</td>
<td>Hurtz</td>
<td>Modellierung von Sicherheitsaspekten in einer service-orientierten und modellgetriebenen Anwendungslandschaft (Modelling of Security Concerns in a Service Oriented and Model Driven Environment)</td>
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<tr>
<td>Mareike</td>
<td>Jacobs</td>
<td>Design und Erkennung von taktilen Icons beim Snowboardfahren (Design and Recognition of Tactile Icons for Snowboarding)</td>
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<tr>
<td>Armin</td>
<td>Jäger</td>
<td>Algorithmen für spezielle Graphfärbungsprobleme bei der Berechnung von Jacobi-Matrizen (Algorithms for Special Graph Colouring Problems in the Computation of Jacobian Matrices)</td>
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<tr>
<td>Nils</td>
<td>Holger</td>
<td>Automatendefinierbare Baumrelationen mit Anzahlbedingungen (Automaton-definable Tree Relations with Cardinality Constraints)</td>
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<tr>
<td>Martin</td>
<td>Jansen</td>
<td>Entwicklung eines generischen Qualitätsmodell-Editors und Auswertungswerkzeuge (Development of a Generic Quality Model Editor and Evaluation Tool)</td>
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<tr>
<td>Xiuli</td>
<td>Jiang</td>
<td>MAGIC: Datenzugriff durch Generierung und Übersetzung von Abbildungen (MAGIC: Data Access Based on Mapping Generation and Compilation)</td>
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<tr>
<td>Nadine</td>
<td>Joswig</td>
<td>Robustes kollaboratives Filtern (Robust Collaborative Filtering)</td>
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<td>Hyuk</td>
<td>Jung</td>
<td>Array-Analyse zur Ermittlung paralleler Threads in Sequentiellen Applikationen (Array-Analysis for Discovery of Coarse-Grained Application Parallelism)</td>
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<tr>
<td>Volker</td>
<td>Kamin</td>
<td>Erweiterung der symbolischen Zustandsdarstellung in [mc]square (Extending the Symbolic Representation of States in [mc]square)</td>
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<tr>
<td>Dennis</td>
<td>Kasprzyk</td>
<td>Optimierte Benutzerschnittstelle für Geometrie-Algorithmen (Optimized User Interface for Geometry Algorithms)</td>
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<tr>
<td>Thomas</td>
<td>Keßelheim</td>
<td>Paket-Scheduling mit Interferenz (Paket Scheduling with Interference)</td>
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<td>Maziar</td>
<td>Khodaei-Estiar</td>
<td>Management von Unsicherheiten in mobilen kontextbezogenen multimedialen Systemen (Data Uncertainty in Mobile Context-Aware Multimedia Systems)</td>
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<tr>
<td>Henning</td>
<td>Kiel</td>
<td>Minimierung mentaler Kontextwechsel während der Programmierung</td>
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<tr>
<td>Rifat</td>
<td>Kilic</td>
<td>(Minimizing Mental Context Switches During Programming)</td>
</tr>
<tr>
<td>André</td>
<td>Kolbe</td>
<td>Untersuchung der Anwendbarkeit des Timed Testings in der Eisenbahn-Signaltechnik (Analysis of the Practicability of Timed Testing in Railway Signalling)</td>
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<tr>
<td>Denise</td>
<td>Költner</td>
<td>Validierung und Evolution eines Workflow-Editors auf Basis einer Use Case zentrierten Anforderungsspezifikation (Validation and Evolution of a Workflow-Editor based on a Use Case Centered Requirement-Specification)</td>
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<tr>
<td>Tim</td>
<td>Kosse</td>
<td>Messen von Performance-Metriken in drahtlosen multi-hop Netzwerken (Measuring Performance Metrics in Wireless Multi-Hop Networks)</td>
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<td>Volker</td>
<td>Krause</td>
<td>Kollaborative Lokalisierung von Middle Size League Fußballrobotern (Collaborative Localization of Middle Size League Soccer Robots)</td>
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<tr>
<td>Lars</td>
<td>Krecklau</td>
<td>Interaktive Prozedurale Stadtrekonstruktion (Interactive Procedural City Reconstruction)</td>
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<tr>
<td>Alexander</td>
<td>Kreimer</td>
<td>Entwurf und Implementierung eines Konzepts zur Visualisierung und Optimierung dezentral durchgeführter Auftragsfeinplanung in kleinen und mittelständischen Unternehmen (Design and Implementation of a Visualization and Optimization Concept for Decentralized Detailed Job Order Planning in Small and Medium Sized Enterprises)</td>
</tr>
<tr>
<td>Markus</td>
<td>Kucay</td>
<td>Profilbasierte Dienstsuche in Wireless Mesh Netzwerken (Profile-based Service Discovery in Wireless Mesh Networks)</td>
</tr>
<tr>
<td>Sven</td>
<td>Kulle</td>
<td>Dynamische Bindungsverwaltung für ressourcenbeschränkte eHome-Systeme (Dynamic Management of Bindings for Resource-Constrained eHome Systems)</td>
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<tr>
<td>Thomas</td>
<td>Kurpick</td>
<td>Werkzeuggestützte Prüfungen dynamischer Prozesse (Tool-supported Checks of Dynamic Processes)</td>
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<tr>
<td>Henning</td>
<td>Lategahn</td>
<td>Entwicklung eines texturbasierten Analyseverfahren zur Klassifikation von Darmpolypen für Narrow-Band-Endoskopie (Development of a Textured Based Analysis Algorithm for the Classification of Color Polyps in Narrow-Band Endoscopy)</td>
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<tr>
<td>Inigo</td>
<td>Lazcanotegni Larrarte</td>
<td>Unterstützung der Implementierung von Graphsprachen mittels visueller Spezifikationen (Supporting the Implementation of Graph Languages Using Visual Specifications)</td>
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<tr>
<td>Alexander</td>
<td>Leider</td>
<td>Parallelisierung des ACCESS Schalengenerators unter Berücksichtigung moderner Mehrkern-Rechnerarchitekturen (Parallelization of ACCESS Shellgenerators with Consideration of Modern Multi-Core Computer Architecture)</td>
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<tr>
<td>Leonhard</td>
<td>Lichtschlag</td>
<td>Ein organisches Autorenwerkzeug für Präsentationen (An Organic Authoring Tool for Presentations)</td>
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<tr>
<td>Andreas</td>
<td>Lintermann</td>
<td>Oberflächenrekonstruktion des menschlichen Nasenkanals aus CT-Daten für strömungsmechanische Analysen von Atembeschwerden (Surface Reconstruction of the Human Nasal Cavity from CT-Data for Fluid Mechanical Analysis of Breathing Problems)</td>
</tr>
<tr>
<td>Christoph</td>
<td>Lischkowitz</td>
<td>Erweiterung von BugzillaMetrics zur Auswertung von Daten aus Versionskontrollsystemen (Extension of BugzillaMetrics for Mining Version Control System Data)</td>
</tr>
<tr>
<td>Carsten</td>
<td>Logen</td>
<td>Eine Service Registry zur automatisierten Komposition von REST- und Web Services (Global Service Registry-Automating Mashups of REST-and Web Services)</td>
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<tr>
<td>Ulrich</td>
<td>Loup</td>
<td>Entscheidungsprobleme über dem Bereich der reellen Zahlen (Decision Problems in the Domain of Real Numbers)</td>
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<tr>
<td>Daniel</td>
<td>Marcinkowski</td>
<td>Cision Problems Over the Domain of the Real Numbers</td>
</tr>
<tr>
<td>Stefan</td>
<td>Mau</td>
<td>Design und Evaluierung eines Disk-Schedulers basierend auf Sorting-Buffers (Design and Evaluation of a Disk Scheduler using Sorting Buffers)</td>
</tr>
<tr>
<td>Sarah</td>
<td>Mennicken</td>
<td>Paralleler und verteilter Aufbau des Zustandsraums im Model-Checker [mc] Square (Parallel and Distributed Construction of the State Spaces in the Model Checker [mc] Square)</td>
</tr>
<tr>
<td>Alexander</td>
<td>Mertens</td>
<td>Meta Modell eines simoKIM-Workflows und Prototyp eines simoKIM Workflow-Editors (Meta-Model for a simoKIM-Workflow and Prototype of a simoKIM Workflow Editor)</td>
</tr>
<tr>
<td>Hanno</td>
<td>Middelhaufe</td>
<td>Entwicklung einer Bibliothek zur Simulation von Eingriffsbedingungen bei der mehrachsigen Fräsbearbeitung (Development of A Library for Simulating Engagement Conditions During Multi-axis-Milling)</td>
</tr>
<tr>
<td>Marc</td>
<td>Neumann</td>
<td>Integrierte Visualisierung von multiple, heterogenen Simulationsdaten in virtuellen Umgebungen (Integrated Visualization of Multiple Heterogenous Simulation Data in Virtual Environments)</td>
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<tr>
<td>Martin</td>
<td>Niedermote</td>
<td>Architekturmodellierung und -texturierung basierend auf Fotos (Modeling and Texturing Architecture from Photographs)</td>
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<tr>
<td>Denise</td>
<td>Nimmerrichter</td>
<td>Feature Linien für Quadremeshing (Feature Lines for Quadrangular Remeshing)</td>
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<td>Nsombo</td>
<td>Niandi</td>
<td>Weiterentwicklung eines Regelungssystems zur Einspritzratenformung (Further Development of an Injection Rate Shaping Control System)</td>
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<td>Martin</td>
<td>Oczko</td>
<td>Ansätze zur Verschlüsselung von Network Attached Storage (NAS) (Approaches to Network Attached Storage Encryption)</td>
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<tr>
<td>Jens</td>
<td>Otten</td>
<td>Entwurf und Evaluation einer dynamisch re-konfigurierbaren und erweiterbaren Cross-Layer-Signalisierungsarchitektur (Design and Evaluation of a Dynamically Reconfigurable and Extendable Cross-Layer Signalling Architecture)</td>
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<tr>
<td>Dennis</td>
<td>Pannhausen</td>
<td>Induktives Policy-Lernen (Inductive Policy Learning)</td>
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<tr>
<td>Christine</td>
<td>Pape</td>
<td>Identifikation von Invarianten in Transportprotokollen und deren flexible Komposition in Kommunikationssystemen (Identification of Invariants in Transport Protocols and their flexible Composition in Communications Systems)</td>
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<td>Michael</td>
<td>Parting</td>
<td>Terminierungsanalyse mit Dependency Pairs und Induktionsbeweisen (Termination Analysis with Dependency Pairs using Inductive Theorem Proving)</td>
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<td>Sebastian</td>
<td>Patzak</td>
<td>Aktive WLAN-Positionierung (Active WLAN Positioning)</td>
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<td>Martin</td>
<td>Plücker</td>
<td>Terminierung von Integer-Termersetzungssystemen (Termination of Integer Term Rewrite Systems)</td>
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<td>Fei</td>
<td>Qin</td>
<td>Adaptives OFDMA Scheduling für 3GPP-LTE (3GPP-LTE Adaptive OFDMA Scheduling)</td>
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<td>Wenyun</td>
<td>Quan</td>
<td>Strategien mit Verzögerung in unendlichen Spielen (Finite-Delay)</td>
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<td>Arne</td>
<td>Rache</td>
<td>Entwicklungs- und Bewertung eines skalierbaren und angriffsresistenten Verfahrens zur Verteilung von Netzinformationen in einem Anonymisierungsnetz (Design and Evaluation of a Scalable and Attack Resistant Technique for Network Information Distribution in Anonymization Networks)</td>
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<tr>
<td>Dominik</td>
<td>Renzel</td>
<td>MobSOS-Ein Testbett für Mobile Multimedia Community Dienste (MobSOS-A Testbed for Mobile Multimedia Community Services)</td>
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<tr>
<td>Marcus</td>
<td>Reul</td>
<td>Verbessern der Benutzbarkeit von Software zur Steuerung von Industrieanlagen (Bringing Usability to Industrial Control Software)</td>
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<tr>
<td>Georg</td>
<td>Richlofsky</td>
<td>Analyse von Softwareentwicklungs- und Wartungsprozessen auf Basis von Change Request Daten (Analysis of Software Development and Maintenance Processes Based on Change Request Data)</td>
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<tr>
<td>Daniel</td>
<td>Rose</td>
<td>Benutzermodellierung in Privatsphäre schützenden mobilen eHomes. (User Modeling in Privacy Protecting, Mobile eHomes)</td>
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<tr>
<td>Dominik</td>
<td>Sandjaja</td>
<td>Entwicklung und Evaluierung von Methoden und Gegenmaßnahmen beim Website-Fingerprinting (Development and Evaluation of Methods and Counter-measures for Website Fingerprinting)</td>
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<tr>
<td>Ingo</td>
<td>Schaarschmidt</td>
<td>Web 2.0 Unterstützung für die sportinformatische Video-Annotation am Beispiel Volleyball (Web 2.0 Support for Video Annotation in the Sport Informatic Domain of Volleyball)</td>
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<td>Henning</td>
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<td>Bewertung der Prozessqualität von Open-Source-Entwicklungsprojekten auf Basis von Software-Prozessdaten (Process Quality Assessment of Open Source Projects Based on Software Process Data)</td>
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<tr>
<td>Michel</td>
<td>Schanen</td>
<td>Parallele Monte Carlo Integration in heterogenen diskreten Unterräumen des IR3 (Parallel Monte Carlo Integration in Heterogeneous Discrete Subspaces of IR3)</td>
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<td>Patrick</td>
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<td>Analyse von Fast-Flux Service Networks (Analyzing Fast-Flux Service Networks)</td>
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<td>Matthias</td>
<td>Schiffer</td>
<td>Outlier Mining mittels lokaler Dichteschätzung in statistisch relevanten Projektionen (Outlier Mining via Local Density Estimation in Statistically Relevant Projections)</td>
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<tr>
<td>Dirk</td>
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<td>Platzierung von OpenMP-Programmen auf hierarchischen Speicherarchitekturen (Placement of OpenMP Programs on Hierarchical Memory Architectures)</td>
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<td>Marc Andre</td>
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<td>Erarbeitung und Implementierung von Methoden zum automatisierten Komponententest für Embedded Software (Development and Implementation of Methods for Automated Component Test of Embedded Software)</td>
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<td>Volker</td>
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<td>Analyse von diffuser indirekter Beleuchtung (Analysis of Diffuse Indirect Illumination)</td>
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<tr>
<td>Ulrich</td>
<td>Schrempp</td>
<td>Branch-And-Price Verfahren für das Traveling Tournament Problem (Branch-And-Price Algorithms for the Traveling Tournament Problem)</td>
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<td>Till</td>
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<td>Strukturorientierte Analyse von Internetströmen (Structure Oriented Analysis of Internet Stream)</td>
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<td>Ifan</td>
<td>Simsek</td>
<td>Identifizierung von Invarianten in verteilten Hash Tabellen und deren modulare Implementierung (Identification of Invariants in Distributed Hash Tables and their Modular Implementation)</td>
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| Marcel      | Soboll      | Prozessmodellierung der mobilen Datenerfassung für den Rettungsdienst beim Massenanfall von Verletzten (Process modeling of
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<tr>
<td>Gunter</td>
<td>Spöcker</td>
<td>Konzeption und Implementierung eines Frameworks für CAM-Module am Beispiel der Laserstrukturierung (Conception and Implementation of a Framework for CAM Modules using the Example of Laser Ablation)</td>
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<tr>
<td>Philip</td>
<td>Stadermann</td>
<td>Untersuchung von Algorithmen zur Inline-Inspektion komplex texturierter Kunststoffoberflächen (Analysis of Algorithms for the Inline-Inspection of Plastics Surfaces with Complex Textures)</td>
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<tr>
<td>Konstantin</td>
<td>Steinhauer</td>
<td>Beziehungen zwischen Integrationsregeln: Unterstützung durch Werkzeuge (Tool Support for Relationships Between Integration Rules)</td>
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<td>Nils-Per</td>
<td>Steinmann</td>
<td>Inhaltsbasiertes Attribute-Matching zur Klassifikation von Werkzeugdaten (Content-based Attribute Matching for the Classification of Cutting Tool Data)</td>
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<td>Martin</td>
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<td>Relevance-Feedback auf Bildsignaturen mittels EMD (Relevance Feedback on Image Signatures Using the EMD)</td>
</tr>
<tr>
<td>Jan Manuel</td>
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<td>Optimierte CSG-Scankonvertierung für die NC-Abtragssimulation (Optimized Scan Conversion of CSG for NC Milling Simulation)</td>
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<tr>
<td>Sven</td>
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<td>Weiterentwicklung einer Softwarearchitektur für ein Rapid-Control-Prototyping-System für den Einsatz als Motorsteuerung (Further Development of a Software Architecture for a Rapid Control Prototyping System Used as an Engine Control Unit)</td>
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<tr>
<td>Christoph</td>
<td>Tillmann</td>
<td>Vergleichende Untersuchung der Eignung von Software Entwicklungsplattformen für mobile Endgeräte für zukünftige mobile Anwendungen (Comparative Study of the Suitability of Software Development Platforms for Mobile Devices for next Generation Mobile Applications)</td>
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<tr>
<td>Christian</td>
<td>Tummel</td>
<td>Entwurf, Implementierung und Test eines Algorithmus zur Bestimmung der Fahrzeugreihenfolge basierend auf GPS-Signaturen (Design, Implementation and Test of an Algorithm to Determine the Order of Vehicles - Based on GPS Signatures)</td>
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<td>Merih Seran</td>
<td>Uysal</td>
<td>Quadratische Form Distanzen für Signaturen zur Ähnlichkeitssuche in Multimedia-Datenbanken (Quadratic Form Distances on Signatures for Similarity Search in Multimedia Databases)</td>
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<tr>
<td>Helga</td>
<td>Velroyen</td>
<td>Automatische Nicht-Terminierungsanalyse imperativer Programme (Automatic Non-Termination Analysis for Imperative Programs)</td>
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<tr>
<td>Matthias</td>
<td>Vianden</td>
<td>Entwurf und Realisierung eines Ansatzes zur Modernisierung der Architektur eines formularbasierten Informationssystems (Design and Realisation of an Approach for Architecture Modernisation of a Form-Based Information System)</td>
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<tr>
<td>Hanno</td>
<td>Vieten</td>
<td>Entwicklung eines CAM-Moduls zur Messfahrtplanung und Messdatenverarbeitung (Development of a CAM Module for Measuring Paths Planning and Processing of Measured Data)</td>
</tr>
<tr>
<td>Nicolai</td>
<td>Viol</td>
<td>Design und Evaluation von effizienter, verzögerungstoleranter Wegewahl in mobilen Sensornetzwerken (Design and Evaluation of Efficient Delay Tolerant Routing in Mobile WSNs)</td>
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<tr>
<td>Bodo</td>
<td>von der Heiden</td>
<td>Planspielportal für große (Studierenden-)Gruppen zur webbasierten Umsetzung von strategischen Lernspielen in Q-Key und Micro-Key (Business Game Portal for Large (Student-)Groups for Web-based Implementation of Strategic Educational Games Such as Q-Key and Micro-Key)</td>
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<td>Benjamin</td>
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<td>Modell ortsabhängiger Zugriffskontrollen auf Basis von RBAC und XACML (RBAC-Model of Location-Dependent Access Control Implemented with XACML)</td>
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<td>Julie</td>
<td>Wagner</td>
<td>Silikonbasierte Eingabegeräte für interaktive Tische mit Rückprojektion</td>
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<td>Lingxi</td>
<td>Wan</td>
<td>Eliminations Techniken auf CRS Darstellung linerisierter Berechnungsgraphen (Elimination Techniques on CRS Representation of Linerized Computaiona Graphs)</td>
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<td>Yan</td>
<td>Wang</td>
<td>CONTICI Dashboard für community-bewusstes Requirements Engineering (The CONTICI Dashboard for Community-Aware Requirements Engineering)</td>
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<td>Iris</td>
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<td>Untersuchung und Umsetzung einer modellgetriebenen Transformation von Simulink-Modellen zur Produktlinienverwaltung (Analysis and Realization of a Model-Driven Transformation of Simulink Models for Product Lines)</td>
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<td>Thomas</td>
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<td>Entwurf, Implementierung und Validierung einer Java-basierten Benutzerschnittstelle zur Simulation von Kegelrad Frasprozessen (Design Implementration and Validation of a Java Based User Interface for Simulation of Bevel Gear Cutting)</td>
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<td>Jörg</td>
<td>Wernerus</td>
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<td>Log-Linear Mixture Models für Patch-basierte Objekterkennung (Log-Linear Mixture Models for Patch-based Object Recognition)</td>
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<td>Sumedha</td>
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<td>Sascha</td>
<td>Christian Wiedenfeld</td>
<td>Techniken zur Exploration großer Datenmengen mittels multidimensionaler Skalierung (Techniques for Exploring Large Datasets via Multidimensional Scaling)</td>
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<td>Analyse und Reengineering eines regelbasierten Lizenzmanagementsystems (Analysis and Reengineering of Rule-based License Management Systems)</td>
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<td>Julian</td>
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<td>Systematische Unterstützung zur Auswahl von Hardwareplattformen eingebetteter Systeme auf Basis eines interaktiven Webtools (Systematic Support for Hardware Platform Selection in Embedded Systems Based on an Interactive Webtool)</td>
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<td>Daniel</td>
<td>Wilms</td>
<td>Kontextsensitives 'Application Mash-Up' in öffentlichen Räumen mit heterogener Dienstumgebung (Context Aware Application Mash-Up in Public Places with Heterogeneous Service Environments)</td>
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<td>Moritz</td>
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<td>Laufzeitkontrolle von Diensten in dynamischen eHome-Systemen (Runtime Control of Services in Dynamic eHome Systems)</td>
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<td>Shu</td>
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<td>Shun</td>
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<td>Design-by-Contract für Plattformeigenschaften eingebetteter Systeme (Design-by-Contract for platform properties of Embedded Systems)</td>
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<td>Zerin</td>
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<td>Erweiterung von IMS Datenbanklösungen zum Ermöglichen kontextgestützter und personalisierter Entscheidungen im Netzwerk (Extension of IMS Database Solutions Enabling Context Aware and Personalized Decisions in the Network)</td>
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<td>Zustandsautomaten (Reengineering of Embedded Systems Using State Machines)</td>
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<td>Shanshan Zhang</td>
<td>Netzwerk-unterstütztes Raytracing für Echtzeit-Rendering (Network-Assisted Ray-Tracing for Real-Time Scene Rendering)</td>
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<td>Analyse und Visualisierung von flex und bison Automaten (Analysis and Visualization of Automata Generated by Flex and Bison)</td>
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<td>Martin</td>
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<td>Zeit-optimierte Gewinnstrategien in unendlichen Spielen (Time-Optimal Winning Strategies in Infinite Games)</td>
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<td>Ruben</td>
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<td>Werkzeuggestützte Variantenprogrammierung im Bereich Automotive (Tool-Supported Variant Programming for Automotive Systems)</td>
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<td>Cognitive Radio Management for Wireless Sensor Networks</td>
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<td>Ali</td>
<td>An Obligation Framework &amp; Language for Data Handling in Service Composition</td>
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<td>Efficient Implementation of a Platoon Controller Using a Rapid-Prototyping System</td>
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<td>Mobile Storytelling for Social Software Engineering</td>
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<td>Ivica</td>
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<td>Synthesizing an Instruction Set Simulator for Model Checking Embedded Systems Software</td>
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<td>Bommasandra Sadasiva</td>
<td>Deployment Algorithm for Programming Distributed Heterogeneous Sensor Environment</td>
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<td>Combining Social Networks with Context Awareness</td>
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<td>Query Rewriting using Generic Schema Mappings</td>
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<td>A Hero's Journey - A Template Engine for Non-linear Storytelling</td>
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<td>Security for Body Sensor Networks</td>
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<td>Dynamic Identity Provider Selection in a Context-Aware Information Rights Management System</td>
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<td>Development of a Fault-Tolerant Communication Protocol for a Safety-Exital Medical Application</td>
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<td>Mobile Access to LAS Services with Mobile Web Services</td>
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<td>Design and Implementation of Adaptivity Extensions of TinyOS</td>
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<td>Rasool</td>
<td>Model Checking Programs for the Renesas R8C/23 Microcontroller using [mc]square</td>
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<td>Sagbas</td>
<td>An Analysis of Application Scenarios for Network of Information</td>
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<td>Sonaimuthu</td>
<td>Concept and Prototype for the Automated Test Case Execution in a Mobile Environment</td>
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<td>Soncu</td>
<td>Web-based Administration Interface for Wireless Mesh Network</td>
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<td>Velina</td>
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<td>Testbed An Approach for Ontology Learning with Text Mining using Customer Reviews for Home Textile Products</td>
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<td>Dan</td>
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<td>Data Mining Algorithms on Multicare Architectures</td>
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<td>Schema Integration Using Conjunctive Mappings</td>
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**Master Theses Media Informatics**

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<td>Hasan</td>
<td>Abdel Halim</td>
<td>Implementation and Evaluation of Dynamic Source Routing Protocol Enhancements to Avoid Selfish Modes in Mobile Ad-hoc Networks</td>
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<td>Anggraeni</td>
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<td>PLEM: A Web 2.0 Driven Service for Personal Learning Management</td>
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<td>Nachiket</td>
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<td>A Metadata-Based Media Player for Viewing and Sharing of Streaming Content</td>
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<td>Zhanna</td>
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<td>Physics Abstraction Layer for Virtual and Augmented Reality Applications</td>
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<td>Process Support in the Emergency Management Domain</td>
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<td>Semi-Automatic Validation of Semantic Business Process Models</td>
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<td>Application of the SIOC Ontology for the Development of Workspace Interoperability in MS-Sharepoint</td>
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<td>Khamene Mohammadreza</td>
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<td>Development of a Semiautomatic Graffiti Tag Identification System</td>
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<td>Florian</td>
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<td>Robuste Logoerkennung in Farbdokumenten unter Verwendung regionenbasierter Formdeskriptoren (Robust Logo Recognition from Color Documents Using Region-Based Shape Descriptors)</td>
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<td>Resource Allocation and Access Control in a Dynamic Process Management System</td>
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<td>Disk-based Interface für Semantic Composition</td>
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<td>Computation of Saliency Maps in Street Videos Acquired by a Moving Camera</td>
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<td>Exchange of Graphical Data between Application Specific Software and COTS Software</td>
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<td>A Combinatory Categorial Grammar Parser in the Natural Language Toolkit</td>
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<td>Ali Sura</td>
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<td>Towards a Flexible, Modular Geodata Visualization System</td>
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<td>Dinesh</td>
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<td>Concept and Implementation for Context-Based Documents within Groupware Systems</td>
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<td>Ferry</td>
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<td>Data Continuity Service for Web Browser Application on Portable Storage Device</td>
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<td>Santana Alvarez</td>
<td>Time-based Video Annotation and Time-based Video Linking - A Concept Analysis Realized with the Joomla! Framework</td>
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<td>Design and Evaluation of a Minimally-Distraeting In-Car Video Communication System</td>
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<td>Honggi</td>
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<td>Image Clustering Using Machine Learning Algorithms</td>
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Some Statistics

Number of Diploma Students

Number of BSc Students
### Overall Number of Students and Graduations

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</table>
Research
Algorithms and Complexity

Staff

• Faculty
  Univ.-Prof. Dr. Berthold Vöcking (chair)
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  Dipl. Inform. Heiner Ackermann
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  Dipl. Inform. Alexander Fanghanel
  Dr. Simon Fischer (until March 2009)
  Dipl. Inform. Sascha Geulen (since October 2009)
  Dr. Martin Hoefer (since October 2007)
  Dipl. Inform. Thomas Kesselheim (since April 2009)
  Dipl. Math. George Mertzios
  Dipl. Inform. Marcel Ochel (since December 2007)
  Dipl. Inform. Alexander Skopalik

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

• Student Researchers and Teaching Assistants
  Nadine Bergener
  Johannes Dams
  Viktor Engelmann
  Oliver Göbel
  Alexander Heinsius
  Benjamin Kaminski
  Simon Keller
  Wied Pakusa
  Thomas Schleiden
  Robert Schulte
  Andreas Tönnis
  Lisa Wagner
  Faried Abu Zaid

• Guests
  Tobias Harks (TU Berlin)
  Piotr Krysta (University of Liverpool)
  Xavier Muñoz (UPC Barcelona)
  Harald Räcke (University of Warwick)
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. For example, the sequencing of the human genome would not have been possible without the invention of new algorithmic ideas speeding up computations by several orders of magnitudes.

The algorithms and complexity group works on the design and analysis of algorithms. Our core competences lie in the following areas:

- 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, graph algorithms, and probabilistic analysis of algorithms achieving various publications in leading conferences and journals.

Quite successfully, we started a new research direction dealing with algorithms for scheduling and power assignment in wireless networks, focusing on realistic networks models defined by SINR constraints. As newcomers in this field, 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 present results about SINR scheduling on major conferences in distributed computing and theoretical computer science. One of our papers about received a best paper award at ICALP 2009, and we were invited to provide a chapter in a new Spring-Book about Theoretical Aspects of Distributed Computing in Sensor Networks edited by Sotiris Nikoletseas and José D.P. Rolim. Together with other researchers working in this field, we will organize two workshops on this topic, one at Schloss Dagstuhl and one in Bergen, as satellite workshop of SWAT 2010.

In addition, we co-edited a new book with the title "Algorithms Unplugged" about some of the most beautiful algorithmic ideas presented in 42 articles written by different authors in colloquial English. Originally most of these articles have been produced within an initiative among German-language universities to communicate the fascination of algorithms and computer science to high school students during the Informatikjahr 2006. The book can be understood without any particular previous knowledge about algorithms and computing. Presumably, the book will be published by Springer at the beginning of next year. We hope that it is enlightening and fun to read not only for students but also for interested adults who want to get an introduction to the fascinating world of algorithms.
Research Projects

Altruism in Games and the Complexity of Nash Dynamics and Sink Equilibria

A. Skopalik, M. Hoefer
funded by GIF

Algorithmic game theory has been focused on game-theoretic models for a variety of important applications in the Internet. A fundamental assumption in these games, however, is that all agents are selfish. Their goals are restricted to optimizing their direct personal benefits, e.g. their personal delay in a routing game. The assumption of selfishness in the preferences of agents is found in the vast majority of present work on economic aspects of the Internet. However, this assumption has been repeatedly questioned by economists and psychologists. In experiments it has been observed that participant behavior can be quite complex and contradictive to selfishness.

This project studies the effects of introducing altruistic agents into several game theoretic models. Altruistic behavior is modeled by a trade-off between selfish and social objectives.

We investigate the existence of, the computational complexity of, and the speed of convergence to Nash equilibria in atomic congestion games and selfish load balancing with coordination mechanisms. In addition to these results for uncoordinated dynamics, we consider a scenario in which a central altruistic institution can motivate agents to act altruistically. We develop more general mechanisms to incentivize agents to adopt favorable behavior.

Studying Nash dynamics is an important approach for analyzing the outcome of games with repeated selfish behavior of self-interested agents. Sink equilibria has been introduced by Goemans, Mirrokni, and Vetta for studying social cost on Nash dynamics over pure strategies in games. However, they do not address the complexity of sink equilibria in these games. Recently, Fabrikant and Papadimitriou initiated the study of the complexity of Nash dynamics in two classes of games. In order to completely understand the complexity of Nash dynamics in a variety of games, we study the following three questions for various games: (i) given a state in game, can we verify if this state is in a sink equilibrium or not? (ii) given an instance of a game, can we verify if there exists any sink equilibrium other than pure Nash equilibria? and (iii) given an instance of a game, can we verify if there exists a pure Nash equilibrium (i.e., a sink equilibrium with one state)?

We investigated almost all of the above questions for a variety of classes of games with succinct representation, including anonymous games, player-specific and weighted congestion games, valid-utility games, and two-sided market games. In particular, for most of these problems, we show that (i) it is PSPACE-hard to verify if a given state is in a sink equilibrium, (ii) it is NP-hard to verify if there exists a pure Nash equilibrium in the game or not, (iii) it is PSPACE-hard to verify if there exists any sink equilibrium other than pure Nash equilibria. To solve these problems, we illustrate general techniques that could be used to answer similar questions in other classes of game.
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 protocols for distributed resource sharing in the context of symmetric congestion games. These protocols use a mix of imitation of successful strategies and exploration of the strategy space. With a careful combination of these ingredients this allows for favorable properties of the resulting dynamics, i.e. a large population of self-interested agents can reach an approximately balanced state rapidly. Also, we were able to show that for certain special cases these states result in near-optimal resource usage. Considering variants in which less global information is required, we analyzed protocols for symmetric load balancing problems with users that have quality of service constraints. In this case even rapid convergence to exactly stable states could be shown. This result can be extended to a case when the population of users is heterogeneous in their quality of service constraints. Finally, we studied a model that introduces graph-based locality and goes beyond a symmetric positioning of users. In this case we can still design efficient distributed algorithms, but the convergence times to stable states are significantly slower than in symmetric models. On the other hand, our protocols work not only for congestion games but can be seen as distributed algorithms for a large variety of games in this scenario.

For the following years we plan to address models related to frequency assignment, interference minimization, and request scheduling 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 adjusting request structure.

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.

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Theoretical Analysis of OFDMA Scheduling

M. Ochel, B. Vöcking

Orthogonal frequency division multiplexing (OFDM) has become an increasingly popular technology in the area of broadband communication. In this transmission scheme data is sent
in parallel over a number of narrowband orthogonal subcarriers instead of being transmitted in a single higher rate wideband data stream. The main advantage of this technique is its robustness to noise and inter-symbol interference.

If one of the subcarriers is shared by several users heavy interference could be caused. For this reason the shared usage of subcarriers is explicitly forbidden in OFDMA which is the composition of OFDMA and FDMA (frequency-division multiple-access) as a medium access technology.

Engineers implementing OFDMA are facing the following inherent optimization problem: how to find the 'best' assignment of subcarriers to users (e.g., the one with the lowest overall power consumption)? While answering this question is NP-hard in general, some restricted versions of this problem are accessible to theoretical analysis and allow the construction of efficient exact or approximation algorithms.

Finding important subproblems and developing polynomial time algorithms with provable worst-case bounds is a main topic of this project.

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Reducing the Price of Anarchy in Wardrop's Traffic Model

L. Olbrich, M. Hoefer, A. Skopalik

funded by AlgoSyn.

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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 agent 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.

Mathematical Analysis of and 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.

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. 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 to bridge 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).

In particular, we came up with a measure of interference that allows us to easily estimate the number of channels/time slots that any algorithm needs at least to schedule some set of communication requests. This was complemented by an algorithm calculating an approximate solution.

Another problem is how to choose power levels for the different communication requests. In a distributed environment, it is sensible to make the decision which power a sender should use only dependent on the distance to its corresponding receiver. We proved that these oblivious power assignments can yield very long schedules in a certain model. However, in a different setting, taking a power proportional to the square root of the distance is nearly optimal.

A third aspect to mention is that, at the beginning, it is not clear which communication request will actually arise. Decisions have to be made without knowledge of the future. The field of online algorithms gives us definitions and tools to state under which circumstances we can guarantee a reasonable performance without knowledge of the future and when this is not possible.
In this project the problem of battery management in hybrid cars is studied. A hybrid car has two engines, one combustion engine operated with petrol, and one electrical engine using a battery. An algorithm has to decide at which time the battery for the electrical energy should be recharged by the combustion engine. For this purpose, the economical caching problem is considered. An online algorithm is given a sequence of prices for a certain commodity. It has to manage a buffer of fixed capacity over time. One unit of the commodity is consumed per time step. The algorithm can buy this unit at the current price, can take a previously bought unit from the storage, or can buy more than one unit at the current price and put the remaining units into the storage. In this context, prices correspond to the combustion efficiency which, e.g., depends on the rotational speed. Obviously, the economical caching problem is quite generic and one can think of multiple other applications beyond hybrid cars, e.g., purchasing petrol at gas stations where prices vary on a daily basis, caching data streams in a mobile environment in which services that operate at different price levels are available in a dynamic fashion etc.

We analyze this problem in a probabilistic analysis, i.e., the prices of the resource are modeled by a probabilistic input model. This way we want to synthesize algorithms which are able to solve this problem with low expected cost. Compared to a worst case analysis this leads to algorithms which perform better in practice.

Several special problems were considered during the last year:

For the Minimal Manhattan Network Problem in three dimensions (MMN3D), one is given a set of points in space, and an admissible solution is an axis-parallel network that connects every pair of points by a shortest path under L_1-norm (Manhattan metric). The goal is to minimize the overall length of the network. We show that MMN3D is NP- and APX-hard, with a lower bound on the approximability of 1+2•10^{-5}

Further improvement were made on the following problems:

- Interval Constrained Coloring,
- Xor Picture Generation by Rectangles and
- Isoparametric Graph Recognition.
Other Activities

Courses
Our group offered the following lectures and seminars:

**Winter semester 2008/09**
- Lecture on Algorithmic Cryptography
- Seminar on Special Graph Classes
- Proseminar on Complexity Theory
- Bridging Course on Theoretical Computer Science at BIT

**Summer semester 2009**
- Lecture on Network Algorithms
- Lecture on Efficient Algorithms
- Seminar on Algorithms for Wireless Networks
- Seminar on Algorithmic Cryptography
- Proseminar on Algorithm Theory
- 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 50th Annual IEEE Symposium on Foundations of Computer Science (FOCS), 2009
- Member of the program committee of Tenth ACM Conference on Electronic Commerce (EC), 2009
- Member of the program committee of Fifth Workshop on Internet and Network Economics (WINE), 2009
Talks and Publications

Talks


Martin Hoefer: *Concurrent Imitation Dynamics in Congestion Games*. Universität Freiburg, Germany, March 2009, Invited Talk.


George B. Mertzios: *A new intersection model and improved algorithms for tolerance graphs*. Lehrstuhlseminar Algorithmen & Komplexität, Computer Science 1, RWTH Aachen University, June 2009.

George B. Mertzios: *A new intersection model and improved algorithms for tolerance graphs*. 35th International Workshop on Graph-Theoretic Concepts in Computer Science (WG), Montpellier, France, June 2009.

George B. Mertzios: *The longest path problem is polynomial on interval graphs*. Lehrstuhlseminar Algorithmen & Komplexität, Computer Science 1, RWTH Aachen University, August 2009.


George B. Mertzios: *The recognition of tolerance and bounded tolerance graphs is NP-complete*. Discrete Mathematics Computer Science Seminar, University of Toronto (U of T), September 2009.


Marcel Ochel: *Approximability of OFDMA Scheduling*. 17th Annual European Symposium on Algorithms (ESA), Copenhagen, Denmark, September 2009.


Lars Olbrich: *Doing Good with Spam is Hard*. AlgoSyn Meeting, Aachen, Germany, July 2009.


### Publications


Kyriaki Ioannidou, George B. Mertziou, and Stavros D. Nikolopoulos. *The longest path problem is polynomial on interval graphs*. In Proc. of 34th International Symposium on


Staff

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

- **Secretary**
  Birgit Willms

- **Research Assistants**
  Dipl.-Inform. Joachim Kneis
  Dipl.-Inform. Alexander Langer
  Dipl.-Inform. Stefan Richter (until May 2009)
  Dr. rer. nat. Daniel Meister (since Oct. 2009)

- **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
- Anonymity in P2P Networks

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

We are particularly interested in solving NP-hard problems. Many problems relevant in practice are in this category, and hence often solved by inexact methods that do not necessarily output the optimal solution, although in the case of approximation algorithms, there still is a guarantee of how close the computed solution is to the exact one. While approximation algorithms are often very useful, they frequently have a very large running time even for rather bad approximation ratios. On the other hand, sometimes exact solutions are asked for, and we concentrate on such exact algorithms.

Research in the field of exact algorithms aims to improve the running time required to solve NP-hard problems. While it is commonly believed that NP-hardness of a problem implies an exponential worst-case running time, the asymptotic worst-case behavior can sometimes be neglected under practical considerations: For example, $1.25^n n < n^{10}$ for $2 < n < 217$, but an algorithm that requires $216^{10} \sim 2.2 \cdot 10^{23}$ steps is far from having practical relevance anyways. If the running time of the algorithm is therefore growing only moderately exponentially in the input size, then exponential running time is not necessarily a drawback in practice: It turns out that for example the classical Independent Set problem can be solved in $O(1.2132^n n^2 m)$ steps, and tests on instances of size up to 200 nodes reveal feasibility.

In the area of parameterized complexity, instances contain an additional parameter, and the goal is to find algorithms whose running time has exponential dependence on the parameter, but grows only polynomial in the input size. In practical instances the parameter is often very small compared to the input size, which yields surprisingly fast algorithms even for large inputs. On the other hand, one can sometimes improve the exponential running time by using parameterized algorithms and techniques. For example, the currently fastest exponential time algorithms for the Maximum Leaf Spanning Tree and Irredundant Set problems of $O^*(1.8966^n)$ and $O^*(1.96^n)$, respectively, were obtained using parameterized approaches.
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 to
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.

Towards Sharing Large Data Volumes in Privacy

Stefan Richter

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

Courses
Our group offered the following lectures and seminars:

Winter 2008/2009
• Lecture on "Parametrisierte Algorithmen"
• Seminar on "Helping Donald Knuth"

Summer 2009
• Lecture on "Formale Systeme, Automaten, Prozesse"
• Seminar on "Graphentheorie"
• Seminar on "Medizinische Bildverarbeitung" (with Deserno, Kobbelt, Ney, Seidl, Spitzer)
Talks and Publications

Talks


Publications


**Technical Reports**


Software Modeling and Verification

Staff

- **Professors**
  - Prof. Dr. Ir. Joost-Pieter Katoen PD
  - Prof. em. Dr. Klaus Indermark
  - Prof. Dr. Erika Ábrahám
  - [http://moves.rwth-aachen.de/](http://moves.rwth-aachen.de/)

- **Secretary**
  - Elke Ohlenforst

- **Lecturer**
  - AOR Priv.-Doz. Dr. Thomas Noll

- **Researchers**
  - Dr. Henrik Bohnenkamp
  - Xin Chen, M.Sc.
  - Dr. Tingting Han
  - Dipl.-Inform. Jonathan Heinen
  - Dipl.-Inform. Nils Jansen
  - Dr. Carsten Kern
  - Dipl.-Inform. Daniel Klink
  - Dipl.-Inform. Ulrich Loup
  - Dr. Etienne Lozes
  - Alexandru Mereacre, M.Sc.
  - Dipl.-Inform. Martin Neuhäußer
  - Viet Yen Nguyen, M.Sc.
  - Dr. Stefan Rieger
  - Dipl.-Inform. Haidi Yue

- **Technical Staff**
  - Arnd Gehrmann

- **Diploma/Master Students**
  - M. Bretsch
  - S. de Carolis
  - F. Fiedler
  - R. Grossman
  - C. Hapsari Ayuningtyas
  - C. Jansen
  - S. Herting
  - M. Kampschulte
  - M. Odenbrett
  - S. von Styp-Rekowski
P. Richter

- **Student Researchers**
  - M. Brockschmidt
  - B. Bruetsch
  - F. Dulant
  - C. Dehnert
  - D. Guck
  - F. Gretz
  - C. Kuhl
  - F. Korzilius
  - M. Maass
  - M. Sarej
  - M. Scheffler
  - V. Serebro
  - C. Xu

- **Visiting Scientists**
  - Tim Albu (Fraunhofer Institut for Lasertechnik, D)
  - Dr. Pieter Collins (CWI, NL)
  - Muhammad Fadlisyah (University of Oslo)
  - Marijn Jongerden (University of Twente, NL)
  - Prof. Dr. Bengt Jonsson (Uppsala University, S)
  - Natali Kalinnik (Albert-Ludwigs-University, D)
  - Prof. Dr. Barbara König (University of Duisburg-Essen, D)
  - Prof. Dr. Marta Kwiatkowska (Oxford University, UK)
  - PD Dr. Martin Leucker (TU München, D)
  - Daniela Lepri (University of Oslo, N)
  - Dr. Etienne Lozes (ENS Cachan, F)
  - Dr. Larissa Meinecke (Macquarie University, Sydney)
  - Dr. Anne Remke (University of Twente, NL)
  - Dr. Julien Schmaltz (Radboud University Nijmegen, NL)
  - Thomas Sturm (Universidad de Cantabria, SP)
  - Tino Teige (University of Oldenburg, D)
  - Daniel Wagner, (Imperial College, UK)
  - Dr. Michael Weber (University of Twente, NL)
  - Ralf Wimmer (Universität Freiburg, D)
  - Dr. Ivan Zapreev (CWI, NL)
  - Dr. Lijun Zhang (Universität des Saarlands, D)
Overview

In 2009, significant progress has been made in the international project Quasimodo, an EU FP7 project on the quantitative verification of embedded systems, and COMPASS, a project funded by the European Space Agency (ESA). Within the context of Quasimodo, major advances in the theory of probabilistic model checking have been achieved. Amongst others, important progress has been made on two long outstanding problems: verifying continuous-time probabilistic models against linear-time probabilistic specifications, and determining the optimal policy for time-bounded reachability probabilities in continuous-time Markov decision processes. These results form the basis for numerous new research challenges.

In the COMPASS project, together with the Italian research institute FBK (the group of Alessandro Cimatti) and the French company Thales Alenia Space (one of the leading companies in satellites), we are in the second year to convince the ESA that formal methods are pivotal to model and analyze both correctness and efficiency aspects of aerospace systems. A true and interesting challenge indeed. This spring a first prototypical tool was well-received by the ESA and at the time of writing this introductory, several students and assistants are active in realizing the final toolset which will be extensively tested by Thales Alenia Space. The toolset supports the automated verification of AADL models that are extended with timed, hybrid, and probabilistic error aspects. This is an important step towards bridging the gap between engineering languages (such as AADL) and mathematically rigorous verification. At ETAPS’09, we organized an international workshop with participation of e.g., the NASA Laboratory JPL, on COMPASS-related issues. Scientific results of the COMPASS project have been presented at several international conferences and events.

In the context of the Research Training Group ALGOSYN, we have worked on compositional abstraction techniques for nondeterministic and probabilistic models. First results show the enormous benefits of applying aggressive abstraction in a component-wise manner. Other activities in ALGOSYN concern parameter synthesis of stochastic models and the verification of hybrid systems.

Besides the above running projects, the junior research group "Theory of Hybrid Systems" of E. Ábrahám, embedded in the "Software Modeling and Verification" group, started new activities in different fields. The three main research topics are (1) the analysis and the state space representation for hybrid systems, (2) counterexample generation for probabilistic systems, and (3) SMT-solving for the real algebra and its application in hybrid system verification. We established international cooperation with several research institutes working in the above fields, and applied for fundings.

Last but not least, we took part in, and also initiated some events for the motivation, support, and information of pupils interested in computer science. The Cybermentor project, which we support with out participation, aims at mentoring female pupils interested in mathematics, natural sciences, computer science, and technology. We co-organized the pupil's university (Schüleruniversität) 2009. We also started the development of a sequence of videos informing teenagers about the contents of computer science.

2009 was a very successful year in terms of successful completions of doctoral studies. Three PhD students at the MOVES chair received their PhD degree. Carsten Kern successfully defended his dissertation on "Learning of Communicating and Nondeterministic Automata" on the last day of August, Stefan Rieger did the same in September with a thesis on "Verification of Pointer Programs", and finally, Tingting Han defended her dissertation both
in Twente and in Aachen, on "Diagnosis, Synthesis, and Analysis of Probabilistic Systems" in October. All dissertations were happily approved by national and international examiners.

The are happy to report on the three highly motivated PhD student Nils Jansen, Ulrich Loup, and Xin Chen who started their PhD studies 2009 in the junior research group.

We kindly welcome Dr. Etienne Lozes (ENS Cachan), an expert on calculi for mobile systems and heap-manipulating programs, to our chair. Funded by an Alexander von Humboldt grant, Etienne will stay at the MOVES group for 18 months as a visiting professor.

The steering committees of the international conferences QEST (Quantitative Evaluation of Systems, www.qest.org) and CONCUR (Concurrency Theory) have accepted our offer to organize these conferences as a joint event in the Super C building in September 2011. The possibility to host these two renowned conferences in Aachen can be seen as a recognition of the contributions of our CS department to these fields in the last decades.

Finally, we like to mention the enormous productivity and creativity of the researchers at the chair. Various high-quality papers have been produced, and important scientific advances have been achieved. An enormous effort has been made to handle the substantial teaching load, and all managerial and administrative issues.

It's an extremely enjoyable endeavour and very stimulating to work with such an active and talented team!

Joost-Pieter Katoen.
Research Projects

QUPES: Verification of Quantitative Properties of Embedded Software

T. Han, J.-P. Katoen, M. Neuhäusler

Embedded software typically executes on devices that, first and foremost, are not personal computers. Due to its embedded nature, its robustness is of prime importance, and timely reactions to stimuli from its -- mostly physical -- environment are essential. The aim of the QUPES project is to assess these quantitative aspects (e.g., timeliness and robustness) as an integral part of the embedded software validation phase.

To accomplish this, probabilistic model-checking techniques can be applied for models that are equipped with randomness and variants thereof which also exhibit nondeterminism. Based on efficient numerical methods and abstraction techniques, quantitative properties can be checked automatically even on large state space with millions of states using dedicated tools. Opposite to, amongst others, the essential feature of model checking, where evidences will be provided on a property refutation, counterexamples generation in probabilistic model checking is almost not developed. We provide the theoretical and algorithmic foundations for counterexample generation in probabilistic model checking, in particular for discrete-time Markov chains. One of the key principles is the casting of the concepts of strongest evidence and smallest counterexample as (variants of) shortest path problems. This enabled the use of efficient and well-studied graph algorithms for counterexample generation. These results can be extended to Markov chains with rewards, to Markov decision processes (MDPs), to LTL model checking, and have been recently been adopted in probabilistic counterexample-guided abstraction-refinement (CEGAR) techniques for MDPs as well as in counterexample generation for continuous-time Markov chains (CTMC) and cpCTL logic. Compact representation of a counterexample by regular expressions are also studied.

Further, compositional reasoning is a key strategy in analyzing complex systems as it allows the use of hierarchical and modular modeling formalisms like stochastic process algebras, stochastic activity networks or generalized stochastic Petri nets. Continuous-time Markov Decision processes (CTMDPs) are the nondeterministic counterpart of the aforementioned CTMCs and are well suited for compositional verification techniques. We define stochastic logics (like CSL) on CTMDPs and provide their measure-theoretic basis. Further, well-known equivalences like strong and weak bisimulation relations are adapted to CTMDPs which considerably reduce the state-space needed for quantitative analysis.

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.

In a first project phase, we concentrated on (possibly cyclic) singly-linked list data structures. A pointer logic for specifying heap properties with linear-time (LTL) operators for reasoning about system executions was developed, and finitary abstractions for the dynamic creation of both heap cells and processes were investigated. This framework supports the validation of temporal properties addressing absence of memory leaks, dereferencing of null pointers, dynamic creation of cells, and simple and position-dependent aliasing for list-manipulating programs.

Subsequently, 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. Again a temporal logic was employed to specify program properties.

This technique was successfully applied to dynamic data structures such as doubly-linked lists, binary and ternary trees (also with connected leafs), and red-black-trees. In particular, after implementing a prototype tool is was possible to establish the termination, correctness, and completeness of the well-known Deutsch-Schorr-Waite traversal algorithm in a fully automatic way.

Current focus is on improving the usability of the framework. As graph grammars for abstracting realistic heap data structures tend to become very large, developing them by hand is a complex and error-prone procedure. One promising approach that we follow is to adopt learning techniques to automatically derive abstraction grammars for the data structures occurring in the given program. Another strand of research concentrates on analyzing the (backward) confluenve properties of graph grammars, which guarantees the uniqueness of abstractions.
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 nondeterminism is therefore crucial for obtaining efficient tools for analysis and verification.

The goal of this project, carried out in close cooperation with the Embedded Software Laboratory of our department, is to develop formal computation models and state-space reduction techniques to tackle this problem. A first approach was taken by defining a general automata-based model for microcontrollers, taking into account both the hardware, the software, and the environment of the system. This model was used to prove the correctness of a particular abstraction method, called delayed nondeterminism, which resolves the uncertainties caused by undetermined input values only if and when this is required by the application code. More concretely, a simulation relation between the concrete and the abstract state space was established, thus showing the soundness of delayed nondeterminism with respect to "path-universal" verification logics such as ACTL and LTL. Current efforts concentrate on refining this technique using interval-based approaches.

Another source of nondeterminism is the potential occurrence of interrupts. Aiming at reducing the number of program locations where interrupt handlers have to be considered, a reduction technique was developed and proven correct which further reduces the state space that needs to be inspected. The effectiveness of this abstraction was demonstrated in several case studies.

**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 strongly based on 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 where components are defined by their type (interface) and implementation. Components communicate via ports allowing for message and continuous communication. The internal structure of a component implementation is specified by its decomposition into subcomponents, together with their HW/SW bindings and their interaction via connections over ports. Component behavior is 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 formal analysis techniques such as model checking and probabilistic variants thereof. The precise character of these techniques and the SLIM semantics yield a trustworthy modeling and analysis framework for system and software engineers. The formal analysis is based on state-of-the-art model checking techniques such as bounded SAT-based and symbolic model checking, and extensions of model checking with numerical and simulative means to reason about quantitative requirements such as performance and dependability. The analysis facilities support, among others: automated derivation of dynamic (i.e., randomly timed) fault trees, FMEA tables, assessment of FDIR, and automated derivation of diagnosability requirements.

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 studying critical on-board computer-based systems from the satellite domain. Another outcome of the project is a proposal for possible extensions of AADL, its Error Model Annex and the corresponding semantics, which are currently under investigation by the AADL standardization bodies. More information on the project is available at http://compass.informatik.rwth-aachen.de/.

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**Quasimodo**

*H. Bohnenkamp, H. Yue, J.-P. Katoen*

The MOVES group participates in the European research project ‘Quasimodo’, funded by the European Commission under the IST framework programme 7 for Information and Communication Technology, ICT.
The objective of the Quasimodo project is to develop theory, techniques and tool components for handling quantitative (e.g. real-time, hybrid and stochastic) constraints in model-driven development of real-time embedded systems. Ultimate aim is to increase the competitiveness of European industrial companies which develop, implement and deploy embedded systems.

More specifically, the project aims are:

1. Improving the modelling of diverse quantitative aspects of embedded systems.
2. Providing a wide range of powerful techniques for analysing models with quantitative information and for establishing abstraction relations between them.
3. Generating predictable code from quantitative models.
4. Improving the overall quality of testing by using suitable quantitative models as the basis for generating sound and correct test cases.
5. 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.

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

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

H. Bohnenkamp, C. Weise (i11), R. Mitsching (i11)

Testing is one of the most natural, intuitive and effective methods to increase the reliability of software. Formal methods have been employed to analyse and systematise the testing idea in general, and to define notions of correctness of implementations w.r.t. specifications in particular.

In cooperation with the company Scheidt & Bachmann in Moenchengladbach we work on a case study in the area of railway signaling and station management. Our goal is to gain experience on the problems that arise when applying a formal testing theory in practice. Ultimately we plan to develop a methodology which meets industrial requirements for application of the formal testing approach on a daily basis in real projects.

Part of this project is the development of a testing tool for timed testing, which is based on the tiocom testing theory. Work is in its early stages.

This project is in cooperation with i11.

Ultra High Speed Mobile Information and Communication

H. Bohnenkamp, J.-P. Katoen, H. Yue

Energy consumption is a core feature of the wireless networks which is receiving more and more attention in research. Three distinct levels for analysis of energy consumption can be identified which are strongly related but provide different abstraction levels: signal processing level, radio link level, network level (operation as well as deployment planning). Our mean is model checking technique and our goal is to provide insight to theoretical bounds on the energy consumption at any of these three levels and minimize the energy consumption of the network. More precisely, given a protocol or an algorithms, after making some necessary simplifying assumptions regarding the system models and scenarios considered, we can model it in an appropriate model checker (e.g. PRISM, SPIN, MRMC or UPPAAL, etc.). By applying probabilistic model checking technique, we can then not only verify quantitative or qualitative properties (e.g. is it deadlock free?) of diverse network but also predict some network features with respect to energy consumptions. For example, in the field of radio network, what is the expected value of energy consumption to elect a leader. In contract to simulation based techniques, model checking explores the whole system states and hence provide theoretical soundness.
This project aims at keeping female pupils interested in the MINT sciences (mathematics, computer science, natural sciences, technology). The female teenagers (mentees), get a female mentor assigned, who supports her with clarifying informations and helpful suggestions for their choice of study. We support the project with our participation.
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).
- Board Member of the Dutch Society on Theoretical Computer Science (NVTI).
- Senior member of the Association of Computing Machinery (ACM)
- Member of the Program Committee of the following events: FORMATS 09, PSI 09, SOFSEM 09, YR-CONCUR 09.
- Invited speaker at:
  - Nordic Workshop on Programming Theory
  - IFIP WG 2.2 on Programming Concepts and Methodology
  - CDC Workshop on Stochastic Hybrid Systems
- Member of the IFIP Working Group 1.8 on Concurrency Theory.
- Member of the EPSRC Review College (Engineering and Physical Sciences Research Council), UK.
- Member of the NWO Computer Science Evaluation (VENI) Committee
- Organizer of the CONCUR Workshop for Young Researchers, Bologna, Italy, September 2009.
- Guest Professor at MacQuarie University, Sydney, Australia, March 2009.
- Member of several external PhD committees.

Th. Noll

- Program committee member of the 4th International Workshop on Systems Software Verification (SSV 2009)
- Program committee member of the 3rd IEEE International Conference on Secure System Integration and Reliability Improvement (SSIRI 2009)
- Program committee member of the 2nd IEEE International Conference on Secure System Integration and Reliability Improvement (SSIRI 2008)
- Member of the examination boards for CS Bachelor and Master
- Student advisor for the following applied subjects within CS: Electrical Engineering, Civil Engineering, and Medicine
- Organization of teaching service of CS Department (http://www-i2.informatik.rwthaachen.de/Teaching/Service/)
Talks and Publications

Talks


Tingting Han. Quantitative model checking of continuous-time Markov chains against timed automata specifications. Talk at VOSS Meeting, University of Twente, NL, 2009.


**Publications**


Programming Languages and Verification

Staff

• Faculty:
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• Secretary:
  Elke Ohlenforst

• Research Assistants:
  Dipl.-Inform. Fabian Emmes (since January 2009)
  Dipl.-Inform. Carsten Fuhs (partially funded by GIF)
  Dipl.-Inform. Carsten Otto (funded by DFG, since October 2008)
  Dipl.-Inform. Martin Plücker (since September 2009)
  Dr. rer. nat. Peter Schneider-Kamp (until December 2008)
  Dipl.-Inform. Stephan Swiderski (funded by DFG, until March 2009)

• Student Assistants:
  Karsten Behrmann
  Marc Brockschmidt
  Tim Enger
  Christian von Essen
  Patrick Kabasci
  Andreas Kelle-Emden
  Christian Kuknat
  Lars Noschinski
  Michael Parting
  Ulrich Schmidt-Goertz
  Thomas Ströder
  Sebastian Weise

• Technical Staff:
  Arnd Gehrmann
Overview

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

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

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

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

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

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

In the winter term 2008/09, we held the first-year course on *Programming Concepts* for more than 500 students. We also offered a seminar on *Automated Termination Analysis*. In December 2008, together with the Lehrstuhl Informatik 2, we organized the annual *Tag der Informatik*. In the summer term 2009, Prof. Giesl was on a sabbatical.

Since October 2008, three new Ph.D. students joined our group: Carsten Otto, Fabian Emmes, and Martin Plücker. In January 2009, Peter Schneider-Kamp left our research group and took up an assistant professor position at the University of Southern Denmark. He defended his PhD thesis on December 8, 2008. His PhD thesis will be awarded with the *Friedrich-Wilhelm-Preis* for outstanding scientific contributions in November 2009. In March 2009, Stephan Swiderski left our research group and took up a position in a company in Aachen.
Research Projects

APROVE: Automated Program Verification Environment

J. Giesl, F. Emmes, C. Fuhs, C. Otto, P. Schneider-Kamp, S. Swiderski, R. Thiemann

We are developing a verification environment which allows a fast and easy implementation of new approaches and techniques for program verification. In this way, their practical applicability can be evaluated and experiments can be performed to develop heuristics which increase their degree of automation. The system is designed in a modular way such that the implemented tools can be extended and modified easily.

Our verification framework is also applicable for teaching purposes in courses on formal methods, term rewriting, or program verification. The tool is written in Java and verification can be performed both in fully automated or interactive mode via a graphical user interface.

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

http://aprove.informatik.rwth-aachen.de/

Termination Analysis for Functional and Imperative Programs

J. Giesl, F. Emmes, S. Swiderski, P. Schneider-Kamp, R. Thiemann, C. Otto, M. Raffelsieper

The goal of this project (funded by the DFG) is to use the wealth of techniques developed for termination analysis of term rewrite systems in order to perform automated termination analysis for “real” programming languages as well. To this end, programs in these languages
have to be translated into term rewrite systems. Then one can prove termination of the resulting term rewrite systems instead. However, it is not trivial to develop translations which yield rewrite systems that are suitable for an automatic analysis. We are working on such techniques for termination analysis of Haskell and Java. Our results are integrated in our system AProVE.

**Satisfiability Checking for Termination Analysis and Termination of Java Bytecode**

*J. Giesl, C. Otto, M. Codish, M. Brockschmidt, C. von Essen, C. Fuhs, A. Middeldorp, P. Schneider-Kamp, R. Thiemann*

This project is partially funded by the GIF and is a collaboration with the Ben-Gurion University, Israel, and the University of Innsbruck, Austria. Here, we work on new efficient algorithms to tackle the search problems arising in automated termination proofs. In particular, our goal is to encode them as SAT problems in a suitable way and to investigate the use of SAT solvers in automated termination analysis. Examples for termination techniques where SAT solving leads to speedups by orders of magnitude are lexicographic and recursive path orders as well as polynomial orders. The tremendous increase in efficiency will allow us to adapt termination methods from term rewriting to new application areas like termination analysis of Java Bytecode.

**Termination Analysis for Context-Sensitive Rewriting**

*J. Giesl, F. Emmes, S. Lucas, P. Schneider-Kamp, C. Fuhs, R. Thiemann, R. Gutiérrez, C. Otto*

This project is funded by the DAAD. In collaboration with the UP Valencia, Spain, we develop and improve techniques for termination analysis of programs with specific evaluation strategies. One way of expressing such strategies is the use of context-sensitive evaluation restrictions. In this context, we are also investigating the automation of modified versions of termination techniques like polynomial orders on real or rational numbers with SAT solving.

**Termination Proving for Systems with Integers**

*J. Giesl, M. Plücker, P. Schneider-Kamp, S. Falke, C. Fuhs, C. Otto, L. Noschinski, D. Kapur*

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

Connecting Termination Proving and Inductive Theorem Proving

J. Giesl, S. Swiderski, P. Schneider-Kamp, C. Fuhs, M. Parting

There exist several natural algorithms whose termination proof requires the verification of a conjecture by mathematical induction. However, up to now all termination provers failed for such algorithms. The goal of this project is to connect termination proving and inductive theorem proving. To this end, we develop methods that detect suitable inductive conjectures during a termination proof and call an inductive theorem prover. Moreover, one has to integrate this approach with other existing termination methods. In addition, we are also investigating the use of inductive theorem proving for proofs of non-termination.

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 different well-known prover. In this project with the TU Munich and the University of Innsbruck, Austria, 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 proof is automatically certified by Isabelle afterwards.
Other Activities

J. Giesl:

- Program Co-Chair of the *International Joint Conference on Automated Reasoning (IJCAR '10)*, Edinburgh, UK, 2010
- Chair of the *IFIP Working Group 1.6 on Term Rewriting* and organizer of the WG 1.6 meeting 2009 (Brasilia, Brazil)
- Editor of a special issue of the *KI* journal on *Automated Deduction*, 2010
- PC-Member of the *22nd International Conference on Automated Deduction (CADE '09)*, Montreal, Canada, 2009
- PC-Member and participant of the *19th International Conference on Rewriting Techniques and Applications (RTA '09)*, Brasilia, Brazil, 2009
- PC-Member of the *9th International Workshop on Reduction Strategies in Rewriting and Programming (WRS '09)*, Brasilia, Brazil, 2009
- PC-Member of the *32nd Annual Conference on Artificial Intelligence (KI '09)*, Paderborn, Germany, 2009
- PC-Member of the *15th International Conference on Logic for Programming, Artificial Intelligence, and Reasoning (LPAR '08)*, Doha, Qatar, 2008
- 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*
- Participant of the *10th International Workshop on Termination (WST '09)*, Leipzig, Germany, 2009
- Participant of the *AlgoSyn Meeting*, Wassenberg, Germany, 2008
- Participant of the *TeReSe* workshop in Nijmegen, The Netherlands, November 2008
- Reviewer for several PhD theses: Peter Schneider-Kamp (RWTH Aachen, Germany), Manh Thang Nguyen (KU Leuven, Belgium), Stephan Falke (University of New Mexico, USA), Harald Zankl (University of Innsbruck, Austria)
- Reviewer for two habilitation theses: Georg Moser (University of Innsbruck, Austria), Étienne Payet (University of Réunion, France)
- Project Reviewer for the DFG (several projects) and the INRIA
- Reviewer for many international journals and conferences

F. Emmes:

- Research Visit (funded by the DAAD) at the UP Valencia, Spain, November 2008
• Participant of the TeReSe workshop in Nijmegen, The Netherlands, November 2008
• Participant of the 10th International Workshop on Termination (WST ’09), Leipzig, Germany, June 2009
• Reviewer for many international journals and conferences

C. Fuhs:
• Research Visit (funded by the DAAD) at the UP Valencia, Spain, November 2008
• Participant of the TeReSe workshop in Nijmegen, The Netherlands, November 2008
• Research Visit at CNAM Paris / INRIA Saclay Orsay, France, December 2008
• Research Visit at the University of Southern Denmark, Odense, Denmark, May 2009
• Participant of the 10th International Workshop on Termination (WST ’09), Leipzig, Germany, June 2009
• Participant of the Marktoberdorf Summer School on “Logics and Languages for Reliability and Security”, Marktoberdorf, Germany, August 2009
• Research Visit at the TU Munich, August 2009
• Research Visit (funded by the GIF) at the Ben-Gurion University, Beer-Sheva, Israel, September 2009
• Participant and editor of the proceedings 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
• Editor of the Department Of Computer Science Technical Reports of RWTH Aachen
• Reviewer for many international journals and conferences

C. Otto:
• Research Visit (funded by the DAAD) at the UP Valencia, Spain, November 2008
• Participant of the TeReSe workshop in Nijmegen, The Netherlands, November 2008
• Participant of the 10th International Workshop on Termination (WST ’09), Leipzig, Germany, June 2009
• Research Visit (funded by GIF) at the Ben-Gurion University, Beer-Sheva, Israel, July 2009
• Reviewer for many international journals and conferences
Talks and Publications

Talks

C. Fuhs: *SAT Modulo Non-Linear Arithmetic for Termination Analysis*, IMADA Computer Science Colloquium, University of Southern Denmark, Odense, Denmark, May 2009.
C. Otto: *Automated Termination Analysis of Java Bytecode, 10th International Workshop on Termination (WST ’09)*, Leipzig, Germany, June 2009.
J. Giesl: *Proving Termination of Integer Term Rewriting, 10th International Workshop on Termination (WST ’09)*, Leipzig, Germany, June 2009.
C. Fuhs: *Inductive Theorem Proving meets Dependency Pairs, 10th International Workshop on Termination (WST ’09)*, Leipzig, Germany, June 2009.

Otto: *Automated Termination Analysis of Java Bytecode*, Ben-Gurion University, Beer-Sheva, Israel, July 2009.


Fuhs: *SAT Modulo Non-Linear Arithmetic for Termination Analysis*, TU Munich, Germany, August 2009.


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

**Publications**


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  Dipl.-Wirt.-Inf. T. Gülke (since April 2009)  
  Dipl.-Wirt.-Inf. A. Haber (since July 2009)  
  Dipl.-Inform. T. Heer (DFG funded until June 2009)  
  Dipl.-Inform. C. Herrmann (since April 2009)  
  R. Jnidi, DAAD scholarship (since October 2009)  
  Dipl.-Inform. A. Körtgen (until August 2009, DFG funded until June 2009)  
  Dipl.-Inform. T. Kurpick (since April 2009)  
  Dipl.-Inform. C. Mengi (funded by DFG Graduate College)  
  Dipl.-Inform. A. Navarro Pérez (since October 2009)  
  Dipl.-Inform. C. Pinkernell (since January 2009)  
  Dipl.-Wirt.-Inform. H. Rendel (since January 2009)  
  Dipl.-Inform. D. Retkowitz  
  Dipl.-Inform. J. O. Ringert (since January 2009)  
  Dipl.-Inform. M. Schindler (since April 2009, EU funded)  
  Dipl.-Inform. S. Völkel (since February 2009, EU funded)  
  Dipl.-Inform. E. Weinell (until July 2009)  
  Dipl.-Inform. I. Weisemöller (since May 2009, EU funded)  
  Dipl.-Inform. R. Wörzberger

- **External Researchers/Members**
  Dipl.-Inform. M. Dukaczewski  
  Dipl.-Inform. (FH) F. Fieber, M.Sc.
Dipl.-Inform. D. Klar
Dipl.-Inform. H. Krahn
Dr. S. Kriebel
Dipl.-Wirt.-Inf. D. Reiss
Dipl.-Ing. F. Schroven
Dipl.-Inform. M. Stein
Dipl.-Inform. A. Zechner

• **Guest Researcher:**
  Dr. S. Maoz

• **Technical Staff:**
  MaTA M. Breuer (part time 50%)
  Dipl.-Math. (RUS) G. Volkova

• **Student Researchers:**
Overview

This academic year, starting at October 1\textsuperscript{st}, 2008 was characterized by a number of events. Professor Dr. Manfred Nagl received his emeritus status on August 1\textsuperscript{st}, 2009. To ensure a smooth transition, his successor Professor Dr. Bernhard Rumpe started already January, 1\textsuperscript{st}, both with teaching and research activities. So this year, we see quite a number of active researchers and their projects, because a substantial number of researchers also followed Professor Rumpe to his new university. As collateral event, the whole chair left its rooms during summer into interim rooms, while the home of “Informatik 3 (Software Engineering)” was substantially renovated. In June 26\textsuperscript{th} the Fachgruppe Informatik, the Faculty and the RWTH celebrated Professor Nagl’s retirement (Photos can be seen at the web as well as later in the report). Other activities were the opening of the “Software Engineering Laboratory” (SE-Lab) in order to foster application of engineering activities, the party after moving back to our rooms in combination with the “Student Open Night”.

While preserving the continuity of the software engineering research, the goals and research activities have also been adapted slightly and are cumulating in the SE mission statement:

Research domains are application of graph grammars and models for software development. At the heart of research lays the question, how to improve software development based on well-founded modelling techniques, either based on UML or on domain-specific languages (DSLs). While using and extending tools developed in-house, these tools as well as software engineering principles, practices, and methods were applied in the following application domains: e-home, business processes, web systems, energy monitoring, autonomous driving of cars, trucks and trains, requirements management, product line engineering, and management of complex function nets.

Funding comes from various sources, including DFG, EU and as major industrial partner, Volkswagen.

Link to research activities of the group: http://www.se-rwth.de/
Prof. Nagl’s retirement: http://www.se-rwth.de/emeritus/
Teaching

The group is engaged in teaching on undergraduate and graduate level for computer science and other students.

The following courses are offered for computer science in general and for the focus “Software Engineering”:

- Bachelor Seminar, every semester
- Bachelor Lab Course Software Development
- Introduction to Software-Engineering (L3+E2), winter
- Model-Based Software Engineering (L3+E2), winter
- Architectures of Software Systems (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,
- Graduate Lab Project in Software Engineering (E2), every semester
- Seminar on “New Topics of Software Engineering”, every semester
- Working group for graduate and postgraduate students, during the whole year

Link to education activities of the group:  http://se-rwth.de/teaching/
During development processes in chemical engineering, a plant is described from multiple inter-dependent perspectives by numerous logical documents, which are created by developers using different software tools. Between the contents of these documents fine-grained dependencies exist. The subject of this project were incremental and interactive tools (integrators) to support developers in consistency maintenance concerning these dependencies.

This project was funded by the Deutsche Forschungsgemeinschaft as subproject T5 of the Transfer Center 61, a follow-up project of B2 from the Collaborative Research Center 476, and ended in summer 2009. It was carried out in close cooperation with our industrial partner Comos Industry Solutions GmbH and aimed at extending the results of B2 and in transferring them to industry.

In B2, an approach was developed for a-posteriori integration. It is based formally on rules describing corresponding structures. Fine-grained dependencies are recognized and installed by the integrator by means of the rules. These dependencies are managed and stored explicitly in an integration document. Together with our industrial partner, an integrator framework was created, which contains an interpreter/compiler that can execute and/or interpret integration rules at runtime.

In T5, the approach was extended by means of so-called repair actions in cases once corresponding structures get inconsistent after changes have been performed on the source or target documents. Different kinds of repair actions are derived dynamically for such structures and are proposed to the user for re-establishing a rule-based state.

One major issue in supporting and accelerating the development of integrators - besides their configuration - concerns the integration rule modeling process. Usually, integration rules are modeled manually. Two approaches were introduced to induce integration rules from existing correspondence relationships either between (i) elements on the document level or (ii) types and attributes on the document model level. These correspondence relationships are established by a foregone correspondence analysis, which is also performed by an integration tool. Both correspondence analyses needed further rule language constructs when being applied with the integration approach to match similar structures and types.

Furthermore, there was a need to support relationships between rules, e.g., there are redundant parts modeled in multiple rules which have to be maintained. In 2009, the semantics of different relationship kinds were specified and a tool for their support was developed. In addition, these relationships provided a basis for a dependency analysis between executable rules during integration. They help the user with decisions when rules are conflicting.

For transferring the results to industry, the system Comos PT of Comos Industry Solutions played a central role. It is used during all engineering phases, e.g. for the creation of flow sheets. In 2009, a universal integrator platform for Comos PT was realized based on the integrator framework of B2. It implements the new concepts and comes along with easy to
use tools for rule modelling, interacting with the tool during integration. The results of T5 were part of the dissertation of Anne-Therese Körtgen who graduated in summer 2009.

**T6: Management of Dynamic Processes Based on Existing Systems**

R. Wörzberger, T. Heer, M. Nagl,
G. Volkova, C. Briem, C. Außem, S. Leong, F. Meyer, J. Hormes, A. Fischer, T. Kurpick, T. Lake

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

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

Together with Comos Industry Solutions we extended their main product, the Lifecycle Engineering System Comos. New workflow management functionality as well as process modification functionality of the AHEAD-prototype was integrated into Comos. This resulted in the component PROCEED (PROCess management Environment for Engineering Design processes). In the year under report we developed an integrated approach for time management and progress control. This includes the automatic scheduling of dynamic task nets based on workload estimates, where available resources are assigned to the defined tasks. The approach for progress measurement combines several techniques from practice and adds newly developed progress measures, which are specific for design processes represented as dynamic task nets. The previously developed solution for measuring the progress of running workflow instances has been integrated in the overall approach. Earned value analysis and the visualization of performance indices complete the solution. Additionally, a component was realized to import WPL process models and simulation results into PROCEED, which are provided by the prototypes of two other research groups of the transfer center.

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

“Energie Navigator” – a software framework for optimizing energy efficiency of buildings

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

The “Energie Navigator” project focuses on importing these data from different types of buildings and facilities. After data import the 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 (frontends) are implemented, e.g. a data visualization toolkit that visualizes data as line- or carpet-plots. The “Energie Navigator” application addresses three groups of persons:

1) energy experts and consultants
2) building and facility managers
3) building occupants.
A main aspect of the expert tool is a rule- and metric-toolkit that 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.

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

The interdisciplinary workgroup of the project consists 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).

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**DRAGOS: A Parameterizable Database For Development Environments**  
E. Weinell, M. Breuer, G. Volkova, I. Lazcanotegui, A. Scheuermann

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

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

In 2009 we completed the definition of the core language as well as the DRAGOS-based reference implementation. Especially, we added control flow support to the execution engine which therefore covers the entire core language. We also finalized the concepts for the rule-based transformation approach to become an integral part of the language development platform. The core language's concepts have, in addition, been validated by representing a relevant subset of the PROGRES graph transformation language.

eHome Systems


eHome systems are built on top of integrable net-aware devices in households. This way, eHome services can offer complex functionalities across multiple devices. Typical areas of application are multimedia and entertainment, medical surveillance and support of elderly people, reducing energy consumption, and security services. Automated smart home environments will have important influence on our everyday life in the future.

Due to recent developments in hardware technology and the trend towards pervasive and ubiquitous computing, eHome systems are gaining more importance. Research in this area is also attractive with respect to its increasing market potential. However, there are a number of problems to be solved before eHome systems are ready for the market, e.g. the dynamic usage and mobility aspects, the respective problems concerning configuration and service composition, the interaction of arbitrary devices, the way 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 regarding mobility and dynamics in the eHome.

Furthermore, an approach for the semantic adaptation of eHome services was investigated, which addresses incompatibility problems that arise when composing heterogeneous services from different vendors. The ontology-based approach allows for automatically generating adaptor components which are used to enable service composition by mediating incompatible services. We also have 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 he is moving from one eHome to another one (inter-eHome mobility). Our approach is based on users carrying mobile devices which store their profiles, allowing them to release the personal data to eHomes when needed. Thus, eHome services can adapt their functionality to the user preferences. This enables ubiquitous usage of personal functionality.

Furthermore, 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 for minimizing the amount of personal data released to each eHome. This is done by identity management combined with negotiation-based authentication and mobile service execution on handheld devices. The extension of the authentication approach by anonymous credentials ensures unlinkability of user identities between multiple eHomes. On the other hand, the eHomes have to be protected against malicious users and services. This is done by role-based access control techniques combined with anonymous credentials.

To evaluate and demonstrate our tools, an eHome software simulator was built, which allows to simulate home environments with inhabitants and installed devices. We also are working on a simulator in Second Life for more fancy demonstrations.

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Modelling Families of Functional Networks in Automotive Software Engineering

C. Mengi, M. Nagl, F. Akhoundi, Ö. Babur, N. Dickmeis, A. Navarro Pérez, R. Zimmermann

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 CO$_2$, (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 the 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 new approaches to reduce the complexity. One promising approach is the introduction of so called functional networks. Functional networks formalize the functional requirements by modelling system functions together with their communication connections in a logical way. That is, functional networks abstract from the underlying hardware platform, partitioning decisions, and any kind of real-time system realization (deployment, bus structure, protocols etc.). Therefore, functional networks describe a first virtual realisation of the static and dynamic system structure. So, functional networks form a plain 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 functional networks to full capacity it is important to follow modelling guidelines such as abstraction of functions and connections, grouping of semantically equal functions and their connections, and establishing hierarchies. For this purpose, we develop a checklist of modelling guidelines the aim of which is to support the system architect during design.

To handle the variations, the first important step is to get a unified terminology about existing variation points. A classification allows 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 annotated by constraints in order to express mandatory, optional, and exclusive variation points. Third, for variability of functional networks, we integrate them with the variability model. Finally, to derive specific variants of functional networks we provide a mechanism to configure the variability model.

Besides applying the variability model to functional networks, we also support the concept on source code level. Here, the software engineer gets the possibility to associate his code lines with the variability model which can be used in parallel to the source code. This improves readability and understandability of source code, as only those parts of the code are displayed which belong to the configuration.

In future work, we also want to apply the variability concept to behavioral models, as MATLAB® Simulink®. Simulink does not support variability mechanisms. Providing our variability concept on these models will help the model designer to handle variation in a more intuitive way.
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.

Development of Domain Specific Languages with MontiCore


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 of rules for the static analysis of models in DSLs and for development of code generators. The department of computer science 3, headed by professor Rumpe, continues the work of the institute for software systems engineering at the Technische Universität Braunschweig on MontiCore.

![Figure 2: Compositional Development of Languages with MontiCore](image)

DSLs developed with MontiCore are used in a variety of projects at the department, e.g., the MODELPLEX project, rUML, UML/P, and MontiWeb. Languages and language modules that have been developed and quality assured previously can be stored in a library. At the time being, this library already contains modeling languages of general applicability such as UML, GPLs, programming languages such as C++ and Java, and specific modeling languages, for instance languages to be used in automotive software engineering.

Quality assurance, as an essential part of all development processes, is not limited to the languages itself, but most also include models or programs in these languages. We developed a framework for the validation of coding or modeling guidelines, which is applicable to both domain specific and general purpose languages. In cooperation with an automotive OEM, we used the framework for the validation of UML/P sequence charts and of C++.

For future versions of MontiCore, we aim at compliance to the wide spread Eclipse Modeling Framework. We also plan to substantially improve the process of building symbol tables, and we plan to develop a model transformation engine for MontiCore.
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 classview language.

In 2009 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).
PROGRES: A Suite For Specifying Prototypes
M. Breuer, M. Heller, M. Nagl, U. Ranger, G. Volkova, E. Weinell
In cooperation with: A. Schürr, Technical University of Darmstadt

PROGRES and prototypes
Since 1989, we are developing the graph rewriting system PROGRES which allows rapid prototyping of complex software systems. The process of creating a PROGRES prototype is divided into several stages: First, the prototype's static and dynamic features are modelled using the PROGRES language. Since PROGRES uses graphs as underlying data structure, the specification comprises a graph schema representing the static structure of the prototype. A collection of declarative graph transformations is added, which describe the behaviour of the system to be modelled. Using control structures for combining diverse transformations, PROGRES offers the possibility to define complex graph transformations.

Having defined the structure and the behaviour of the prototype with the PROGRES language, the PROGRES environment is used to generate efficient C or Java source code from the specification. In combination with the UPGRADE framework, a prototype featuring a graphical user interface can be built based on the generated code. We have used PROGRES for applications in various domains, e.g. for analysis of telecommunication systems (ECARES), the authoring tool CHASID, and the process management system AHEAD.

The years 2008 and 2009 were devoted to minor bug-fixing and performance optimisations. This enabled us to apply the PROGRES system in another case study at the GraBaTs 2008 ToolContest. Furthermore, a student team demonstrated that the PROGRES-generated applications can integrate nicely with modern technologies like the Eclipse platform.

Experiences have shown however that the PROGRES codebase can hardly be maintained on current operating systems. Therefore, we decided to close this project in favour of a future restart on an up-to-date basis. Nevertheless, we were able to show PROGRES' conceptual fitness in several academic and industrial application scenarios, which definitely have brought forward the domain of graph-based software engineering tools as a whole.

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

Like the PROGRES project, UPGRADE is being closed down for now. Conceptual insights like the virtue of user-customizable filter stacks, still being a unique feature amongst competing tools, will be transferred to future research projects. PROGRES and UPGRADE, including example specifications, will remain available on the department’s website for practical experiences, but support will be discontinued.
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 precisely defined in the current UML standard. The main goal of the DFG project 1431/1-2 (rUML) therefore is 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 aims 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 known 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.
Future work is concerned with the implementation of a simulator to practically validate the denotational semantics. It is planned to keep the simulator configurable such that semantic variation points can be implemented as configurations options of the simulator.

**BEST Architecture Evaluation**

*H. Grönniger, H. Krah and B. Rumpe*

_In cooperation with: Siemens IT Solutions and Service (Braunschweig)_

Successful products have to be adapted and extended continuously due to changing requirements of customers, changing interfaces to surrounding systems or technological changes. In the long run, such complex systems may show “erosion” that hinders maintainability.

The goal of this project was to evaluate the architecture of a complex and long-running system that monitors and controls logistic processes, for example, ground processes on airports. Specific criteria of the evaluation were the sustainability and maintainability of the system.

The approach taken was based on the architecture evaluation method *Architecture Tradeoff Analysis Method* (ATAM). For this, quality attributes (such as performance, modifiability and so on) are evaluated and assessed based on specific scenarios. Scenarios in this context are short descriptions of architectural features that affect one or more of the quality attributes. Also risks and non-risks were documented. Additionally, the development process was also evaluated by using a check lists developed by the Software Engineering Group itself.

The results of the evaluation of the architecture and the development process led to recommendations how to enhance the architecture and to reduce risks.
Terex Corporation develops various equipment for the construction, infrastructure, quarrying, recycling, mining, shipping, transportation, refining, utility, and maintenance industry. In cooperation with this industrial partner, processes in overcast mines are analyzed to identify workflows which are suitable for system automation. Based on this analysis, a comprehensive document was deducted to describe necessary features and properties of a system which shall operate in an automated manner. In another project with this industrial partner, a prototype for a camera-based augmentation system was developed to support equipments’ operators in overcast mines.

Software Product Lines

C. Berger, H. Rendel and B. Rumpe

In cooperation with: VOLKSWAGEN AG, Business Unit Braunschweig

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 (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-certificate. 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.

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**Continuous Requirements-Management**

*T. Gülke and B.Rumpe*

*In cooperation with: VOLKSWAGEN AG*

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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, the Chair for Software Engineering will map out all hidden processes, tools, and documents which contribute in some way to the discovery, engineering, and management of requirements.
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 deduced 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.
Other Activities

Software Engineering Lab

The newly founded Software Engineering Lab connects industrial partners, associates of the chair of software engineering, and committed students to provide both, the conduct of industrial projects with sophisticated, problem-tailored software engineering methods and the introduction of highly motivated software engineering students to practical tasks and solutions.

Thus it establishes first contact between entrepreneurs and skilled future graduates, who can get involved in the context of their thesis, student jobs or practical course.

Software of high quality is achieved with the development in project-centered teams, guided and counselled by members of the chair, and the appliance of cutting edge software engineering knowledge. The SE-Lab meets the needs of small and medium sized software projects demanding innovative and up to date thinking.

SoSyM Journal

Software and System Modeling (SoSyM) is an English language quarterly 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 that further understanding of the theoretical underpinnings of modeling languages and techniques, present rigorous analyses of modeling experiences, and 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.

Conference Activities and Academic Administration

A. Körtgen:
• Co-organizer of the “Girls Day” 2009

M. Nagl:
• Speaker of the Collaborative Research Center 476/Transfer Center 61 of German Research Foundation (DFG) until June 09.
• Chairman of German Informatics Faculties Conference (Fakultätentag Informatik) until end of 2008, since then Chairman Substitute.
• Chairman of the Board of 4ING (Union of Faculty Conferences in Mechanical Engineering, Electrical Engineering, Civil Engineering, and Informatics) until end of 2008, since 2009 member of the board.
• Additional Member of the Faculty for Electrical Engineering and Information Technology.
• Member of the Finding Commissions of the Professorships IKV “Institut für Kunststoffverarbeitung” and “Baustatik und Baudynamik”.
• Organization of the 1st Polish-German Workshop on Research Promotion (with A. Borkowski, Warsaw), supported by German Research Foundation (DFG).
• SEI ’09 Software Engineering, Jahrestagung 2009, Kaiserslautern (Member of the Program Committee)
• Fujaba Days 2009 (Member of the Program Committee)

B. Rumpe:
• Editor-In-Chief of the International Journal of Software and System Modeling (Sosym), Springer Verlag, Heidelberg.
• Co-Founder and Steering-Committee-Member of the GI Querschnitts-Fachausschuss “Modellierung”.

• PC Member International Conference on Model Driven Engineering Languages and Systems, September 28 – October 3, 2008, Toulouse, France

• PC Member International Conference on the Quality of Software-Architectures, October 14-17, 2008, Karlsruhe, Germany

• PC Member International Conference on Information Systems Technology and its Applications, April 20-24, 2009, Sydney, Australia

• Co-organizer of the workshop “Modeling in Software Engineering 2009” (MiSE09) at the ICSE-conference (International Conference on Software Engineering), May 17-18, 2009, Vancouver, Canada,

• PC Member IEEE International Workshop UML and AADL, June 2nd, 2009, Potsdam, Germany

• PC Member 1st International Workshop on Domain Engineering, June 9th, 2009, Amsterdam, The Netherlands

• PC Member Fifth European Conference on Model-Driven Architecture Foundations and Applications, June 23-26, 2009, Twente, The Netherlands

• PC Member International Conference on Model Transformation Theory and Practice of Model Transformations, June 29-30, 2009, ETH Zurich, Switzerland

S. Völkel:

• Co-organizer of the workshop “Modeling in Software Engineering 2009” (MiSE09) at the ICSE-conference (International Conference on Software Engineering), Vancouver, Canada, May 17-18, 2009

E. Weinell:

• Member of the Program Committee of Graph Transformations and Visual Modeling Techniques 2009 (GT-VMT09)
Talks and Publications

Talks

Armac, I.: Privacy-Friendly Smart Environments, Third International Conference and Exhibition on Next Generation Mobile Applications, Services and Technologies (NGMAST'09), October 2009, Cardiff, UK.


Heer, T.: Support for Modeling, Enactment and Monitoring of Engineering Design Processes. 8th World Conference on Chemical Engineering (WCCE ’09), August 2009, Montreal, Canada

Heer, T.: Integrated Modeling, Simulation and Enactment of Design Processes in Chemical Engineering. 8th World Conference on Chemical Engineering (WCCE ’09), August 2009, Montreal, Canada


Körtgen, A.: Tools For Consistency Management between Process Design Products, 8th World Conference on Chemical Engineering (WCCE ’09), August 2009, Montreal, Canada


Nagl, M.: Supporting Design Processes by Tools: Joint Research Project of Engineers and Computer Scientists, Beijing Institute of Technology, Beijing, China, 27.2.2009

Nagl, M.: CRC 476 and Novel Design Process Support by Tools, Dalian University of Technology, Dalian, China, 2.3.2009

Nagl, M.: Tool Support for Consistency Management in Engineering Design, South East University, Nanjing, China, 4.3.2009

Nagl, M.: Managing Development Processes in Engineering Design, University of Science and Technology, Nanjing, China, 5.3.2009

Nagl, M.: Consistency Management Support by Tools: Results of the CRC IMPROVE, Tongji University, Shanghai, China, 6.3.2009


Nagl, M.: IMPROVE, a Prestigious Research Project on Design Processes, 8th World Congress of Chemical Engineering, Symposium on Knowledge Engineering, Montreal, Canada, 26.8.2009

Nagl, M.: Service-oriented Architectures and Tool Integration, 8th World Congress of Chemical Engineering, Symposium on Knowledge Engineering, Montreal, Canada, 26.8.2009


Schindler, M.: *Design Guidelines for Domain Specific Languages*. 9th OOPSLA Workshop on Domain-Specific Modeling (DSM'09), October 2009, Orlando, Florida, USA


Weinell, E.: Visual compilation of behavioral modeling languages. Graph Transformations and Visual Modeling Techniques (GT-VMT09), March 2009, York, UK

**Publications**


Nagl, M., Marquardt, W.: IMPROVE, a Prestigious Research Project on Design Processes or From Fundamental Research to Technology Transfer, 8th World Congress on Chemical Engineering, Montreal, Canada, 2009.


Software Construction

Staff

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  Dipl.-Inform. Veit Hoffmann
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  Dipl.-Inform. Matthias Vianden
  (since Apr. 2009, third-party funds position)

• **Student Researchers:**
  Philip Ritzkopf
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 and Project Management
- Lecture Object-Oriented Software Construction
- Lecture Managing Software Development Projects
- 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

Model-Based Engineering of Small Embedded & Real-Time Systems

Nyßen, H. Lichter

External cooperation: ABB Corporate Research Center, Ladenburg, Germany

As the history of software engineering unveils, abstraction is the means to face complexity. While the 1970’s and 1980’s have been strongly based on functional and data abstraction, and while the 1990’s and early 2000’s have been dominated by object-orientation, model-based software development (MBSD) seems to be the predominant development paradigm of the present and upcoming decade.

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

As only a common, integrated methodology, formed by a systematic and concise method, by profound supporting tools, and by underlying languages, being related via common concepts and principles, allows to unleash the full potential of model-based development, it is the central goal of this project to deliver the latter. Regarding the very special constraints, being additionally faced in the domain of small embedded & real-time systems, the approach should in particular be applicable to a domain, which has been very much elided so far.

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. In practice use cases often consist of two parts: an overview diagram which depicts the relations between the single use cases and a set of more or less detailed textual descriptions of the behaviour encapsulated by the single use cases. One of the major advantages of use case related techniques is the informal structure of the textual behaviour descriptions, which makes them a good means for communication especially between developers and customers.

This informality is at the same time their biggest drawback. Hence, it is impossible to keep track of model completeness as well as of consistency of the textual descriptions themselves and between textual descriptions and other requirement documents especially the use case overview diagrams automatically. To overcome those issues we defined a formal meta-model for textual use case descriptions. This meta-model only affects the structure of textual behaviour descriptions, but does not restrict the language that can be used to describe the behaviour itself.

Thus on the one hand the enriched descriptions remain simple enough to be usable as a communication means and on the other hand the application of the formal model enables tool support which leads more sophisticated, consistent use case descriptions.
During the last year we created ViPER-NaUTiluS. ViPER-NaUTiluS adds integrated tool support for specifying, editing and analysing of enriched use case descriptions to the ViPER-IDE. Furthermore the NaUTiluS framework includes a use case simulator for the specified behaviour descriptions. Thus NaUTiluS enables prototyping of the system behaviour very early in the development process.

GUI-Supported 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 allowing the addition of needed testing information into semantically-processed flows of events descriptions of use cases, which will
form quality use case scenarios of various possible system functionality traces (simulation traces) that can be visual in a tabular format, and the other research phase is to allow a usable graphical visualization of test traces (based on the simulation traces). Such graph would be more convenient for practical use if having a Bi-relationship with the previously mentioned tabular traces records. The tester has then a flexible ability to choose graphically and easily a trace to generate its test case or many test cases at the same time if wanted.

In summarized words, an enhanced use case meta-model has to be developed recursively, that will capture functionality traces with testing information. A corresponding tool support is additionally needed on two levels, the modelling level so that the automated generation of test cases at such early stage will be more accomplishing to its purpose when it is based on such solid, standardized, and fair data-containing modelling of the requirements available, and the graphical step-wise test cases generation based on a suitable criteria selection approach as well as the selection possibility for the tester himself.

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**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.
Solid and well engineered processes are the basement of successful software development projects. The outer constraints for project businesses however are constantly changing, so the processes need to adjust. Also processes should be continuously mined for improvements. The key questions are, if the underlying processes need some adjustments and if so, what parts of the processes need to change.

To answer the first question, it is inevitable to constantly measure the projects and their results - the products. Therefore 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 and by that answering the second question above.
Other Activities

- Member of the international program committee, 24th Annual ACM Symposium on Applied Computing Software Engineering Track Honolulu, March 8-12, 2009, *H. Lichter*
- Member of the international program committee, Software Engineering (SE) Track at the 24th Annual ACM Symposium on Applied Computing (SAC 2009), Honolulu, March 8-12, 2009, *H. Lichter*
- Member of the program committee, 3rd IEEE International Conference on Secure Software Integration and Reliability Engineering Shanghai, China, July-8-10, 2009 *H. Lichter*
- Member of the program committee, Software Engineering 2009, Kaiserslautern, March 2-6, 2009, *H. Lichter*
- Reviewer for dpunkt-Verlag Heidelberg and computing reviews, *H. Lichter*
- Organization of the Computer Science Department’s mentors program, *H. Lichter*
- Member of the Computer Science Department’s committee for Service-Lehre, *H. Lichter*
- Member of the examination board of Computational Material Science, *H. Lichter*
- Member of the examination board of Bachelor Computer Science, *H. Lichter*
- Member of the selection committee of professorships Software Engineering and Parallel Programming, *H. Lichter*
- Reviewer for PhD thesis A. Vehreschild, *H. Lichter*
- Organization of the Beginner’s Course in Computer Science 2009, *H. Lichter, V. Hoffmann*
- Presentation of MeDUSA and the ViPER Tool Support, ABB Alzenau, October 29, 2008, *Alexander Nyßen*
Talks and Publications

Talks


S. Pricope: *Towards a Metric Based Approach to Evaluate SCAMPI Appraisals*. 10th International Conference PROFES 2009, Oulu, Finland, June 15-17.


Publications


Communication and Distributed Systems

Staff

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  Dipl.-Inform. Ulrich Meis
  Farshad Naghibi, M.Sc.
  Dipl.-Ing. Kittisak Ormsup (until 1.6.2009)
  Dipl.-Inform. Andriy Panchenko
  Dipl.-Inform. Stefan Penz (until 31.8.2009)
  Dipl.-Ing. Oscar Puñal
  Dr. Ulrich Quernheim
  Dr.-Ing. Jürgen Rapp
  Dipl.-Inform. Tim Seipold
  Dipl.-Inform. Benjamin Schleinzer
  Thitinan Tantidham, M.Sc.
  Dr. Dirk Thißen
  Elena Tojtovska, M.Sc.
  Dipl.-Inform. Alexander Zimmermann

• **Technical Staff**
  Helen Bolke-Hermanns
  Kai Jakobs
  Rainer Krogull
Overview

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

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

Funding for research staff comes from various sources, including the German Research Council, Federal and State Governments, the European Union, and industry. In addition to the mandatory undergraduate courses teaching focuses on communication systems (‘Data Communication’, ‘Distributed Systems’, ‘Web Protocols and Practice’, ‘Data Communication and Internet Technology’), security aspects (‘Security in Communication Networks’, and ‘Privacy Enhancing Techniques’). Practicals in ‘Agent Technology’ and ‘Network Programming’ as well as a virtual practical ‘Computer Science’ have also been offered. For further information please see:

http://nets.informatik.rwth-aachen.de
Recent discussions have identified the need for incorporating hardware effects in network simulations. The need for considering hardware effects is mainly motivated by the strong demand for evaluating the impact of algorithms and protocols in wireless communications and networking on energy consumption and execution time through simulations. However, contemporary network simulation tools are not capable of considering these effects due to missing architectural support and hardware simulation models. Hence, this path finder project aims at designing and implementing a network simulation framework to include such effects. The proposed architecture is based on two approaches which enable the evaluation of hardware effects on two levels of abstraction:

1. Modeling of energy consumption and execution delay of algorithms and protocols in a discrete event simulation tool.

2. Providing a co-simulation framework which enables a SystemC based virtual platform (VP) containing virtual processing units (VPU) to interact with a network simulation tool.

Once these steps are taken, they allow the consideration of execution delay and energy consumption within the simulation potentially at all layers of the communication stack. If detailed models are of interest, the VP can be used as framework (where the simulation code has to be integrated into the VP). If less detailed models are of interest, the direct method of modeling the hardware effects inside the network simulation tool can be chosen. However, in this case the values for execution delay and/or energy consumption still have to be determined. Ways of generating these values will be considered by the project as well.

With the goal of enabling a unified service control architecture that allows the delivery of rich multimedia services that satisfy the expectations of the users in a pervasive world, the 3rd Generation Partnership Project (3GPP) introduced the IP Multimedia Subsystem (IMS) as a service control architecture aimed at realizing network and service convergence, which will allow users to access their services in a unified way without regard of the network connectivity existing in their environments (e.g. WLAN, GPRS, UMTS), the kind of subscription (e.g. fixed, mobile, data), nor the end devices used for connecting to the network.

In order to enable the development of IMS services and of trial of concepts around core the IMS elements, it is necessary to have a trustworthy testing environment that allows evaluating the impact of these proposed approaches. Because the success of the IMS adoption will considerably depend of the flexibility offered to the users when accessing their services, a key component of any IMS deployment will consist on reliable clients that allow to easily
managing the services deployed in the network. With the goal of giving an overview of the status regarding the development of IMS endpoints, this project presented the results of a set of performance tests applied to four free different IMS clients available at the time of writing.

Figure 1: Average Response Times for Typical SIP Requests [ms]

Evaluation of a Service-Oriented Platform for Indexing Media Collections
Juan Miguel Espinosa Carlin

Nowadays, many industries own large media archives that need to be efficiently indexed, a process that very often implies the integration of legacy applications with newly developed software. In such scenarios, an SOA development approach allows addressing the correspondent needs for integration, data sharing and interoperability.

However, the key technologies on top of which a typical SOA-based deployment is built today still face some challenges in terms of performance and scalability when compared to the communication performance of other distributed applications. With the goal of evaluating the real performance of XML Web Services and ESB, this project was aimed at developing a SOA-based approach for enabling a distributed media indexing platform, and compares it to other approaches in terms of performance and overhead. Additionally, it provides a set of guidelines for the construction of a performing and scalable SOA.
Aimed at evaluating the performance of the core components of an IMS network, the ETSI developed the IMS/NGN Performance Benchmark Specification, consisting of guidelines for applying a set of tests to determine how the system behaves when the load on the system is increased. The specification consists of three parts; the first one providing a general introduction to the environment in which the Benchmark exists, the second one providing the subsystem configurations, use-cases and design objectives corresponding, and the third one documents the benchmarks tests through definitions of traffic sets and traffic-time profiles.

With the goal of gaining knowledge in the field of performance benchmarking of IMS deployments, this project focused on doing a performance evaluation based on the mentioned specification, using a well-known open source IMS reference implementation and state of the art analyzing tools for collecting the related measurements. Moreover, the paper also evaluates the impact of the distribution of the core IMS components, with the goal of determining the influence of such improvement in the system.
The China-EU-Standards project promotes research collaboration and engagement between research and policy in relation to Information Technology standardisation in China and Europe – a question that will have an important bearing upon their respective roles in the global economy in the 21st Century.

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

This project brings together leading European and Chinese centres for research into ICT Interoperability Standards to undertake a comparative examination of ICT standardisation processes and associated policies between EU and China. The project develops a knowledge network of leading players in the field, within Europe, China and beyond. Moreover, the project is examining the new ICT standardisation activity emerging in China, apparently linked to its goals to promote indigenous technology. It compares these emerging standardisation processes with those that have emerged and are being currently pursued by European players.

A set of empirical studies focussed upon 4th Generation Mobile Telephony, Audio-Visual Systems, and Mobile Broadcasting. The studies examined the standardisation approach
Radio Frequency Identification (RFID), and succeeding technologies, will change people’s lives perhaps even more dramatically than Information and Communication Technologies (ICT) have done so far.

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

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

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

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

Adaptive Self-Organizing Protocols for Wireless Mesh Networks

Martin Krebs

Wireless Mesh Networks (WMNs) are a flexible technology to provide wireless high-speed broadband coverage to areas where the installation of a wired infrastructure is impossible or too costly, for example in rural areas and developing countries. Deployment scenarios in industrialized countries are community, emergency, disaster recovery, or municipal networks. However, a lot of research work at protocol level is still required to integrate different classes of devices with respect to their capabilities. Furthermore, protocols for WMNs must be adaptive to improve the overall performance under various network conditions like neighborhood stability and resulting connectivity. Finally, future protocols must be self-healing.

For example, current service discovery protocols have a static behavior with respect to their architecture and their message dissemination strategies. For instance, protocols for wireless ad-hoc networks use optimized flooding techniques, whereas protocols for usage within the Internet are usually server-centric. In contrast, wireless mesh networks are much more flexible in their way of connecting nodes as they can consist of different types of nodes like mesh backbone routers or mobile mesh clients. Generally, a hybrid protocol that supports only two operation modes is not sufficient to cope with the high complexity of mesh networks. Therefore, we investigate a new multi-stage-based protocol that adapts its operation mode with respect to its environment and current network condition.

Anonymous Communication

Andriy Panchenko

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

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

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

Wireless Mesh Networks
Fahad Samad and Sadeq Ali Makram

Wireless communication networks are getting importance as the technology makes progress with state-of-the-art software systems and hardware devices. In a ubiquitous environment, evolving technological environments like RFID systems and Wireless Mesh Networks play great role in making the species in this world capable of performing computations and communicating with each other in an efficient way. Deploying huge and complex networks with cables or wires of thousands of meters in length is no more cost effective solution.

But these advancements in communications technologies do not come for free and always have some evolving issues. These issues also exist in securing those communication networks. For an integrated environment like two or more heterogeneous networks, vulnerabilities regarding security and privacy of information in intranets and internets bring even greater threats like eavesdropping, denial of service, wormhole attacks, black hole attacks and most importantly the secure switching between different heterogeneous networks. This means that mobility with security is also a real challenge in these networks.

For this project, we focus on QoS routing, security and privacy issues in Wireless Mesh Networks and hence provide a comprehensive state-of-the-art solution.
Energy Efficiency Design for Portable Storage on Battery Powered Devices
Thitinan Tantidham

Since the rapid advance of mobile computing and communication technologies, the ratio of price to performance for battery-powered devices (e.g. PDAs, smart phones and laptop computers) as well as portable storages (e.g. USB flash drives) has decreased. It becomes popular that people on the move can suspend and restore services from one device to another by the capability of wireless communication ports (e.g. WLAN, GSM or UMTS) for accessing their remote storage, or by a USB port for accessing a portable storage, since the USB interface has become available on industrial computers. In reality, due to high access cost and inadequate network coverage, while traveling, as well as a finite battery capacity of mobile devices, users are mostly in disconnection mode and work on their own local copy or on data replication. Therefore, in order to keep service continuation and protect data loss which may cause by battery exhaustion and inadvertently system disruption, the techniques of a portable checkpointing for execution programs and a data replication engine on a portable storage with powerful log management are required.

This research focuses on the energy efficiency design for different storage characteristics between an internal hard disk drive of a laptop computer and a USB-storage device. In the beginning of the research, it was a study of the battery characteristics and its lifetime by observing multiple systems. It has been found that the battery lifetime ranges from a few minutes to a few hours and the battery capacity degrades within 2-3 years after use. Furthermore, the discharge battery model based on CMOS power consumption basis and regression method analysis as well as the battery lifetime prediction framework relied on smart battery information have been developed. The results show that this model can improve the mean average error of the battery lifetime estimation under dynamic system workloads compared to the techniques given by the Advanced Configuration and Power Management Interface (ACPI) and smart battery. Moreover, the experimental study results of USB-storage devices reveal that onward USB flash drives (UFDs) provide energy efficient storage media compared to WLAN Internet connection to data server and USB hard disk drives and also UFDs can support well in read transfer throughput as well as the performance of random read and synchronous write in small request sizes. However, UFDs have the cost per bit higher than hard disks and a finite of number of erase-write cycles.

Finally, the framework for power aware data allocation management between a UFD and a hard disk drive in the context of energy efficiency has been investigated. This framework is devised into two phases upon energy power sources: AC or battery. In AC power phase, the energy cost function is investigated for making the decision to allocate the appropriate data file according to data file access pattern schemes and the storage performance profiles. The challenges are that the access patterns in the means of read/write operations, random/sequential access, I/O request sizes are dynamic. In battery power phase, there is no recommendation for any data maintenance. Data replication profile and the descriptions of storage and system discharge rate are pre-configured. A replication log processed in the background is kept maintenance and synchronization between the local hard drive of the mobile computer and the one on the available UFD. Replicated data is selected, which satisfies the constraints of UFD space capacity and energy and maximizes the profit function. The replication scheduling in battery-powered mode is classified into two policies: one
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 constraints. While efforts exist 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.

Distributed filesystems for Wireless Mesh Networks

Benjamin Schleinzer

In my thesis, I am exploring new ways for information sharing and collaboration of multiple users across disciplines and institutions, while ensuring that the content of exchange and thus of the files remains secured against unauthorized manipulation. I would like to show how P2P techniques and self-organization can be used to create a distributed file system that is especially well suited for wireless multi-hop networks. A critical aspect of such a system is that the content of the files must be secured against unauthorized manipulation while information sharing and the collaboration of multiple trusted users must still be possible. To satisfy this assumption and maintain the ability to store files on untrusted nodes strong encryption is needed. At the same time some data like the file system descriptors must be readable by everyone while still be resilient against manipulation. In my thesis an approach is used that copies data rather then changing it directly. The copied version is then changed, thus
preventing users from overwriting data. Using this copy-on-write technique also has the benefit that older versions of a file or directory can be easily retrieved at a later time.
Publications


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International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (IC3K), Madeira, Portugal, October 2009. Springer CCIS.


Distributed Systems

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Overview

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

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

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

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

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

- **New Network Architectures:**
  - Flexible and Scalable Communication Support in/for Distributed Systems
  - Support for Various Communication Forms
  - Mobility Support for Distributed Systems
  - Support for Services in the Network and their Composition
  - Bridging the Limitations/Heterogeneity of Today's Internet
Research Projects

A Flexible and Versatile Software Architecture for Modular Protocol Development and Cross-Layer Adaptation

Ismet Aktas, Klaus Wehrle

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

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

Muhammad Hamad Alizai, Olaf Landsiedel, Klaus Wehrle

Accurate estimation of link quality is the key to enable efficient routing in wireless sensor networks. Current link estimators focus mainly on identifying long-term stable links for routing. They leave out a potentially large set of intermediate links offering significant routing progress. Fine-grained analysis of link qualities reveals that such intermediate links are bursty, i.e., stable in the short term. In this project, we use short-term estimation of wireless links to accurately identify short-term stable periods of transmission on bursty links. Our approach allows a routing protocol to forward packets over bursty links if they offer better routing progress than long-term stable links. We integrate a Short Term Link Estimator and its associated routing strategy with a standard routing protocol for sensor networks. Our evaluation on standard testbeds measures an average of 19% and a maximum of 42% reduction in the overall transmissions when routing over long-range bursty links. Our approach is not tied to any specific routing protocol and integrates seamlessly with existing routing protocols and link estimators.

Modular and Transparent Incremental Code-Updates for Sensor Networks

Olaf Landsiedel, Muhammad Hamad Alizai, Klaus Wehrle

Long-term deployments of sensor networks in physically inaccessible environments make remote re-programmability of sensor nodes a necessity. Ranging from full image replacement to virtual machines, a variety of mechanisms exist today to deploy new software or to fix bugs in deployed systems. However, TinyOS - the current state of the art sensor node operating system - is still limited to full image replacement as nodes execute a statically-linked system-image generated at compilation time. In this project, we introduce Dynamic TinyOS to enable the dynamic exchange of software components and thus incrementally update the operating system and its applications. The core idea is to preserve the modularity of TinyOS, i.e. its componentization, which is lost during the normal compilation process, and enable runtime composition of TinyOS components on the sensor node. The proposed solution integrates seamlessly into the system architecture of TinyOS: It does not require any changes to the programming model of TinyOS and existing components can be reused transparently. Our evaluation shows that Dynamic TinyOS incurs a low performance overhead while keeping a smaller - upto one third - memory footprint than other comparable solutions.
Wild animals display a wide range of complex behaviors, often taking place in hard to observe environments. To analyze individual mechanisms of behaviors, laboratory studies have been proven to be extremely helpful. However, their complex interplay and interaction in natural environments is still only poorly understood.

Efficient wildlife monitoring as well as modeling tools is 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 under-water environments.

In this interdisciplinary project (in cooperation with the Department of Zoology at Tübingen University), we develop a novel system for animal surveillance in the wild, using sensor node technology. Using highly integrated microcontrollers with radio and sensing capabilities, it is possible to autonomously observe target individuals, in this case wild Norway rats. The aggregated information is forwarded to researchers via stationary base nodes. These are located in more accessible locations and are visited by the animals on an irregular basis. The collected animal data is then used for further analysis, including trajectory reconstruction, daily activity profiles, and interaction graphs.

The main challenges in designing such a system are the sporadic connectivity and the limited size and carrying capacities of the animals under research. While currently developing new forwarding and communication strategies, the modeling of complex behavior plays an important role in aggregation and behavior classification.

Funded by DFG, the project "Adapt" aims to enable the re-use of existing and established Internet applications in mobile ad-hoc networks. Based on a modular protocol framework, it focuses on mechanisms to provide Internet-based applications a runtime environment with Internet-like characteristics. Furthermore, its scope includes the development and demonstration of transparent extension of existing applications, services, and protocols for their specific use in mobile ad-hoc networks.

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

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

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

*Tobias Heer, Klaus Wehrle*

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

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

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

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.

**UMIC Simulation Framework**

*Georg Kunz, Olaf Landsiedel, James Gross, Klaus Wehrle*

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

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

By enhancing classic network simulation with detailed physical layer and hardware models, the scope of network simulation is significantly broadened. Based on the new framework, communication systems can be evaluated as a whole, hence allowing deeper and more detailed insights.

**Modular and Platform-Independent Communication Protocols**

*Olaf Landsiedel, Klaus Wehrle*

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

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

Security for Pervasive Healthcare
Oscar Garcia-Morchon, Klaus Wehrle

Wireless medical sensor networks enable ubiquitous health monitoring of patients during their everyday life. Security is a key requirement to guarantee safety and privacy of users. However, the resource-constrained nature of the sensor nodes and the operational requirements of MSNs hinder the use of traditional security solutions.

We focused our attention on polynomial-based alpha-secure systems as our preferred solution for key agreement in MSNs. We carried out simulations to validate the advantages of distributed alpha-secure-based key agreement approaches regarding delay or packet losses in large medical sensor networks. A multidimensional alpha-secure key establishment scheme was developed exploiting deployment- or feature-based distribution of keying material to enhance system security. Further research into key establishment includes the assessment of the resource requirements depending on the finite field size and the definition of segment diversification techniques to increase network resiliency.

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

Current work concentrates on the management of the patient area network security domains regarding their security architecture as well as access control methods, handshakes and policies based on alpha-secure technology.
Massively multiplayer online games (MMOGs) played via the Internet have become very popular in recent years, because they allow thousands of players to share a single game world. Because of consistency, such a world is usually run on a high-performance and high-availability server cluster. However, such infrastructure is inflexible and error-prone and downtimes of several hours are not uncommon. Also, MMOGs are an interesting challenge and chance for the future development of the Peer-to-Peer (P2P) paradigm. A wide variety of aspects are only theoretically solved or completely unsolved. E.G. security and trust problems appear as well as the need to prevent cheating. Consistent data storage is a problem and decisions and transactions have to be performed in a decentralized way.

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

The complex interactions and the distributed nature of communication protocols make automated testing and debugging before deployment a necessity. 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, the seamless transition between the testing and bug replay makes KleeNet a usable and attractive testing approach. As a case study, we integrated KleeNet into Contiki OS and found several insidious bugs in the TCP/IP protocol stack.

The main challenge in this project is the scalability. We plan to test larger distributed scenarios to detect new bugs and get better understanding of challenges and limitations of our approach.
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 partly 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.

This project expands on earlier proposals of cross-layer signaling, i.e. exchange of information between protocol layers to facilitate more efficient cooperation between different parts of the network stack. This way, an application can signal its ability to process partially corrupted data, and lower layers can choose to ignore errors in packet payloads. As a second step, we also look into how to deal with errors that occur in the packet headers. These have to be corrected, so that the information is restored, because it is used to correctly process the packet in the protocol 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 analog signal is a 0 or 1. This approach has been used for some time already in turbo coding schemes, and is used for voice communication in mobile scenarios. In a packet-switched network, however, the two decoders would reside in the APP and PHY layer, respectively, and therefore be separated. Cross-layer signaling 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 similar to pilot bits, boosting the perceived speech quality of a VoIP stream after decoding with an iterative decoder.

New Evaluation Methods and Tools for Massively Distributed Systems

Elias Weingärtner, Klaus Wehrle

With the increasing pervasiveness of networked devices and corresponding services, there is a vital need for adequate tools that support according research and development efforts. Within
the research funded by the DFG Project MoMenTum, we design new evaluation concepts that match the challenges of today. Specifically, progress was accomplished in the following research efforts:

• A core contribution is our work on Synchronized Network Emulation, which integrates event-based network simulations with real-world software prototypes for the sake of combining their advantages. Network simulators offer an unsurpassed degree of flexibility and scalability, given their principle of abstraction. On the other hand, this basic principle often limits the observability of real-world problems. While real-world prototypes allow for detailed investigations, they fall far short if it comes to the analysis of large real-world deployments that involve a high number of communication peers.

While we already sketched the fundamental concept of this approach in the year 2008, a large progression in this project was made due to the utilization of the emerging ns-3 simulator. Moreover, a comprehensive evaluation of our analysis framework has shown its efficiency and its applicability to real-world scenarios.

• Speaking of the actual implementation of network protocols and applications, they are commonly known to be hard to analyze. A special problem is distributed debugging. Over the past months, we have developed a distributed debugging framework that allows for the analysis of implementations running on multiple virtual machines. Our framework allows one to examine the execution of such using global soft-state information. Moreover, it supports the automated execution of conditional monitoring paths, as we utilize a script language that may control the entire debugging process.
Other Activities

Klaus Wehrle is a member of the steering board of “GI-Beirat der Informatikprofessoren (GIBU)”, and the steering committee of the GI/ITG board on “Kommunikation und Verteilte Systeme (KuVS)”. He also is an active reviewer for several journals, publishers, and boards. In 2008/2009, he also served as a member of the program committees of the following conferences and workshops:

- PC Member of the ISOC ServiceWave Conference 2008
- PC Member of the IEEE Conference on Distributed Computing and Networking (ICDCN 2009)
- PC Member of the IEEE Workshop on Mobile Peer-to-Peer Computing (MP2P’09)
- PC Member of Kommunikation in Verteilten Systemen (KiVS 2009)
- PC Member of the OMNeT++ Workshop 2009
- PC Member of IFIP Networking 2009
- PC Member of the IEEE Symposium on a World of Wireless Mobile and Multimedia Networks (WoWMoM 2009)
- PC Member of the EuroSys Doctoral Workshop
- PC Member of the ACM Workshop on Mobility in the Evolving Internet Architecture (MobiArch 2009)
- PC Member of the IEEE Conference on Peer-to-Peer Computing (P2P’09)
- PC Member of the IEEE Conference on Local Computer Networks (LCN’09)
- PC Member of the Symposium on Stabilization, Safety, and Security of Distributed Systems (SSS’09)
- PC Member of the Workshop on the Network of the Future (FutureNet II)
- PC Member of the ReArch Workshop (ReArch'09)

In October 2008, Samu Varjonen and Mika Komu from the Helsinki Institute on Information Technology (HIIT) and from Helsinki Technical University visited our group for some weeks. In February 2008, Kevin Klues from the University of California - Berkeley visited our group on invitation by UMIC and held a lecture on the topic of TinyOS operating system.

The Distributed Systems Group successfully applied for participating and continuing the collaborative research project (DFG Forschergruppe) “Quality in Peer-to-Peer Systems” with Technical University of Darmstadt.

Klaus Wehrle was invited to serve on the examination board of the federal tournament in Computer Science (Bundeswettbewerb Informatik). The final round of the challenge was hosted by RWE IT Systems in Wanderath and Essen in September 2009.

Klaus Wehrle was selected and invited by the New York Academy of Science to represent the European Science Community as one of two young researchers at the 6th Science, Technology and Society Forum, held in Kyoto from October 5th to 6th. In the following, he was invited on a study tour organized by the Japanese Society Promoting Science and Research (JSPS).

Klaus Wehrle was invited to participate in the interdisciplinary forum “Neue Verantwortung”, a think tank of young potentials from science, business, art and politics.

Klaus Wehrle was elected member of the German Academy of Science and Engineering ACATECH (Deutsche Akademie der Technikwissenschaften). ACATECH represents the interests of German sciences and technology in Germany and abroad.
Talks and Publications

Talks


Klaus Wehrle, „Mobile, Cooperative and Secure Mobile Internet Access with PISA“, Invited Talk at C.S. Colloquium, Tübingen University, February 2009.

Elias Weingärtner, „ProMoX: A protocol stack monitoring framework“, Konferenz in verteilten Systemen (KiVS09), Kassel, March 2009.


Tobias Heer, „Introduction to Service Identifiers for HIP Services“, IETF 74, HIP Research Group (HIPRG), San Francisco, March 2009.


Klaus Wehrle, „Mobile ACcess – Mobile and Distributed Internet Access with PISA“, Invited Talk at RegioIT Workshop, Eurogress, Aachen, June 2009.


René Hummen, „HIP Tutorial“, RWTH-Aachen University, Aachen, July 2009.


Georg Kunz, VIPE - A Virtual Platform for Network Experimentation, ACM SIGCOMM Workshop on Virtualized Infrastructure Systems and Architectures (VISA'09), Barcelona, Spanien, August 2009.

Publications


in the Evolving Internet Architecture (ACM MobiArch '09), ACM Sigcomm/Sigmobile, Krakow, Poland.


**Contribution to Internet Standardization**


**Patent Applications**

Heer T, Wehrle K: Trusted-proxy based Pre-Authentication and Pre-Configuration (TPPP)
Information Systems

Staff

• **Professors:**
  - Prof. Dr. rer. pol. Matthias Jarke
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  - Sandra Geisler
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  - Anna Hannemann (ne Glukhova)
  - Matthias Häusler (since 04.05.2009)
  - Jessica Huster (since 15.05.2009)
  - David Kensche
  - Dr. Ralf Klamma
  - Dejan Kovachev (since 01.05.2009)
  - Stefan Kreutter (since 01.01.2009)
  - Xiang Li
  - Dominik Lübbers (since 02.06.2009)
  - Zinayida Petrushyna
  - Manh Cuong Pham
  - Dr. Christoph Quix
  - Dr. Jürgen Rapp
  - Khaled Rashed
  - Dominik Renzel (since 16.03.2009)
  - Dominik Schmitz (since 01.05.200)
  - Dr. Satish Srirama (until 31.07.2009)
  - Yao Wang (since 15.04.2009)
  - Dietlind Zühlke (since 01.04.2009)

• **Visiting Lecturers:**
  - Dr. Wolfgang Broll, Fraunhofer FIT
  - Stefan Hirschmeier, Fraunhofer FIT (until 31.03.2009)
• **Technical Staff:**
  Tatiana Liberzon
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• **Student Researchers:**
  Martin Bachwerk, Aleksandar Bojinovic, Xi Chen, Niels Drobek, Darko Dugosija, Martin Frericks, Adam Gasior, Marcus Gelderie, Ahmet Goer, Christian Haasler, Georg Hackenberg, Stephan Hackenbracht, Michael Hackstein, Andreas Hahne, Christian Hocken, Zille Huma, Holger Janßen, Christian Kalla, Florian Linke, Can Liu, Tim Niemüller, Tomas Novotny, Sebastian Rüsche, Patrick Selders, Leszek Seweryn, Patrick Schlebusch, Christoph Schwering, David Sosnitza, Quan Tran, Edwin Yaqub, Ming Zhang, Ziquan Zhu

• **Cooperation Partners:**
  aiXtrusion GmbH, Daimler AG, Ericsson Eurolabs, European Microsoft Innovation Center Aachen, European Schoolnet, Feuerwehr Düsseldorf, IBM Zurich Labs, IKV Aachen, Inform GmbH, Microsoft Deutschland GmbH, European Philips Research, SAP AG, T-Systems GEI Aachen, WZL Aachen
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.

The academic year 2008-2009 has been extremely busy for us. After ten years of funding, the Aachen-Bonn-Cologne SFB 427 “Media and Cultural Communication” was completed successfully in December 2008. In 2009, Prof. Jarke was elected vice coordinator of the excellence cluster UMIC (Ultra-High speed Mobile Information and Communication) in which we participate with two major projects and a postdoc. In addition to continuing the DFG-funded requirements engineering project CONTici jointly with four other NRW universities, two large European projects on technology enhanced learning began. One focuses on Responsive Open Learning Environments (ROLE), and the other supports the European Schoolnet for Teachers’ Lifelong Learning Networks (TeLLNet), a cooperation network of over 45,000 schools. The subgroup of Prof. Berlage secured the new ExPrimage BMBF project in medical informatics. Smaller projects were also started in cultural heritage (with Harokopio University, Greece), on model-based data integration (with Technion, Israel), and on model-based information integration in mechanical engineering (RWTH Pathfinder project with WZL and PLT). Within the university-wide future concept “RWTH-2020: Meeting Global Challenges”, we continued with the strategic activity “International Recruiting” and started a junior research group on “Natural Media” jointly with colleagues from the Humanities and from Medicine within RWTH Aachen HumTec initiative. Last but not least, the cooperation with Ericsson Eurolabs in the field of mobile web services was complemented by a major data integration and analysis project within the German national CoCar initiative.

Informatik 5 organized the 8th International Conference on Web-based Learning (ICWL’09) in Aachen with over 150 participants. We also co-organized a Dagstuhl Perspective Seminar on High-Impact Requirements Engineering, the European Summer School on Technology Enhanced Learning in Slovakia, and the 11th International Conference on Mobile Interaction (MobileHCI’09) in Bonn.

In terms of teaching, two large undergraduate courses with a total of well over 400 students were taught in the summer semester 2009 alone, leading to heavy teaching load on top of the specialist courses and seminars offered by the group. We also were among the first universities in Europe to introduce a focused lecture program on the new field of Web Science. Another noteworthy teaching-related activity concerned the accreditation of the Bachelor program in ICT for Business and Engineering at the German University of Technology in Oman (GUtech).

Informatik 5 cooperates closely with the Fraunhofer Institute for Applied Information Technology (FIT) of which Prof. Jarke is Executive Director and Deputy Chairman of the Fraunhofer ICT group. Two FIT area managers, Prof. Wolfgang Prinz and Prof. Thomas Berlage, hold cross-appointments as Associate Professors in Informatik 5. Prof. Jarke is also one of the Founding Directors of the Bonn-Aachen International Center for Information Technology (B-IT). Within B-IT, a third joint professorship has been established and filled with Prof. Thomas Rose. The new B-IT Research School for doctoral training funded by the NRW State Government started its operations in the fall of 2008 under the coordination of
Prof. Jarke and Prof. Cremers (Bonn), and is now already supporting 18 doctoral candidates with scholarships.

Doctoral Seminar, September 8-9, 2009, Hürtgenwald
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.

**Mobile Applications and Services UMIC:**

*Ultra High-Speed Mobile Information and Communication*

M. Jarke, R. Klamma, C. Quix, Y. Cao, S. Geisler, D. Kensche, X. Li, S. Srirama, M. Jansen (Sbg), G. Toubekis (Sbg), C. Hocken, X. Chen, C. Liu

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”.

**Future Mobile Internet Services: Virtual Campfire**

M. Jarke, R. Klamma, Y. Cao, S. Srirama, M. Jansen (Sbg), G. Toubekis (Sbg), A. Hahne, C. Hocken, P. Schlebusch, D. Kovachev, X. Chen, C. Liu

A “Mobile Host” capable of providing basic web services from smart phones was developed and the performance analysis of the tool proved the technical feasibility of the concept. The huge number of Web services possible, with each Mobile Host providing some services in the wireless network, makes the discovery of these services quite complex. The aspects of service discovery, mediation, and quality of service issues like security and scalability, application and usability analysis strategies for mobile web service providers were analyzed.

As a demonstration scenario for mobile social software based on mobile internet services, the Virtual Campfire scenario has been further developed to bridge media and communities across mobile platforms. In Virtual Campfire, user-generated cultural heritage information is to be integrated into a multimedia non-linear digital storytelling system to enhance information reuse, learning and sharing across professional communities. Furthermore, research focuses on context-aware semantic mobile multimedia data management. MPEG-7 based metadata and Web 2.0 tagging approaches are applied to annotate, search and share multimedia data in a unified way. A mobile multimedia test bed is established to evaluate and monitor the mobile service calls by various mobile clients and to measure mobile multimedia communities based on certain information system success models.
The concept and prototypes were demonstrated on a number of international conferences (e.g. the 10th IEEE International Conference on Mobile Data Management 2009 in Taipei, Taiwan) and workshops, as well as other events such as UMIC Day 2008. In the real world setting of the Bamiyan Community (http://www.bamiyan-development.org) Informatik 5 and Aachen’s Urban History department bring together international researchers, governmental and administrative officers for the conservation work in Bamiyan, Afghanistan. The results were presented e.g. to M. Zia Afshar (Deputy Minister of Afghan Ministry of Information and Culture), and M. Yousaf Pashtun (Minister of Afghan Ministry of Urban Development).

Mobile Multimedia Service Monitoring Architecture and Mobile Storytelling on iPhone within the Virtual Campfire Scenario

Mobile and Wearable P2P Information Management in Health Net Applications

M. Jarke, C. Quix, S. Geisler, D. Kensche, X. Li, N. Sonjampa, S. Kim (MedIT), P. Kranen (Informatik 9), N. Jungbecker (ITA), U. Meyer, J. Barnickel (IT Security)

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 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 groups have created a prototype for a body sensor shirt which includes an ECG sensor and accelerometer. The sensor information is processed by a device which sends the data to a mobile client (e.g. a PDA or a mobile phone). The client forwards the patient's data to a server where health experts can analyze the data in detail. To avoid sending of a huge amount of data, the data is pre-classified on the mobile client according to normal and emergency
situations. In normal situations, only a highly aggregated summary of the data will be sent; if an emergency situation is suspected, detailed information will be sent to the server.

The work of Informatik 5 in this project focuses on the development of a peer data management system which supports the information exchange between the devices (PDAs and smart phones of patients and medical staff on the one hand, integrated information systems such as hospital information systems on the other hand). This work applies the basic research results of the model management project. In addition, requirements for the integration of mobile devices in a hospital information system have been analyzed. The integration of the sensor data into a hospital information system will use the HL7 message standard.

CoCar – Cooperative Cars

M. Jarke, C. Quix, S. Geisler, T. Rose, G. Gehlen (Ericsson GmbH Eurolab), G. Jodlauk (Ericsson GmbH Eurolab), J. Javed

The Cooperative Cars (CoCar) project, supported by the German Federal Ministry for Research and Education, tested the suitability of UMTS technologies and their foreseeable extensions 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. Five partners from telecommunications and automobile industry will identify which traffic management and driver assistance applications are suitable for use of this technology.

Informatik 5 cooperates in this project with Ericsson Eurolab 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. First results are quality- and priority-based traffic information fusion architecture and 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.
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 ROLE, IKYDA and TeLLNet in 2009 and finished the EU TEMPUS project CUELC. We have now strong funding in technology enhanced learning and cultural heritage management with a “Web Science” research approach. We combine strong 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.

The new lecture “Web Science” started in WS 2008/09 was very successful with two guest lecturers: Dr. Marc Spaniol from the Max Planck Institute for Computer Science in Saarbrücken and Prof. Markus Strohmaier from the Technical University in Graz, Austria. We organized two workshops in the Multimedia Metadata Community (http://www.multimedia-metadata.info) in Toulouse (WMM’09) and in Graz (SeMuDaTe’09) as well as workshops about social software engineering environments (SENSE’09) in Kaiserslautern and about storytelling and educational gaming (STEG’09) in Aachen.
Highlight of the year was our strong participation in the organization of the ICWL’09 in Aachen in August 2009.

The following projects have been worked on in the year 2008-2009:

| DFG SFB 427: “Media and Cultural Communication” and HumTec Project “Natural Media” |
| M. Jarke, R. Klamma, Y. Cao, M. A. Chattī, M. Spaniol, M. Bachwerk, N. Drobek, Z. Petrushyna, D. Renzel, S. Grandhi, I. Mittelberg (HumTec) |

The collaborative research center was completed successfully in December 2008 with a symposium about “The planetary – Culture –Technology – Media in the Age of Post-Globalization”. The symposium and the final newsletter demonstrated again the claim and the ability of the research center to think new media as a game changer for societal processes at large. Consequently, the sub-project “Agency in Digital Social Networks by Visualization of Multidimensional Patterns of Disturbance” incorporated the newly developed media theory of transcriptivity in design processes for complex community information systems in as different application domains as cultural heritage management, entrepreneurship, aphasics’ therapy, and technology enhanced learning. A number of new concepts like agency and patienthood were jointly researched in the context of the Web 2.0 and social software dominating lately information systems development. Main results included the development of a new reflective information systems architecture based on those media processes in professional communities of practice and the concept of Mediabases. These are very large pattern-oriented data management systems for Web 2.0 media for conducting interdisciplinary empirical research and knowledge discovery by visualizing dynamic network analysis results. The strongly transdisciplinary research was documented in a number of international journal and conference publications with an inclusion in the special issue of German Informatik Spektrum about computer science and the humanities in 2008.

Building on these successful experiences, an 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) has been approved for funding 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 newly hired Junior Prof. Irene Mittelberg; our new postdoc Sukeshini Grandhi (formerly New Jersey Institute) represents computer science and information systems there, focusing on the different roles of computer games in the Natural Media context.
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, 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 2008-2009, we concentrated on data mash-up issue with the investigation of possible techniques which can be used to integrate data from digital libraries. Two large data sources (DBLP and CiteSeer) are currently considered as a case study. We further investigate dynamic network analysis, especially clustering techniques, and the possibility to apply these techniques to recommender system (especially Collaborative Filtering recommendation) to improve the performance of traditional recommendation algorithms and make them more suitable for application in digital libraries. A prototype called AERCS (An Academic Event Recommender system for Computer Scientist) provides visualization and recommendation tools for research communities of conferences in Computer Science.
EU Integrating Project ROLE: Responsive Open Learning Environments
M. Jarke, R. Klamma, Z. Petrushyna, D. Renzel, D. Dugosija, F. Linke, D. Sosnitza

ROLE, started in February 2009, 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, psycho-pedagogical 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 (to mashup) new components and functionalities, which can be adapted by collaborating learners to meet their needs and to enhance the effectiveness of their learning. Learners are empowered to generate new tools and functions according to their needs, and can help to establish a livelier and personally more meaningful learning context and experience. The generic ROLE framework uses an open source approach, interoperable across software systems and technology.

Project has 16 partners across Europe and China from both academia and industry and covers all required pedagogical and technical competencies necessary for research and development in this highly interdisciplinary project. Informatik 5 is the vice-coordinator of the project, acting as technical leader and community facilitator. This year’s highlight was the ROLE general assembly in conjunction with ICWL 2009 in Aachen.

EU Life Long Learning Program TeLLNet: Teachers’ Lifelong Learning Networks
M. Jarke, R. Klamma, Y. Cao, Z. Petrushyna, R. Vuorikari (European Schoolnet)

The new EU Life Long Learning Project TeLLNet supports the European Schoolnet, a cooperation network of over 45,000 schools, in cooperation with the Open University the Netherlands, and Institute for Prospective Technological Studies (IPTS) as one of European Commission Joint Research Centers. Social Network Analysis (SNA) applies graph theories, 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. SNA provides a useful approach to identifying social capital and social structure. Small world effect and scale-free networks are observed and analyzed. This research work is based on both theoretical research and practices. A couple of practical prototypes provide user communities useful tools to get to know their networks well and to find out their social network patterns. The eTwinning Network Visualization (eVA) provides the visualization and performs Social Network Analysis of 45,000 schools in Europe.
EU Tempus Project CUELC: Cairo University E-Learning Centre

M. Jarke, R. Klamma, M.A. Chatti, Z. Petrushyna, S. Hackenbracht,
M. Fayek (Cairo University), K. Maillet (INT Evry)

CUELC aims to bridge the currently existing gap between the advanced technology enhanced teaching (TEL) and learning methods in Europe and Egypt. In 2008 a CUELC Programming Competition was organized and the winning team consisting of three students from RWTH Aachen received their prizes - iPod Shuffles - personally from Prof. Dr. Matthias Jarke. The CUELC team presented the project results at two important TEL events, namely ICT-Learn’08 and EC-TEL’09. Furthermore, during the last year, three project meetings were organized at the partner institutions in Aachen, Paris, and Cairo.

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)

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 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 etc. Researchers from Harokopio University have paid two visits in June 2008 to exchange knowledge with the colleagues at Informatik 5.

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 2008-2009, we concentrated on constructing the faked multimedia dataset, analyzing the impact of low-level descriptors (e.g. color, texture) in multimedia fake detection, and investigating possible alternative techniques and descriptors.

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.

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.

Model Management
M. Jarke, C. Quix, M.A. Chatti, S. Geisler, D. Kensche, X. Li, C. Schwering

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 2009, the group worked particularly on methods for query rewriting in peer data management systems. The GeRoMeSuite application was extended by a user interface for defining generic queries and a component for peer-to-peer communication. A query posed to one peer is rewritten into a query against the schema of another peer using the generic
mapping language of GeRoMe. A number of master thesis projects were conducted in this context, including in particular master students within the European Master of Informatics Erasmus-Mundus program in cooperation with the University of Trento (Prof. Fabio Casati, Prof. Maurizio Marchese) and the University of Edinburgh. In addition, the following projects were worked on beyond participation in UMIC:

ERS Pathfinder Project: Conceptual Design of a Metamodel for Industry Automation  
*M. Jarke, C. Quix, D. Schmitz, M. Zhang*

The control of production plants has challenged 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 architecture 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.

A goal of this project is to define the requirements for a common, uniform metamodel for industry automation, both for discrete manufacturing and for process engineering. This includes the definition of a common terminology and the basic structures of the metamodel. 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.

RWTH – Technion Umbrella Project: Models for Quality Management in Schema Matching with Applications to Medicine  
*M. Jarke, C. Quix, S. Geisler, D. Kensche, X. Li, A. Gal (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. Two applications in the area of medicine of such an outcome are online monitoring of patient's health and personal medical records.

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 modeling, 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. In addition, version 7.2 includes many improvements in query evaluation and object processing.

The book Metamodeling for Method Engineering, edited by Manfred A. Jeusfeld, Matthias Jarke, and John Mylopoulos is now also available. The book presents the theoretical basis of metamodeling for method engineering, and reports also on applications of the metamodeling approach to method engineering. These applications have been developed using the Telos language and the ConceptBase system.

AdMIRE: Advanced Music Information Retrieval Environments
M. Jarke, D. Lübbers

In this project we investigate user-friendly music information retrieval systems that combine content-based feature extractors and collaborative similarity functions. Our main focus is the development of an immersive multimodal three-dimensional virtual landscape in which the user can freely navigate guided by surrounding acoustic clues and explore a given music collection which has been organized according to a well-defined notion of similarity.

In this academic year we primarily focused on the integration of personalized similarity measures into our research prototype soniXplorer. Observing the user’s interaction with the exploration environment we reweight a mixture of implemented distance functions covering
different musical aspects and thereby adapt the organization strategy to his notion of similarity.

**IT Summit 2008: Interactive Project Map for erlebe-it.de**

*M. Jarke, C. Quix*

Informatik 5 and Fraunhofer FIT developed an interactive map for the technology recruitment initiative of BITKOM, the Federal Association for Information Technology, Telecommunications and New Media. The website http://www.erlebe-it.de features information about cooperation projects between IT industry and schools. The initiative provides information at pupils about education and study programs in IT. The interactive map provides a geographical overview of the activities in Germany. IT-Scouts (professionals with an expertise in education and IT) and companies participating in this initiative are shown on the map such that a school can easily find a local contact point to learn more about the education possibilities in the IT industry.

**BMBF ExPrimage: Automated Multi-dimensional Tissue Diagnostics to Improve Prognosis and Therapeutic Recommendations in Breast Cancer**

*T. Berlage, D. Zühlke, Y. Wang, M. Häusler*

In this projected, supported by the German Ministry of Research (BMBF), we are working on the image analysis in multiple layers of magnification. The goal is to combine findings at the cellular and local level with an analysis of the global tumor structure. In 2009, we were able to geometrically register multiple images of adjacent slides through the tumor, which were treated with different markers. Using this integrated information, we could identify classes of tumor tissue, both using supervised learning and unsupervised clustering. These annotations will then be combined with local findings, such as areas of inflammatory cells. The work has been conducted in close cooperation with the University of Hamburg (Pathology Niendorf) as the medical partner and Zeiss and Qiagen as major industrial partners.
Other Activities

Service

Within the RWTH Future Concept “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 the present situation, the departmental requirements, and 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 almost 50%, and very significant quality improvements in international master student recruiting can be observed in several study programs.

Prof. Jarke’s other major administrative and service activities in 2008-2009 included:

• Deputy coordinator, UMIC Excellence Cluster on Mobile Information and Communication, RWTH Aachen University
• Executive Director, Fraunhofer FIT, Birlinghoven, and Deputy Chairman, Fraunhofer Information and Communication Technology group
• Founding Director, Bonn-Aachen International Center for Information Technology (B-IT), and Coordinator, B-IT Research School
• 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)
• Advisory Board, RWTH Aachen International Academy
• Scientific advisory board, Faculty of Informatics, University of Vienna, Austria
• Scientific advisory board, Learning Lab Lower Saxony (L3S), Hannover
• Scientific advisory board (chair), OFFIS, Oldenburg
• Scientific Advisory Board, CIO Colloquium Germany
• Research commission, Free University of Bozen, Italy
• Advisory board, Large Scale Complex IT Systems Initiative (LSCITS), UK
• Review board, Quality Assurance Netherlands Universities (QANU) evaluation of Dutch Economics and Business Faculties 2008-2009
• Review Board, WWTF Austria ICT Initiative
• Reviewer, Learning Media Program, Open University of the Netherlands, Heerlen
• Member in several faculty selection committees
• Reviewer, DFG, NSF, NSERC Canada
• Hochschulrat, FH Köln
• Member of Program Board, LOEWE Excellence Initiative
• Curatory board and scientific advisory board, Leibniz-Zentrum für Informatik, Schloss Dagstuhl
• Jury, Wissenschaftspris Stifterverband der Deutschen Wirtschaft
• Jury, Campus Online competition, Stifterverband der Deutschen Wirtschaft
• Jury, ACM/AIS Best Dissertation in Information Systems Award 2009

R. Klamma is technical leader and community facilitator of the EU IP ROLE.

Y. Cao is member of DIN NI-32 “Data Management and data exchange”.

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Editorial Boards

Matthias Jarke serves on the editorial boards of the following journals: ACM Transactions on Management Information Systems (ACM-TMIS), Decision Support Systems, Group Decision and Negotiation, Wirtschaftsinformatik / Business Information Systems Engineering, Journal of Intelligent Information Systems, Cooperative Information Systems, Requirements Engineering Journal, Journal of Universal Computer Science (J. UCS), VLDB Journal Track. He is currently Guest Editor of a Special Issue of Wirtschaftsinformatik on High Impact Requirements Engineering. He also served as reviewer of several journals, including IEEE TSE and IEEE TLT.

Ralf Klamma serves as associate editor for IEEE Transactions on Learning Technologies (TLT), 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 Metaday Community (www.multimedia-metadata.info) and the Bamiyan Development Community (www.bamiyan-development.org). In the moment he is editing a special issue of the International Journal of Emerging Technologies in Learning (i-JET) for the MASHL 2009 special track at the ICL 2009. He also served as reviewer for IEEE Software, IEEE Internet Computing, IEEE Multimedia, IEEE Transactions on Software Engineering, Annals of Information Systems, JEMA, ET&S, Multimedia Tools and Applications, ILE, VLDB Journal, IJTEL, JTICL, Simulation & Gaming and AIS.

Conference Organization

Yiwei Cao was local co-chair of 8th International Conference on Web-based Learning (ICWL’09), chair of Second International Workshop on Story-Telling and Educational Games (STEG’09). She was member of the program committee of 4th International Workshop on MOBILE and NEtworking Technologies for social applications (MONET’09), 9th and 10th Workshop of the Multimedia Metadata Community (WMM’09 & SeMuDaTe’09), SIRTEL’09, 7th Annual IEEE International Conference on Pervasive Computing and Communications Work in Progress (PerCom’09-WiP), ICWL’09, STEG’09, ACM MEDES’09, Complex’09, MIMIC’09, DEXA’09, IWCES’09, Special issue Multimodal Interaction and MultImodal Content management (MIMIC) on the Multimedia Tools and Applications (MTAP) International Journal. Yiwei Cao was also reviewer for ICALT’09, special issue on context-aware and mobile multimedia databases and services (JDIM-MMD), special issue on mobile and networking technologies for modeling social applications and services published in the Journal of Computing Science and the Engineering, and the PsychNology Journal.

Mohamed Amine Chatti was publicity co-chair of Fourth European Conference on Technology Enhanced Learning (EC-TEL’09), 29 September-2 October 2009, Nice, France. He organized the First International Workshop on Future Learning Landscapes at EC-TEL’09. He was member of the program committee of Second World Summit on the Knowledge Society (WSKS’09), First International Workshop on Building Sustainable Open Source Communities (OSCOMM’09) in conjunction with OSS’09, Workshop on Exploitation of Usage and Attention Metadata (EUAM’09) in conjunction with Informatik 2009, Second International Workshop on Social Software Engineering and Applications (SoSEA’09) in conjunction with ESEC/FSE’09, Second International Workshop on Mash-Up Personal Learning Environments (MUPPLE’09) in conjunction with EC-TEL’09, IEEE ICALT’09, IADIS EL’09.

Anna Hannemann was publicity co-chair of 8th International Conference on Web-based Learning (ICWL2009), RWTH Aachen University, Aachen, Germany, 19-21 August 2009.
She organized First International Workshop on Software Engineering within Social Software Environments (SENSE09) held together with Collaboration and Knowledge Sharing in Software Development Teams in conjunction with the Conference on Software Engineering (SE2009) Fraunhofer Institute Experimental Software Engineering, Kaiserslautern, Germany, 2-6 March, 2009 and the Second International Workshop on Story-Telling and Educational Games (STEG’09) RWTH Aachen University, Aachen, Germany, 21 August, 2009 in conjunction with the 8th International Conference on Web-based Learning (ICWL 2009) RWTH Aachen University, Aachen, Germany, 19-21 August, 2009.

Matthias Jarke was co-chair of the Dagstuhl Perspective Seminar “Science of Design: High-Impact Requirements for Software-Intensive Systems” with Kalle Lyytinen (Case Western) and John Mylopoulos (Toronto/Trento) in October 2008. He served as general chair of the ICWL 09 in Aachen, as program co-chair of the Mobile HCI 2009 in Bonn, and as chair of the SME conference Symposium “Werkstoff Software – Software Engineering Symposium 2009” at the B-IT in Bonn. Furthermore, he served on the following program committees: CAiSE 2009, Amsterdam; EUAM 2009 Workshop at Informatik 2009, Lübeck; ICIS Doctoral Symposium 2008, Paris; ICOODB 2009, Zürich; REFSQ 2009, Amsterdam; SE-2009, Kaiserslautern; WWW 2009, Madrid. He also serves on the Advisory Board of the CIO Colloquium, a network and conferences series of the Chief Information Officers in German industry.

David Kensche was reviewer for Information Sciences (Informatics and Computer Science Intelligent Systems Applications), Elsevier.

Ralf Klamma was general co-chair of the 8th International Conference on Web-based Learning (ICWL 2009), Aachen, Germany, 19-21 August, 2009. He was also co-chair of the following events: 5. JTEL Summer School in Technology Enhanced Learning, Terchova, Slovakia, June 2009, 9th Workshop of the MPEG-7 Community on Multimedia Metadata (WMM'09), Toulouse, France, 19-20 March, 2009, 10th Workshop of the MPEG-7 Community on Semantic Multimedia Databases (SeMuDaTe’09), Graz, Austria, December 2, 2009, First International Workshop on Software Engineering within Social software Environments (SENSE09), Kaiserslautern, Germany, 2-6 March, 2009. He served as program committee member / reviewer for the following conferences: ACM CHI’09, ACM Group’09, ACM Multimedia’09, ACM MTDL’09, ACM CHI’10, IEEE ICALT’09, IEEE SITIS’09, American Control Conference ACC’09, Complex’09, Workshop Virtual Worlds (ViWo’09) at ICWL’09, Wissensmanagement WM’09, Web-based Information Systems (WEBIST’09), Mobile Learning’09, International Conference on Computer Supported Education (CSEDU’09), WMM’09, International Symposium on Collaborative Technologies and Systems (CTS’09), CTS’10, Communities & Technologies’09, Web-based Communities (WBC’09), ICWL’09, International Conference on Web and Information Technologies (ICWIT’09), EC-TEL’09, GI-Workshop Digital Social Networks (GI-DSN’09), Workshop Business Process Management and Social Software (BPMS2’09), Special Track Mashing up Learning Environments (MASHL’09), Interactive Computer Aided Learning (ICL’09), E-Learning’09, I-KNOW’09, STEG’09, Workshop Open Design Spaces (ODS’09), SciTEL’09, HICSS’10, Workshop Computer-based Knowledge & Skill Assessment and Feedback in Learning Settings (CAF’09), Workshop Semantic Multimedia Database Technologies (SeMuDaTe’09), eKnow’09, eKnow’10, International Symposium on Computers in Education (SIIE’09), TenCompetence’09.

Zinayida Petrushyna co-organized the JTEL Summer School 2009, Terchova, Slovakia and was treasurer of 8th International Conference on Web-based Learning (ICWL2009), RWTH
Aachen University, Aachen, Germany, 19-21 August 2009. She was also reviewer for IADIS e-Learning 2009, Portugal.

Software Demonstrations

- Virtual Campfire, UMIC Day 2008, October 19, 2009, Aachen, Germany
- Virtual Campfire, IKYDA Kick-off Meeting, April 24, 2009, Aachen, Germany
- Virtual Campfire - Cross-Platform Services for Mobile Social Software, the 10th IEEE International Conference on Mobile Data Management (MDM’09), Taipei, Taiwan, May 18, 2009
- Virtual Campfire was demonstrated to visitors including Karl Aberer (EPFL), Markus Strohmaier (TU Graz), M. Zia Afshar (Deputy Minister of Afghan Ministry of Information and Culture), and M. Yousaf Pashtun (Minister of Afghan Ministry of Urban Development) in 2009
- UMIC HealthNet prototype was demonstrated at RWTH Aachen Transparent, January 30, 2009, Aachen
Talks and Publications

Talks


Y. Cao: *Mobile Access to MPEG-7 Based Multimedia Services*, the Tenth International Conference on Mobile Data Management, Taipei, Taiwan, May 18-20, 2009

Y. Cao, R. Klamma: *A Multimedia Service with MPEG-7 Metadata and Context Semantics*, the 9th Workshop on Multimedia Metadata (WMM'09), Toulouse, France, March 19-20, 2009

Y. Cao: *A Web 2.0 Personal Learning Environment for Classical Chinese Poetry*, ICWL 2009, 8th International Conference, Aachen, Germany, August 2009


A. Hannemann: *Community Driven Elicitation of Requirements with Entertaining Social Software*, the First International Workshop on Software Engineering within Social Software Environments, Kaiserslautern, Germany, March 3, 2009


M. Jarke: *Mobile Applications and Services*, UMIC Advisory Board, Aachen, October 20, 2008

M. Jarke: *Informatik überall – neue Ziele für das Informatikstudium?* Invited talk, 50 Years IT at Hamburg University, Hamburg, November 1, 2008; and 1. Gummersbacher Informatik-Forum der FH Köln, Gummersbach, April 4, 2009


M. Jarke: *Holistic engineering of ultra-highspeed mobile information and communication systems*, Invited Talk, 25th Anniversary of the Faculty of Informatics at Passau University, Passau, January 16, 2009
M. Jarke: *Das Institutszentrum Schloss Birlinghoven*, Presentation to Fraunhofer Board, Birlinghoven Castle, February 2, 2009


M. Jarke: *Fraunhofer Institute Center Birlinghoven Castle*. Presentations to the Fraunhofer Board, 2.2.2009; and to the Science and Culture Attachés of the Embassies in Germany, Birlinghoven, May 11, 2009


M. Jarke: *Requirements modeling – past, present, future*, Symposium in Honor of John Mylopoulos, University of Toronto, June 27, 2009

M. Jarke: *Meta modeling with Datalog and Classes – ConceptBase at the Age of 21*, Invited Talk, 2nd Intl. Conf. Object-Oriented Data Bases (ICOODB 09), ETH Zürich, June 3, 2009

M. Jarke: *Fraunhofer im Bundeswettbewerb Informatik*. Opening statement, award ceremony of Bundeswettbewerb Informatik, Essen, September 25, 2009

R. Klamma, Y. Cao: *You Never Walk Alone: Recommending Academic Events Based on Social Network Analysis*, the First International Conference on Complex Science (Complex’09), Shanghai, China, February 23-25, 2009

R. Klamma: *No Country for Old Men*, Online Round Table, October 8, 2009


R. Klamma: *Offene Lernumgebungen – Chancen, Herausforderungen, Grenzen*, AK E-Learning’09, Berlin, Germany, September 15, 2009


R. Klamma: *ROLE Vision*, ROLE Kick-off Meeting, Lausanne, Switzerland, March 2, 2009

Z. Petrushyna: *The TEL researcher's guide to social network analysis*, JTEL Summer School 2009, Terchova, Slovakia, June 1, 2009


**Publications**

**Books and Edited Volumes**


Journal Articles


Conference and Book Contributions


S. C. Brandt, M. Schlüter, M. Raddatz, M. Jarke: Management of Experience Knowledge in Continuous Production Processes, 13th IFAC Symposium on Information Control Problems in Manufacturing, Moscow, RUS, June 3-5, 2009


Y. Cao, M. Jarke, R. Klamma, O. Mendoza, S.N. Srirama: Mobile Access to MPEG-7 Based Multimedia Services, Proc. of the Tenth International Conference on Mobile Data Management (MDM09), May 18-20, 2009, Taipei, Taiwan, pp. 102-111


R. Klamma, M. C. Pham, Y. Cao: *You Never Walk Alone: Recommending Academic Events Based on Social Network Analysis*, Proceedings of the First International Conference on Complex Science (Complex’09), Shanghai, China, February 23-25, 2009

D. Lübbers, M. Jarke: *Adaptive Multimodal Exploration of Music Collections*, Proc. 10th Intl. Conf. on Music Information Retrieval (ISMIR), Kobe, Japan, October 26-30, 2009


H. W. Nissen, D. Schmitz, M. Jarke, T. Rose: *How to Keep Domain Requirements Models Reasonably Sized*, 2nd Int. Workshop on Managing Requirements Knowledge, MaRK @ RE, Atlanta, USA, September 2009


C. Quix, X. Li, D. Kensche, S. Geisler: *View Management Techniques and Their Application to Data Stream Management*. In Evolving Application Domains of Data Warehousing and Mining: Trends and Solutions, September 30, 2009


**Other Publications (Selection)**

Knowledge-Based Systems &
Cognitive Robotics Group

Staff

• **Faculty**
  Univ.-Prof. Gerhard Lakemeyer, Ph. D.
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• **Research Assistants**
  Dipl.-Inform. Daniel Beck
  Vaishak Belle, MSc (*funded by DFG*)
  Dipl.-Inform. Laurent Calmes (*until September 2008, funded by DFG*)
  Dipl.-Inform. Jens Claßen (*funded by DFG*)
  Dr. rer.nat. Alexander Ferrein (*funded by DFG*)
  Dipl.-Inform. Stefan Schiffer (*funded by DFG*)

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

• **Visiting Researchers**
  Prof. Kurt Krebsbach, Ph. D., Lawrence University, USA
  (June 2009)
  Thomas Meyer, Ph. D., Meraka Institute, South Africa (July – August 2009)
  Prof. Yongmei Liu, Ph. D., Sun Yat-Sen University, China
  (August 2009)
  Prof. Yves Léesperance, Ph. D., York University, Canada
  (August 2009)
Overview

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

As part of our own research in Cognitive Robotics we are concerned with the development of logic-based languages suitable for the high-level control of mobile robots, and their embedding into robotic systems. On the one hand, such languages allow the description of robotic tasks at an abstract level in terms of high-level actions and their effects on the state of the world. On the other hand, by interpreting these languages, the robots are able to reason about their own goals, the actions they have at their disposal and the way the world changes as a result of these actions. The languages we are considering are extensions of Golog, whose semantics is based on the situation calculus and which was originally developed by Ray Reiter and his colleagues at the University of Toronto. We are investigating extensions regarding actions which change the world continuously and actions with probabilistic outcome. In a recent project funded by the German Science Foundation (DFG) and in collaboration with the University of Freiburg, we are investigating the integration of Golog with state-of-the-art planning systems. In another DFG-funded project, we are applying our techniques to the control of robots in highly dynamic domains like robotic soccer and, more recently, in home-robot scenarios, where the interaction with humans plays an increasing role. In this context, we are also working on methods for sound-source localization, in collaboration with Prof. Wagner from Biology and funded by DFG. Last but not least we are also actively engaged in designing and building robots, together with the necessary low-level control software.
Research Projects

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

Alexander Ferrein, Gerhard Lakemeyer

The goal of this project is to develop a deliberative component supporting coordinated actions of multi-robot systems under real-time constraints, using robotic soccer as a benchmark application. This project is part of the research initiative “RoboCup” (SPP 1125) funded by the German Science Foundation. The basis for the deliberative component to be developed in this project is the logic-based action language Golog, which was initially conceived at the University of Toronto. Golog has been extended within our group in recent years and applied successfully to the control of mobile robots in office environments and museums.

In this project, a dialect of Golog featuring models of continuous change and uncertainty will be suitably adapted and integrated into a system, which combines both the reactive and deliberative choice of actions. Moreover, for the action selection process a decision-theoretic planning approach based on Markov Decision Processes is used. With this kind of planning integrated into the Golog framework the robot is able to choose an optimal course of actions with respect to a suitable utility function. Additionally, this framework allows for taking into account the uncertainties arising in the domain, e.g. a pass to a teammate may succeed or fail with a certain probability.

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

To validate our approach in the framework of RoboCup, we apply it to both the simulation league and real robots in the so-called Middle Size League, using our soccer robots which we built in 2002 with a grant of the NRW Ministry of Education and Research and in collaboration with the Department of Electrical Engineering (Prof. Kraiss). Moreover, we evaluated our approach not only in the soccer domain, but also showed its usefulness for the
encoding of computer players (so-called game bots) in interactive computer games like UNREAL Tournament 2004.

Cognitive Service Robotic Systems and Applications

Stefan Schiffer, Gerhard Lakemeyer

The research areas of the Knowledge-Based Systems Group are Knowledge Representation, Reasoning, and as an application Cognitive Robotics. One of our aims is to develop intelligent mobile robot platforms. With a funding from the German National Science Foundation (DFG) in the Priority Program “Cooperative multi-robot teams in highly dynamic domains” and the Ministry for Science of North-Rhine Westphalia, Germany (MSWF) we developed five robots and participate in RoboCup Championships with these robots for several years now. RoboCup is an international research initiative to foster research and education in the field of artificial intelligence and robotics. The common problem is to develop autonomous soccer playing robots (www.robocup.org).

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

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

To be successful in RoboCup@Home we adapted our robot system. The basic components of the robot system were designed in such a way that they could be used in the new scenario without substantial modifications. It was our laser-based localization following a Monte Carlo approach and a very robust collision avoidance and navigation module that provided us with a stable basis to move from the soccer field to the home-like environment. In fact, both these modules work even better in more structured environments and with lower speeds than in the soccer domain. A map building tool which allows for semantic annotations of maps used for localization and navigation was developed. The annotations are available throughout the whole system and especially for the human machine interface. By adapting our ball recognition to other shapes and colors we were also able to detect other objects in the home environment.

Important tasks in the @Home domain are to localize oneself in the home environment, not to collide with anything in the apartment, and to interact with humans living in it (human-machine interaction). The annual tournament is structured in several specific tasks called tests, that each check for one or more important abilities of the robot. In a so-called Open Challenge and in the Final teams can freely demonstrate whatever they think is their robot’s most noteworthy functionality.
In the last three years we continuously enhanced our robot’s abilities both in soft- and in hardware. We installed a six degree of freedom manipulator and a stereo camera to better perceive and to manipulate things in the environment. The control software now features a generic object detection and recognition module, robust and flexible speech recognition used to command the robot, and further a new approach to face detection, recognition, and learning which is indispensable for any human-robot interactive application. After winning the world championship in 2006 and 2007 we became vice world champion in the 2008 competition in Suzhou, China. Furthermore, we won the RoboCup German Open in 2007 and in 2008.

RoboCup Middle-size Soccer Robots
Daniel Beck, Alexander Ferrein, Gerhard Lakemeyer

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

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

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

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

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

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

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

### HeRBiE: Hearing on a robot, binaurally enhanced

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

The aim of this work is to equip a mobile robot with a method of sound source localization by using biologically inspired algorithms. The Jeffress model has been a fruitful scheme for understanding the representation of inter-aural time difference as an azimuthal sound-localization cue. As an improvement over previous work, we used the complete three-dimensional coincidence map for determining the azimuth of a sound source. A first implementation of the algorithm on the mobile robot Carl has been completed with promising results. Localization of broadband sound sources could be achieved with excellent precision. Localization of low frequency, narrowband signals is less than satisfactory. This was initially ascribed to the acoustical characteristics of the microphone mount. With the help of acoustic room simulations conducted in 2006, we could show that the inferior performance for low-frequency, narrowband signals is not caused by the microphone mount and neither by the algorithm, but by room reverberations. We integrated a sound localizer based on inter-aural level differences as well as an attention module with the current system. Furthermore, a beamformer module was developed which allows spatial filtering, i.e., sounds coming from a
given direction can be enhanced while all other directions are attenuated. A first attempt was made at combining laser-based object recognition and sound localization on one of the RoboCup robots. We are currently working on more sophisticated methods for exploiting these two sensor modalities. Specifically, a Markov Chain Monte Carlo-based tracking algorithm is in the process of being implemented, which will make it possible for the robot to track dynamic objects emitting sounds (e.g. humans) over time. In combination with the beamformer, this system can act as a front end for speech recognition, by enhancing speech signals from the direction of a human, on which the robot’s attention is focused.

PLATAS – Planning Techniques and Action Languages

Jens Claßen, Gerhard Lakemeyer, Bernhard Nebel, Gabriele Roeger (University of Freiburg)

Although there is a common origin, research on automated planning on the one hand and action logics on the other hand developed rather independently over the last three decades. This is mainly due to the fact that work on action languages was concerned with formalisms of high expressiveness, whereas for planning methods, the focus had to lie on computational efficiency, yielding input languages with less expressive possibilities. However, one can observe that during the last few years, the two separate fields began to converge again. Exemplary for this trend is the development of the planning domain definition language PDDL, which extends simple STRIPS-based planning by features such as conditional effects, time, concurrency, plan constraints and preferences, and which virtually constitutes a standard in the field of planning.

This DFG-funded project is conducted in cooperation with the Research Group on the Foundations of Artificial Intelligence of Bernhard Nebel at the University of Freiburg. It aims at integrating latest results in the areas of both action languages (in particular, GOLOG) and planning techniques (in particular, PDDL-based planners like Hoffmann and Nebel’s FF) to acquire systems that are both expressive and efficient. In the first project phase, we are for this purpose on the one hand working on establishing a common semantical basis for both GOLOG and PDDL in the situation calculus. Results in this direction have been achieved for certain fragments of PDDL (including ADL, time and concurrency) and will be extended in the course of the project to eventually cover the full scope of the language. Experimental evaluations have shown that combining a GOLOG system with a PDDL-based planner is beneficial in terms of savings in the computation time needed by the overall system. On the other hand, expressiveness is studied by means of compilation schemes; corresponding fragments of both formalisms with the same expressive power have thus already been identified. This work will provide the foundation for embedding state-of-the-art planning systems like FF in GOLOG (which is beneficial in terms of the system’s runtime, as first experiments have shown) and enhancing planners with GOLOG relevant features such as time, concurrency and continuous actions, yielding in both cases systems that are both efficient and expressive.

The second project phase tackles the problem that 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. Therefore, both GOLOG systems and
PDDL-based planners are to be extended with the possibility of using incomplete knowledge in a tractable manner. For that purpose, a logical formalization based on Liu, Lakemeyer and Levesque’s subjective logic SL has been developed. Another aspect being studied is how to speed up the execution of GOLOG programs in those situations where there actually is complete information about the current world state. Instead of only calling a PDDL planner and providing it with the translation of the primitive actions of the GOLOG domain, entire GOLOG programs (that contain valuable control information in the form of macro actions that restrict the space of possible plans) shall be efficiently translated into PDDL problems that can then be solved by a planning system. Furthermore the aim of current research is to not only embed domain-independent PDDL-based planners into GOLOG, but to do so also with systems such as TLPlan or TALplanner that possess the ability to consider domain knowledge to drastically reduce their search space. To this end, sublanguages of the situation calculus are to be identified that correspond to those planners’ underlying input logics. Finally, the newly developed systems and methods shall be evaluated on mobile robots and appropriate benchmark problems.

Self-Aware Humanoid Robots in the RoboCup Standard Platform League
Alexander Ferrein, Gerhard Lakemeyer

This project is a research co-operation between the University of Cape Town, South Africa, the Technical University Graz, Austria, and the Knowledge-Based Systems Group, and is 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.
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).
While the importance of imperfect information games has been long recognized, and efficient equilibria solvers proposed thus, an effective model to reason about knowledge and action in these rich games remains at large. For instance, suppose that Alice and Bob play poker. We want to reason that after Alice has read her card, Bob does not know what she knows but knows that she knows her card. The aim of this work is to introduce semantic models, that bring out this *de re* (knowing "what") and *de dicto* (knowing "that") distinction in games with imperfect information. Further, since the evaluation of strategies, and payoffs thereof, is critical in games, the semantic models must clarify how knowledge over action is to be handled.

An issue of importance here, besides defining what they (players) know, is to also give a declarative account of what they do not know. Consequently, the idea of only-knowing seems appropriate, and this work also addresses how only-knowing works in a multi-agent setting; previously shown to be a non-trivial matter. The logics proposed thus are first-order modal logics, that closely fashion the variant of situation calculus introduced in the past years by Lakemeyer and Levesque. As a consequence, action theories are naturally amenable to regression-based reasoning.
Other Activities

ECCAI Fellows Program

Gerhard Lakemeyer was nominated as an ECCAI Fellow. The ECCAI (European Coordinating Committee for Artificial Intelligence) Fellows Program was started in 1999 to recognize individuals who have made significant and sustained contributions to the field of artificial intelligence in Europe. The recognition is generally for pioneering work in the theory of AI, or exceptional contributions to the applications of AI technology.

Program Committees

Gerhard Lakemeyer was PC member of numerous international conferences, including IJCAI 2009 (Area Chair), and a Program Chair of the 2009 Symposium on Commonsense Reasoning. 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 2009 and of the ERLARS Workshop in 2009.

Technical Committees

Stefan Schiffer served as a member of the Technical Committee in the RoboCup@Home league in 2008 and 2009.

Alexander Ferrein served as the Local Organizing Chair for the Standard Platform League at the RoboCup2009 competition in Graz, and as a Co-Chair of the IJCAI-09 Workshop on Hybrid Control for Autonomous Systems.

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

• In 2009, Prof. Thomas Meyer from the Meraka Institute in South Africa visited our research group for two months. 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.

• In 2009, Prof. Kurt Krebsbach from Lawrence University in Wisconsin visited our research group. Prof. Krebsbach is known for his work on planning under uncertainty. He gave a talk on "Deliberation Scheduling using GSMDPs in Stochastic Asynchronous Domains", a decision-theoretic approach to planning problems using the notion of generalized semi-Markov decision processes.

• In 2009, Prof. Yves Lespérance from York University, Toronto, visited our research group for a month. Prof. Lespérance is known for his work on cognitive robotics and multi-agent systems.

• In 2009, Prof. Yongmei Liu from Sun Yat-Sen University in China visited the group for one month. She is known for her work on reasoning about action and tractable reasoning. She recently co-authored a paper with Prof. Gerhard Lakemeyer on first-order definable theories that are amenable to progression.
Gerhard Lakemeyer visited the University of Toronto in March and September 2009, to collaborate with Prof. Hector Levesque to continue their work on reasoning about knowledge and action.

Tournaments and Competitions

RoboCup German Open 2009.

In April 2009, we participated in the RoboCup German Open 2009 which took place at the Hannover Fair with our newly developed Middle Size League soccer robots for the first time. The RoboCup competitions were located in the fair hall together with a mobile robotics exhibition gaining attention from both industry and visitors. Unfortunately, we experienced massive problems with our vision system which basically “blinded” the robots. Precisely, those problems were due to the very rapidly changing lighting conditions that we weren’t prepared for since we never experienced those before. Despite working hard on the problem we weren’t able to implement a workaround for that problem during the competition and, consequently, didn’t survive the preliminary round. Nevertheless, we made quite some valuable experience and got back into the league after our leave in 2006.

RomeCup 2009.

Upon an invitation by the Fondazione Mondo Digitale we participated the third RomeCup in Italy in 2009. With two of our humanoid robots we took part in a three-way Robo-Olympics Meet and ranked second. RomeCup 2009 was held on seventh of May 2009 at Campidoglio in Rome.

RoboCup 2009.

We participated with our team “AllemaniACs” at the 2009 RoboCup World Championships in Graz, Austria in the RoboCup@Home league. @Home is a league established in RoboCup in 2006 to foster service robotics applications. Besides capabilities like safely maneuvering and localizing in an apartment like scenario human machine interaction is of special interest, that is, the communication between man and machine in a natural way.

After winning the competition in 2006 and 2007 and a decent second place in 2008 we took some risk this year and moved large parts of our software to a newly developed robot control software named Fawkes. This worked out pretty good although we had to cut back on the expectations since competing with a brand new systems also means not already knowing all the pitfalls and how to avoid them. With the AllemaniACs team we only slightly missed the finals. But we were the first team ever 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.

The Knowledge-Based Systems Group also participated in the Standard Platform League with their team “ZaDeAt”. This joint team is run by partners from the University of Cape Town, Technical University of Graz, and the Knowledge-Based Systems Group. During competition the team advanced to the second round, ranking tenth in the end.
Talks and Publications

Talks
Stefan Schiffer: RoboCup@Home - Wettkampf der Service-Roboter, Tagung "58/08: Der Mensch als Vorbild, Partner & Patient von Robotern", Evangelische Akademie Loccum, October 2008.[1]
Stefan Schiffer: Robust Service Robotics in RoboCup@Home - A Team’s Perspective, EURON annual meeting 2009, K.U.Leuven in Leuven, Belgium, April 2009.[1]

Publications
Thomas Wisspeintner, Tijn van der Zant, Luca Iocchi and Stefan Schiffer: RoboCup@Home: Results in Benchmarking Domestic Service Robots, RoboCup Symposium 2009, Graz, Austria, June 30 - July 3, 2009[1]
Gerhard Lakemeyer and Hector Levesque: A Semantical Account of Progression in the Presence of Defaults, Twenty-first International Joint Conference on Artificial Intelligence (IJCAI-09), Pasadena, USA, July 11-17, 2009[1]
Yongmei Liu and Gerhard Lakemeyer: On First-Order Definability and Computability of Progression for Local-Effect Actions and Beyond, Twenty-first International Joint Conference on Artificial Intelligence (IJCAI-09), Pasadena, USA, July 11-17, 2009[1]
Daniel Beck and Gerhard Lakemeyer: Reinforcement Learning for Golog Programs, Relational Approaches to Knowledge Representation and Learning, Workshop at the 32nd Annual Conference on Artificial Intelligence (KI-2009), p.64-78, Paderborn, Germany, September 15-18, 2009[1]
Thomas Wisspeintner, Tijn van der Zant, Luca Iocchi and 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]
Human Language Technology and Pattern Recognition

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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:

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

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:

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

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)

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.

![Speech waveform and FFT spectrum](image)

(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
English, French, German, Italian, Spanish, Greek, Portuguese, Dutch, Danish, Finnish, Swedish, Czech, Hungarian, Polish, Slovakian and is based on corresponding TV broadcasts and internet publications.

- 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.

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

Data Mining Cup 2009

In 2009 the "Lehrstuhl für Informatik 6" organized again a lab course on data mining. In contrast to the previous years the students in the lab participated in the data mining competition hosted at the Knowledge Discovery in Databases (KDD) conference which is one of the leading conferences on data mining. The competition was split into a fast, a large, and a small challenge where the fast challenge required to submit solutions within one week, and small and large challenge required solutions to be submitted within one month. Seven solutions to the small challenge were submitted by the participants of data mining lab. The final solutions achieved ranks 1-2, 5, 10, 12, 19, and 29 out of total 453 solutions submitted.

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 the first half of 2009, the "Lehrstuhl für Informatik 6" participated as a member of the NIGHTINGALE research team, led by SRI. Here, i6 contributed to GALE with the transcription of Chinese audio data into text (automatic speech recognition) and the translation of foreign language material into English (machine translation). The systems pass along pointers to relevant source language data that will be available to humans and downstream processes. The distillation engine integrates information of interest to its user from multiple sources and documents. Starting in summer 2009, the "Lehrstuhl für Informatik 6" is part of the ROSETTA team, led by IBM. RWTH contributes translations from Arabic to English to this project.

NIST Machine Translation Evaluation 2009

In 2009, we took part in the NIST machine translation evaluation for translation of Chinese and Arabic into English. The goals were to evaluate RWTH state-of-the-art machine translation models under real-world conditions and show comparable results to leading research groups from all over the world. The RWTH system achieved good results and was ranked among the best groups.
In the informal system combination track, teams were asked to combine the English output from different MT systems of the same documents to a single translation. Out of the seven participants in the Arabic-to-English subtask, the "Lehrstuhl für Informatik 6" achieved a fourth place with their primary system, and the second place with their contrastive system. In the Urdu-to-English subtask, only four teams participated, out of which i6 scored best.

spoken Language UNderstanding in multilinguAl communication systems (LUNA)

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

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

The first module (WLA) extracts information represented as basic concepts ("yes" is a "response"), while the second module integrates knowledge about the concept level to get a higher level interpretation. The last module takes the dialog state into account and omits all hypotheses that are not possible in this dialog state. Between the modules the hypotheses are transmitted using lattices.

The dialog systems developed in LUNA are multi-domain (e.g. hotel reservation, IT-Help-Desk, Warsaw transportation call-centre) and multilingual. They support the languages French, Italian, and Polish. Within this three-year project the ‘Lehrstuhl für Informatik 6’ contributed mainly to the word lattice annotation module. This component is the most important one for all dialog systems. In some applications like call routing it is satisfactory as input to the dialog manager. ‘Lehrstuhl für Informatik 6’ applies ongoing research in the fields of Conditional Random Fields, positional wise normalized log-linear models and machine translation to the word lattice annotation process. Using system combination, the already good performance of the best single best system could be further improved.

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

Within the TRANSTAC project, RWTH/i6 built machine translation systems for colloquial Iraqi Arabic to English and vice versa. The systems were optimized for real-time operation. The trained models were then integrated into SRI's IraqComm system, a ruggedized, mobile, spontaneous translation system. Additionally, SRI participated at various evaluations with systems delivered by RWTH/i6. Rapid development of new MT systems was tested in a special surprise language track where the researchers have limited time to set up a complete
translation pipeline, e.g. for Malay (Bahasa Malaysia) to English and vice versa. The focus here was on Speech-to-Text translation systems.

**Quaero**

Quaero is a collaborative research and development program, centered at developing multimedia and multilingual indexing and management tools for professional and general public applications such as the automatic analysis, classification, extraction and exploitation of information.

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

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

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

**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.
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.

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**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.

![Sign-Speech System Diagram]

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.
Publications


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Logic & Theory of Discrete Systems

Staff

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  Prof. Dr. Dr.h.c. Wolfgang Thomas
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  Dipl.-Inform. Daniel Neider
  Dipl.-Inform. Jörg Olschewski
  Dipl.-Inform. Frank Radmacher
  Dipl.-Inform. Michaela Slaats
  Dipl.-Inform. Alexandra Spelten
  Dipl.-Inform. Karianto Wong
  Dipl.-Inform. 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)

Further highlights:

• W. Thomas participated in launching two series of electronic conference proceedings that adhere to a high standard by a strictly scientific and non-commercial management and offer open access to the scientific community: At Schloss Dagstuhl, the Leibniz International Proceedings in Informatics (LIPIcs) were founded for the publication of high-level conference proceedings, whereas the Electronic Proceedings in Theoretical Computer Science (EPTCS), published at Stanford, focus on high quality workshops and small conferences.
• The group participated in the launch of B-IT Research School, an institution for integrated doctoral studies in cooperation with the Department of Computer Science of the University of Bonn. W. Fridman joined the school with a research project on distributed controller synthesis.
• C. Löding submitted his habilitation thesis “Logic and Automata over Infinite Trees” and passed the habilitation procedure, thus becoming “Privatdozent”.
• W. Thomas was invited to give one of the two “integrated keynote speeches” of the leading conference on software science in Europe (ETAPS, European Joint Conference on Theory and Applications of Software), York, March 2009.
Research Projects

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 in the analysis of infinite structures, in particular of transition graphs that arise as state-based models of software systems. An overview of the whole field was completed in the survey article [21] to be published in a handbook of the Indian Institute of Science.

- **Reachability Problems**
  This problem is the fundamental question how to decide for two vertices $u, v$ of a given graph whether there is a path from $u$ to $v$. An introduction into the area was presented in an invited lecture at the conference CSR (Computer Science in Russia) in Novosibirsk, August 2009, see [18]. Many more results are contained in the doctoral thesis of Jan Altenbernd “Reachability over Word Rewriting Systems” [2]. Here a regular set of words serves as the universe of a transition graph, and several types of rewriting rules are applied to define the transition relation. Among other things, the thesis provides a rather complete study of rewrite rules that allow modifications of words next to special markers called “tags”. It turned out that the saturation technique from the theory of prefix-rewriting systems can be generalized to the basic setting of tag rewriting, and that for different variations of the problem, more general methods for obtaining decidability proofs have to be applied.

- **Compositional Methods in Model-Checking**
  In a study of I. Felscher [5] the model-checking problem over product structures was analyzed. A fundamental background result is the “Feferman-Vaught Theorem” of first-order model theory which allows to derive information about a product structure from properties of the components and certain information about the way they are composed. In computer science, one is interested in properties expressible in (fragments of) monadic second-order logic. The results of [5] clarify under which circumstances 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.

- **Unfoldings and path logics over infinite graphs**
  In work of A. Spelten, the power of model constructions of unfolding and interpretation (as used in the so-called Caucaal hierarchy) was analyzed. It was shown that model-checking of path logics may become undecidable for limits of models of the Caucaal hierarchy. Other work in progress is concerned with an automata theoretic characterization of path logics. The power of path logics in the presence of constructs of “synchronization” was studied in a contribution for the Festschrift for P.S. Thiagarajan (see [19]).
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. General aspects of the field were discussed in a keynote talk at ETAPS 2009 (see [20]).

- **Controller Synthesis**
  An overview of the structure and the research program of the Research Training Group AlgoSyn was presented in [17], combining a general description by the speaker of the group and five typical research projects, outlined by the respective doctoral students. Another result of interdisciplinary work is the paper [4] 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. M. Holtmann pursued a project (with M. Gelderie) aiming at algorithms for reducing the memory necessary for the implementation of controllers in regular games. Current investigations are concerned with an experimental evaluation of the implemented procedures.

- **Strategies in Parametrized Infinite Games**
  A “parametrized game” is essentially a three player game where the players I and II from the classical setting are joined by a third player executing predefined moves. In another view, this corresponds to a component of the environment with predefined behaviour. This predefined behaviour serves as “parameter” in the resulting game. In the paper [7], two contributions to this type of game were presented: a streamlined proof for a result by A. Rabinovich that characterizes the situations when computable strategies suffice for the respective winner (player I or II), and a clarification of the type of winning strategy for the case where the parameter is generated by a higher-order pushdown system.

- **Time-Optimal Winning Strategies**
  M. Zimmermann succeeded in devising an algorithm for synthesizing optimal controllers that guarantee a partially ordered set of request-response conditions. This work is a continuation and generalization of investigations by F. Horn and N. Wallmeier (see previous annual reports). The results on partially ordered conditions were presented at CIAA 2009 (see [23]). In more recent work, 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 [22]).

- **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. J. Olschewski and W. Fridman obtained results that
realize in many cases a very close link between these two aspects. In the studies of J. Olschewski, “weak” games are considered, where the winning condition only involves conditions on visits of certain system states. A method was proposed that allows to transfer a format of winning condition (such as locally testable) to that of corresponding winning strategies. For several versions of infinite state games (in particular, games over pushdown systems or counter systems), W. Fridman obtained analogous results by rather different techniques. 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 a 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 [9]. These investigations are now continued also for infinite-state games where several new phenomena arise.

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**Tree Automata**

*K. Wong, C. Löding, W. Thomas*

*Funding: DFG*

The research activities were divided in two branches, concerning (1) automata over finite trees (and their relation to the specification of semistructured data such as XML documents), and (2) automata over infinite trees, as a difficult and powerful background theory for program verification and synthesis. For a handbook published by the Indian Institute of Science, C. Löding contributed the chapter on the fundamentals of tree automata theory [15].

• **Automata over Unranked Trees**

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 (to appear 2010). 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. For the latter purpose, a rather expressive MSO-logic over trees was suggested as a component of the automaton transitions. A strong decidability result on the nonemptiness problem for these “sibling constraints” is presented in [13].

• **Automata on Infinite Trees**

In his habilitation thesis [14], C. Löding enriched the theory of automata theory over infinite trees by several new concepts and methods. Main results are concerned with
(1) a solution of the uniformization problem for monadic second-order definable tree relations, using automata theoretic methods,
(2) an approach to the classical “parity index problem” for tree automata, involving a new model of tree automaton (guidable tree automaton) and new valuation structures in automata,
(3) the method of “MSO to FO interpretations”, as a new type of model construction for the generation of structures with decidability properties.

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 [10], 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 current work, 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.

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. 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 graph we can guarantee to compute the solution, if we require that the target to learn can be represented symbolically. Our proof-of-concept implementation uses the learning framework libalf, which is currently developed at the Chairs of Computer Science i2 and i7 [3].
Moreover, as a contrary area of interest in this project, we developed a novel learning technique for visibly one-counter automata. We applied this technique to compute finite automata that are capable of validating well-formed XML streams [16].
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
• Member of Conseil Scientifique d’ Ecole Normale Superieure de Cachan
• Member of the Council of EATCS (European Association of Theoretical Computer Science)
• Member of the Executive Committee of the Research Network AutoMathA (Automata Theory: From Mathematics to Applications) of the ESF (European Science Foundation)
• Member of the Steering Committee for the conference STACS (“Symposium on Theoretical Aspects of Computer Science”)
• Member of the program committees of ICALP 2009 (Track B) in Rhodes, Greece, and Workshop on Reachability Problems (RP 2009) at Ecole Polytechnique, Paris.
• Representative of the Faculty of Mathematics, Computer Science, and Natural Sciences for the organization of doctoral studies.
• Member of Aachen Competence Center for History of Science

W. Oberschelp

• Member of the interdisciplinary working group “Karolingesches Aachen” at the RWTH Aachen
• Member of Aachen Competence Center for History of Science

C. Löding

• Student Advisor for Curricula of Minor Subjects and for Teachers’ Curricula
• Member of the program committee of AutoMathA 2009
Talks and Publications

Talks


C. Löding: *Infinite Games and Automata Theory*, Tutorial at the Games Spring School, Bertinoro, Italy, June 1-5, 2009


C. Löding: *Games and Automata for Verification*, Tutorial at the Games Workshop, Udine, Italy, September 14, 2009

C. Löding: *Tree Automata with Costs for Boundedness Problems*, Games Workshop, Udine, Italy, September 15, 2009


F. Radmacher: *Sabotage Games*, DFG Research Training Group "Algorithmic synthesis of reactive and discrete-continuous systems (AlgoSyn)", RWTH Aachen, January 8, 2009


M. Slaats: *Parametrized Infinite Games and Higher-Order Pushdown Strategies*, AutoMathA: from Mathematics to Applications, University of Liège, Department of Mathematics, June 2009


W. Thomas: *Laudatio auf Jan van Leeuwen and Reinhard Wilhelm*, RWTH Aachen, October 2008


W. Thomas: *The Reachability Problem over Infinite Graphs*, Computer Science in Russia, Novosibirsk, August 2009

K. Wong: *On nondeterministic unranked tree automata with sibling equality constraints*, Workshop on Automata and Algorithmic Logic, Stuttgart, Germany, June 28, 2009

M. Zimmermann: *Prompt and Parametric LTL Games*, Games Workshop 2009, Udine, Italy, September 2009


M. Zimmermann: *Model Checking Parameterized Specifications*, Model-Checking@RWTH, Aachen, Germany, December 2008

**Publications**


[22] M. Zimmermann: Parametric LTL Games, submitted

Diploma Theses

Staff

- Faculty
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- Secretary
  Marianne Kuckertz

- 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
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 (GAME S) 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, M. Ummels

AlgoSyn is an interdisciplinary Research Training Group (Graduiertenkolleg) at RWTH
Aachen University lead by a group of ten professors representing five different disciplines.
Integrating approaches from computer and engineering sciences, the project aims at
developing methods for the automatised design of soft- and hardware. AlgoSyn is funded by
the German Science Foundation (DFG).

Inside this Graduiertenkolleg, our research group mainly focusses on foundational projects on
infinite games. In particular, we aim at extending game-based methodologies from two-player
games to multi-player games and to games that involve infinitary winning conditions.
URL: www.algosyn.rwth-aachen.de

Algorithmic Strategies in Multi-Player Games
E. Grädel, 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

Prizes:

Dr. Łukasz Kaiser received the E.W. Beth Dissertation Prize 2009 for his PhD thesis "Logic and Games on Automatic Structures".

Michael Ummels and Dominik Wojtczak (CWI, Amsterdam, The Netherlands) received the Best Student Paper Award at ICALP 2009, for their paper "The Complexity of Nash Equilibria in Simple Stochastic Multiplayer Games".
Talks and Publications

Talks


E. Grädel, 0-1-Laws and Generalized Quantifiers, ENS Cachan, April 2009.


**Publications**


Staff

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  Dipl.-Inform. Torsten Sattler *(funded by DFG)*
  Dipl.-Inform. Arne Schmitz
  Dipl.-Inform. Volker Schönefeld *(funded by DFG)*
  Dipl.-Inform. Dominik Sibbing *(funded by DFG)*
  Dipl.-Inform. Tobias Weyand
  Dipl.-Inform. Henrik Zimmer *(funded by IKT.NRW, Ziel 2)*

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

The Computer Graphics and Multimedia group at RWTH Aachen is focussing on research projects in the areas of Geometry Processing, 3D Reconstruction, Mobile Multimedia, Computer Vision, and Interactive Visualization but it is also active in related areas such as High Quality Image Synthesis and Global Illumination. Our research projects and collaborations are funded by the Deutsche Forschungsgemeinschaft (DFG), the Federal Ministry of Education and Research (BMBF), the German-Israelian Foundation (GIF), and the European Union (EU). Moreover, we are cooperating with various companies in the automotive and automatization industry as well as with academic research groups around the world (North America, Europe, Asia). We consider our research field as applied basic research since even if the methods and techniques that we are developing often address fundamental and abstract problems we are nevertheless aiming at the application and evaluation of our solutions in real world scenarios.

On the Computer Graphics side, a fully automatic Geometry Processing Pipeline is one of the long term goals on our research agenda. This requires methods for capturing the shape and texture of real objects, turning them into efficient computer models and enhancing the quality of the raw data with respect to surface roughness, sharp feature preservation and topological consistency. More sophisticated algorithms are able to even detect and extract structural information (e.g. in technical objects composed by shape primitives such as cylinders and spheres). Eventually we also need algorithms for the interactive visualization of the potentially massive datasets. To achieve this goal we are investigating new techniques to measure three dimensional data with digital cameras and laser range scanners. Once this data is obtained we have to integrate measurements from several sources into a single 3D computer model and thereby remove erroneous and redundant data. Recently, hybrid geometry representations (which combine surface and volume representations) have attracted our interest since they allow for more robust and more efficient algorithms in various geometry processing tasks. In the area of mesh generation we made significant advances in quad-dominant meshing for arbitrary input geometries.

We have recently started to look more closely into graphics applications in the context of mobile and distributed information and communication systems. This is part of our activities within the DFG research cluster UMIC (Ultra High-Speed Mobile Information and Communication Systems). The other line of research that receives increasing attention is visual simulation and pre-processing of complex geometric models for more sophisticated numerical simulations. Here we hope to be able to establish new collaborations within the DFG graduate school AICES (Aachen Institute for Advanced Study in Computational Engineering Science). In the context of the Mobile Access initiative we are collaborating with the communication systems group in order to develop the basic functionality for mobile multimedia applications in a WLAN-based city network.

The processing of 3D geometry data is becoming more and more important in industrial product design and development. Typical applications go 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 egomotion estimation and tracking, we are building a mobile vision system 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 the sequels Computer Graphics I/II and the sequel Geometric Modeling I/II (held by Prof. Leif Kobbelt) and the courses Computer Vision and Machine Learning (held by Prof. Bastian Leibe). In the Computer Graphics courses we cover the basic as well as the advanced techniques for image synthesis and lighting simulation, image based rendering techniques, and polygon mesh processing. The Geometric Modeling courses are more focused on techniques and algorithms to efficiently process freeform curves (part I) and surfaces (part II). In addition, we offer the practical course "Virtual Aachen Project". The aim of this course is the development of a processing pipeline, which enables the automatic creation and photo-realistic real-time visualization of complex virtual city models from simple 2D city maps and height fields. On the undergraduate level we offer an introductory seminar and practical exercises on topics in Computer Graphics. The Computer Vision course covers the basic techniques for image processing, segmentation, object recognition and categorization, 3D reconstruction, and tracking. The Machine Learning lecture supplements this curriculum by teaching the fundamental concepts and techniques for statistical learning, classification, and probabilistic inference. Together, those two lectures provide the know-how for developing methods that enable a machine to analyze and “understand” images and videos and to learn from experience.
On the following pages, we are going to give a brief overview of our current research projects. These range from sophisticated 2D image processing tools and VR applications to computer vision, mesh optimization and interactive shape modeling. This year our group was again able to publish quite a few innovative research papers on internationally recognized conferences and journals in Computer Graphics.
Although augmented reality has been an active area of research for many years, only few augmented reality applications are in practical use outside of scientific research environments. One main reason for the lacking widespread adoption is that most of these applications require special hardware that is either expensive or bulky. However, the improvement in computational power and camera quality of today's mobile phones now seem to constitute a mass-market hardware base that is capable of running augmented reality applications, resulting in the newly emerging research area of mobile augmented reality.

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

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

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

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

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

The images show a typical input car model and a network of feature curves that outline the car's characteristic geometry.
The creation and animation of human characters is an intensively investigated field in Computer Graphics and Vision research. One particularly promising direction in this discipline is the generation of dynamic 3D character models directly from images or video.

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

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

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

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

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

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

In this figure one can see a synthetic example: (left) shows the pointwise optimization of vertex positions. Stabilizing the process by using the shape model leads to a smooth surface (middle) which deviates only slightly from the ground truth surface (right). In a second stage of this project we will extend our capture system to acquire video data from dynamically moving faces. Tracking natural facial features in time and between views of a multiview stereo system will enable us to perform markerless facial motion capture.
Photorealistic image synthesis is one of the central challenges in computer graphics and vision. In the last years, research on view-morphing and image-based rendering has shown great potential with immense impact on practical applications such as free viewpoint TV of sport events and movies, or simply a realistic 3-dimensional visualization from pictures of the last holiday trip. The basic idea in image-based rendering is to synthesize novel output views of a scene directly from a given set of input images. But although the imaging process has been researched extensively, the goal of real-time, virtually unconstrained free viewpoint rendering of arbitrary and unstructured scenes is still very challenging.

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

Our algorithm is implemented using a special parameterization of the view-space and an efficient continuous optimization framework. In combination these techniques support the generation of 3D proxies even for complex scenes and unconstrained camera setups. In the rendering phase we compute a pixel-accurate camera blending field for a photo-realistic reproduction of the scene appearance from a large number of input views. Our method is optimized for an entirely GPU-based implementation resulting in high performance rendering with unconstrained and interactive 3D user navigation.
The computation of geodesic distances on a triangle mesh has many applications in geometry processing, ranging from segmentation and low distortion parametrization to motion planning and tool path optimization. In most cases the true geodesic distance field is approximated by some fast marching method which leads to acceptable results on nicely structured meshes and away from singularities of the distance transform. However, such simple propagation schemes tend to become numerically unstable on not-so-nice meshes as they often occur in practical applications. Moreover, since they use the same mesh structure as a representation for the input geometry as well as the distance field, the precision is limited by the mesh resolution.

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

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

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

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

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

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

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

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

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

Our main contributions are two-fold. The first is the depth map reconstruction technique based on irregularly oriented laser rays that, by exploiting robust sampling techniques, is able to cope with missing and even wrongly detected laser points. The second is a smoothing operator for the reconstructed geometry specifically tailored to our setting that removes most of the inevitable noise introduced by calibration and detection errors without damaging important surface features like sharp edges.
Offset Surface Generation for Polygonal Meshes
Darko Pavic, Leif Kobbelt

Offset surfaces play a very important role in geometry processing and especially in various CAD/CAM applications. Since all commercial CAD systems are able to handle polygonal meshes or at least provide import and export routines for them, polygonal meshes can be seen as the universal geometry representation for data exchange.

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

From left to right: Morphological opening operation on the Bunny model by computing the inner offset of an outer offset of the original surface, the offset surface generated for a CAD cogwheel model and our volume tiling approach visualized on the offset surface of the Buddah model.
OpenFlipper - An Open Source 3D Geometry Modeling Framework

Jan Möbius, Dirk Wilden, Leif Kobbelt

Today there exist a large variety of different 3D modeling software applications and libraries. Most of them are proprietary or they do not provide all the features required to establish an open platform for research projects in geometry processing. In order to simplify the iterative process of implementing and testing new algorithms for software developers and to provide a common and open platform for 3D geometry processing we developed a flexible 3D geometry modeling framework called OpenFlipper.

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

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

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

Among other features, OpenFlipper offers an easy to use scripting language. Almost the entire functionality can be accessed through this language. Using the scripting option we can run computations and tests in batch mode without user interaction or, by using the modeling features of OpenFlipper, generate high quality 3D animations.
Global Parametrization with Orientation and Alignment Control.
Henrik Zimmer, David Bommes, Leif Kobbelt

Parametric descriptions of 3D objects, i.e., continuous and bijective mappings from a 2D parameter domain to the 3D positions on an object's surface are fundamental for many tasks in Computer Graphics and Geometry Processing.

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

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

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

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

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

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

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

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

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

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

In this example, the original painting from the input video stream (upper left; the used matte as inset) is replaced using the other two shown images (lower left). For each case two frames from the output stream are shown.
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. Taking as input the video streams from a stereo camera pair 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. In this work, we are developing a mobile vision system that is targeted to the many challenges of the complex inner-city scenes such applications will have to deal with.

Our approach starts by estimating scene geometry and our vehicle’s own motion using Structure-from-Motion and dense stereo. In parallel, we perform multi-view/multi-category object recognition to detect pedestrians and cars in both camera images. A subsequent multi-object tracking module analyzes the resulting detections and places them in a 3D world coordinate frame to find physically plausible trajectories. The result quality is maintained by continuous model selection to accurately localize static objects and track moving pedestrians and cars in 3D from our constantly changing viewpoint.
Visual object recognition has made immense progress in recent years. In this project, we are working on ways to make this technology useful for intelligent sensing applications on mobile phones. One of our goals is to showcase the potential of a mobile phone’s camera as an interface to the real world, where internet content can be hyperlinked to real objects and buildings. As a demonstrator for this technology, we are building a mobile tourist guide application, where users can walk around Aachen with their camera phones in their hands. Whenever a landmark building (or hotel/restaurant/shop/etc.) catches their interest, they can simply point the camera to it and take a photo. The image is transmitted to a central localization server which recognizes the image content and determines the mobile user’s current location and orientation. This information is then used to query a rendering server, which visualizes a 3D model of the surrounding city area, overlaid with additional web-based content, and transmits the resulting video stream back to the mobile device, where it is displayed in real-time.

In addition to providing a localization and orientation estimate (which GPS and compass sensors could also deliver), a user-captured photo directly carries the user’s intent, pointing out his/her object of interest. This makes computer vision a very attractive input modality to drive mobile AR applications. The recognition server matches the submitted photo to a large database of geotagged reference images. In order to make such large-scale mobile recognition applications feasible, it becomes important to create and update the application content with as little effort as possible. For this goal, we are working on unsupervised approaches for mining images of landmark buildings from community photo collections and automatically linking them to web content. The aim of this step is to automatically create a database of landmark buildings to be used in mobile visual search applications.
Other Activities

Prof. Dr. Leif Kobbelt

Committees and Organizations:

• General Conference Chair of Pacific Graphics 2009, Jeju, Korea
• Member of the Program Committee: Pacific Graphics 2009 (PG ’09)
• Member of the Program Committee of 3DIM 2009: International Workshop on 3-D Imaging and Modeling, (in conjunction with ICCV 2009), Kyoto, Japan, 2009
• Member of the international program committee of Eurographics 2009 (EG ’09)
• Member of the international program committee of Shape Modeling International 2009
• Member of the program committee of 2009 SIAM/ACM Joint Conference on Geometric and Physical Modeling October 2009, San Francisco, USA
• Member of the international program committee of Eurographics / ACM SIGGRAPH Symposium on Geometry Processing, SGP 2009, Berlin
• Member of the international program committee: Brazilian Symposium on Computer Graphics and Image Processing, SIBGRAPI 2009
• Member of the international program committee: 5th International Symposium on Visual Computing, ISVC 2009
• Member of the Program Committee, GI VR/AR Workshop 2009
• Member of the technical program committee SIBGRAPI'09

Offices:

• Deputy Member in the Senate
• Member of the Editorial Board of the Computers & Graphics Journal
• Member of the Editorial Board, Journal of WSCG (ISSN 1213-6972)
• 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.
• Member of the Society for Industrial and Applied Mathematics SIAM
• Fellow of the Eurographics Association
• Director of the Steinbeis Transfer Center for “Geometry Processing and CAGD”
• Martin Habbecke: Student Advisor, main study period computer science

Awards

Prof. Dr. Bastian Leibe

Awards
• **Outstanding Reviewer Award** for Bastian Leibe at the IEEE International Conference on Computer Vision (ICCV’09), September 2009
• **Outstanding Reviewer Award** for Bastian Leibe at the European Conference on Computer Vision (ECCV’08), October 2008

Committees
• Program committee member, IEEE International Conference on Computer Vision (ICCV’09), Kyoto, Japan, September 2009.
• Program committee member, IEEE Conference on Computer Vision and Pattern Recognition (CVPR’09), Miami, USA, June 2009.
• Program committee member, International Symposium on Visual Computing (ISVC’09), Special Track on Object Recognition, Las Vegas, USA, November 2009.
• Program committee member, Fifth International Cognitive Vision Workshop (ICVW’09), St. Louis, USA, October 2009.
• Program committee member, International Conference on Energy Minimization Methods in Computer Vision and Pattern Recognition (EMMCVPR’09), Bonn, Germany, August 2009.
• Program committee member, IEEE International Workshop on Machine Learning for Vision-based Motion Analysis (MLVMA’09), Kyoto, Japan, September 2009.
• Program committee member, Workshop on Feature Detectors and Descriptors: The State Of The Art and Beyond, Miami, USA, June 2009.
• Program committee member, International Workshop on Visual Scene Understanding (ViSU’09), Miami, USA, June 2009.
• Program committee member, European Conference on Computer Vision (ECCV’08), Marseille, France, October 2008.
• Reviewer for IEEE International Conference on Robotics and Automation (ICRA’09), Kobe, Japan, May 2009.
• Reviewer for Eurographics 2009, Munich, Germany, March 2009.
• Reviewer for International Journal of Computer Vision.
• Reviewer for IEEE Transactions on Pattern Recognition and Machine Intelligence.
• Reviewer for International Journal of Social Robotics.

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

“Software for mobile communication systems”. Research Training Group (= graduate school for top Ph.D. students), 2000-2009, German Research Foundation (DFG), principal investigator

“Brain-Behavior Relationships of Emotions in Schizophrenia and Autism”. Research Training Group (= graduate school for top Ph.D. students), 2006-2010, German Research Foundation (DFG), principal investigator


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:


B. Leibe: Mobile Multi-Person Tracking in Highly Dynamic City Environments, MIRACLE Workshop, Fraunhofer FIT, St. Augustin, October 2009.


B. Leibe: Mobile Pedestrian Tracking in Highly Dynamic Scenes, Robotics Kolloquium, Universität Freiburg, March 2009.


Conference presentations:

D. Bommes: Mixed Integer Quadrangulation, 2009 SIGGRAPH Conference, New Orleans, USA, August 2009


M. Habbecke: An Intuitive Interface for Interactive High Quality Image-Based Modeling, Pacific Graphics 2009, Jeju, Korea, October 2009


A. Schmitz: Beam Tracing for Multipath Propagation in Urban Environments, 3rd European Conference on Antennas and Propagation (EUCAP), Berlin, Germany, March 2009

A. Schmitz: Simulation of Radio Wave Propagation by Beam Tracing, Eurographics Symposium on Parallel Graphics and Visualization (EGPGV), Munich, Germany, March 2009

A. Schmitz: Streaming von interaktiven 3D-Stadtmödlern über OFDM-basierte drahtlose Verbindungen, CeBIT 2009, Hannover, Germany, March 2009

V. Schönefeld: Perception-based Rendering, IRTG Winter School, Philadelphia, USA, 2009


Publications:


Data Management and Exploration

Staff

• **Faculty:**
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  Dipl.-Ing. Marwan Hassani  
  Dipl.-Inform. Philipp Kranen  
  Dipl.-Inform. Hardy Kremer  
  Dipl.-Inform. Emmanuel Müller  
  Dipl.-Inform. Marc Wichterich

• **External PhD Candidates:**
  Dipl.-Inform. Philipp Meisen  
  Dipl.-Inform. Matthias Schiffer
Overview

Research at Computer Science 9 focuses on the aspects of data management and data exploration. In our modern world, more and more digital information is stored and processed. Telecommunication data, medical diagnostic data, environmental data, gene pools, structures of proteins and digital multimedia data are only a few of many examples for large databases storing complex objects. Concerning the aspect of data management, we investigate the problem of storing large sets of complex objects in a way that the data can be searched and retrieved very efficiently. One of our research interests in this direction focuses on Relational Indexing where built-in index structures of Relational Database Management Systems are exploited for efficient and robust data management.

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

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

Data Analysis and Knowledge Extraction. 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. Beyond large data resources data streams constitute endless data resources. Specialized algorithms have to be developed that can handle both the infinite amount of data and the limited and often also varying amount of time available between two stream data items. Exemplary tasks are clustering of streaming data or classification on data streams.

Similarity Search and Data Exploration. 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.

Core Data Base Technologies and Indexing. To obtain acceptable response times for similarity queries and data analysis tasks, many different techniques may be combined. For example, multi-dimensional indexing structures like R-trees or X-trees are very useful for the retrieval of the required information.
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.

**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

Subspace Clustering

Emmanuel Müller, Stephan Günnemann, Ines Färber

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.
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/.

**Anytime Stream Mining**

*Philipp Kranen*

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 the 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).
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.
Similarity Search and Data Exploration

Efficient Multimedia Retrieval Based on Earth Mover's Distance
(funded by DFG SE 1039/1-3)

Marc Wichterich, Christian Beecks

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 8.: 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.

Figure 9.: Color&location signature representation of color images
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.

The authentication 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 himself or herself and therefore has to be authenticated in order gain access to some resource. In most cases the authentication process is based on passwords which a person has to input. However, passwords suffer from the problem that they can be forgotten, since sometimes tens of password have to be remembered. 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 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 database 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.

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**Core Data Base Technologies & Indexing**

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**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 10.: Representation in data space (left) and data structure (right) of an overlap free R-tree.
Other Activities

Teaching

**Winter term 2008:**
- Lecture on “Data Mining Algorithms” (V3)
- Lecture on “Models for Data Exploration” (V3)
- Seminar on “Recent developments in data mining”
- Lab course on “Data mining algorithms”
- Contribution to the lecture on “Bionics”
- Contribution to the lecture on “Medical Image Processing”
- Contribution to the lecture on “Data Intensive Computing”

**Summer term 2009:**
- Lecture on “Data Structures and Algorithms” (V4)
- Seminar on “Data Management and Exploration”
- Lab course on “Application and Evaluation of Data Mining Techniques”

Dissertations

Ruau D.: Global Gene Expression Profile Mining in Stem Cells and their Progeny. Dissertation, Fakultät für Mathematik, Informatik und Naturwissenschaften, RWTH Aachen University. (2009), in collaboration with the Institute for Biomedical Engineering, Department of Cell Biology, Medical Faculty of RWTH and Aachen University Hospital (Prof. Dr. Martin Zenke) and the Fraunhofer Institute for Algorithms and Scientific Computing SCAI (Prof. Dr. Martin Hofmann-Apitius).

Industrial and Academic Collaboration

- UMIC Research Cluster, RWTH Aachen
- Chair of Information Processing, Universität Konstanz
- CIM Aachen GmbH, Aachen
- EXAPT Systemtechnik GmbH, Aachen
- National Instruments GmbH, Aachen
- Bruckmann Steuerungstechnik GmbH (BSG), Uedem
- Aucos Elektronische Geräte GmbH, Aachen
- IBM Deutschland, Software Development BI and Data Mining, Stuttgart
- SAP Research, Karlsruhe

Conference and Workshop Organization

Prof. Seidl acted as co-chair of the Program Committee for the International Symposium of Spatial and Temporal Database Systems (SSTD 2009), July 2009, in Aalborg, Denmark.

Reviewing Activities

As of September 2009, Prof. Seidl is an Associate Editor of the VLDB Journal (Int. Journal on Very Large Data Bases).

Members of the group performed reviews for the following Journals:
- Data Mining and Knowledge Discovery (DMKD)
- Data and Knowledge Engineering (DKE)
The International Journal on Very Large Data Bases (VLDBJ)

Prof. Seidl was a member of the Program Committees of the following conferences:

- ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD 2009)
- IEEE International Conference on Data Engineering (ICDE 2009)
- International Conference on Extending Data Base Technology (EDBT 2009)
- GI-Conference on Database Systems for Business, Technology and the Web (BTW 2009)

Awards

- Dr. Ira Assent won the dissertation award of the GI chapter on databases and information systems sponsored by IBM Germany. The award for her dissertation on “Efficient adaptive retrieval and mining in large multimedia databases" prepared at i9 was handed out on the 13th GI Conference for Database Systems in Business, Technology and the Web (BTW 2009). Ira Assent is an assistance professorship at the Department for Computer Science and Center for Data-intensive Systems (Daisy) of the University of Aalborg in Denmark since September 2008.

- Sergej Fries won the award for the best student contribution of the student program at the 13th GI Conference for Database Systems in Business, Technology and the Web (BTW 2009) sponsored by SAP AG. His contribution on “Determining the optimal branching factor of hierarchical anytime classifiers” was sponsored by SAP AG is based on his diploma thesis prepared at i9.

- Our student Michael Nett got a scholarship for a 6-month research stay at the National Institute for Informatics (NII), Japan. During that time, he worked with Prof. Michael Houle on an interesting indexing problem.

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)
Publications


Wichterich M., Beecks C., Sundermeyer M., Seidl T.: *Exploring Multimedia Databases via Optimization-Based Relevance Feedback and the Earth Mover's Distance*. Proc. 18th ACM
Conference on Information and Knowledge Management (CIKM 2009), Hong Kong, China. (2009)


Ahmadi B., Hadjieleftheriou M., Seidl T., Srivastava D., Venkatasubramanian S.: Type-Based Categorization of Relational Attributes. Proc. 12th International Conference on Extending Database Technology (EDBT/ICDT 2009), Saint-Petersburg, Russia. S. 84-95 (2009)


Kranen P.: Using Index Structures for Anytime Stream Mining. PhD Workshop of the International Conference on Very Large Data Bases (VLDB 2009), Lyon, France (2009)

Wichterich M., Beecks C., Sundermeyer M., Seidl T.: Relevance Feedback for the Earth Mover's Distance. 7th International Workshop on Adaptive Multimedia Retrieval (AMR 2009), Madrid, Spain. (2009)


Matthias Schiffer: *SubRank: Ranking local outliers in projections of high-dimensional spaces*. Studierendenprogramm at the 13th GI-conference on Databases, Technology and Web (BTW 2009), Münster, Germany (2009)


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  Dipl.-Inform. Mostafa Akbari (partly funded by Gender research grant, excellence program of RWTH since October 2008)
  
  Dipl.-Inform. Eva Altenbernd-Giani
  
  Dipl.-Inform. André Calero Valdez (partly funded by RWTH research grant)
  
  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.-Gym. Thiemo Leonhardt (partly funded by MINT research grant, excellence program of RWTH since October 2008)
  
  Anne-Christien Pielka, M.A. (partly funded by Gender research grant, excellence program of RWTH since October 2008)

• **External doctoral candidates:**
  
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  Dipl.-Inform. Karola Merkel
  
  Dipl.-Gym. Nils van den Boom

• **Technical Staff:**
  
  Detlef Wetzel
• **Student Researchers and Teaching Assistants**
  Philipp Brauner, Marc Brockschmidt, Jenny Gursch, Tim Hemig, Sebastian Herrmann, Katrin Illian, Angelika Krischer, Jutta Krusenbaum, Christian Kuhl, Mario Lukas, Carsten Mai, Helen Magiera, Andreas Molitor, Bayarhuu Nyamsuren, Klaas Padeken, Claire Prouve, Leonard Raumann, Tobias Reimes, Maik Scheffler, Jochen Siebert, Gregor Smeets, Kristina Tenhaft, Jascha Ulrich
Overview

The group’s focus in research and teaching covers various topics in computer-supported learning, web technologies, user-centered design methodologies and computer science education, among them

- instructional design of content and eLearning functions:
  - utilization of innovative software engineering methods and tools for the analysis, specification, design and implementation of eLearning scenarios, and contents;
  - innovative instructional theories and their realization with modern web technology (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 and
devlopment of sophisticated learning and authoring tools:
  - informative, individualized and semi-automatic feedback in (self-)assessments;
  - feedback focusing on the learning process;
- tools for user-centered design of interactive systems:
  - seamless integration of different level prototypes;
  - automatic evaluation of user interaction with prototypes;
- 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

This period’s achievements and highlights include successful applications for funding of new research projects, founding a young student computer science lab, the establishment of privately sponsored activities to foster interest in computer science in schools, mentoring a very successful spin-off funded by BMBF Gründungsstipendium as well as establishing and advancing CiL services. We also contributed to RWTH Aachen University’s proposal for student centered learning, which won one of the six awards for “Excellency in academic teaching at universities” this fall.

A scholarship in the gender & diversity research program was granted to Anna Lea Dyckhoff for her research proposal on Tools for gender and diversity sensitive action research in blended learning scenarios. In her dissertation project research tools are to be designed and implemented within L²P to support monitoring and evaluation of the learning and teaching processes (http://www.exzellenz.rwth-aachen.de/ca/k/tji/?lang=en). Our interdisciplinary research project to evaluate follow-up measures for introductory programming workshops in schools has also been granted within the newly acquired virtual project house for gender research (http://www.exzellenz.rwth-aachen.de/ca/bt/sqp/?lang=en), an Exploratory Research Space (ERS) initiative. Both programs are part of 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 2009, we started the 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 already carried out 30 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.

We were also successful in the competition for setting up student laboratories (Schülerlabor Informatik). The student laboratory will offer off-school learning opportunities in computer science for pupils in the age from 10 to 18 (http://www.schuelerlabor-informatik.de). Most of the technology of modern life is based on computer science technology, but most people are not aware of that fact. The Student Lab Informatics (SLI) offers exploratory learning modules to experience computer science fundamentals as well as computer science applications in everyday life scenarios.

The Center for Innovative Learning Technologies of RWTH Aachen University (CiL) has established its services and advanced the learning portal L²P. Some of the highlights were reaching the peak of 1700 virtual course rooms in the summer term, being invited to GUtech in Muscat, Oman to hold three-day qualification workshops in eLearning for GUtech faculty, and participating in the Microsoft Executive Briefing Center at Redmond, USA to discuss new developments of SharePoint technology, presenting what we have achieved with L²P and what our vision looks like.

Our business mentee Tamin Swaid and his colleagues have been very successful with CoboCards (http://www.cobocards.com/) in their first year as a spin-off funded by BMWI within the EXIST business foundation program. They won several prizes for their innovative learning tool, such as the first place in the prestigious founders’ contest start2grow for high-tech companies.

During the 7th eLearning conference in computer science - DeLFI 2009 - our group organized the 3rd workshop on “eLearning 2.0 – social software in the field of technology enhanced learning”.

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Research Projects

**L²P – eLearning and eTeaching Portal of RWTH Aachen University**

*Ulrik Schroeder, Philipp Rohde, Anna Dyckhoff, Anne-Christien Pielka, 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’s study programs, designs the technological, instructional and administrative framework for blended learning at RWTH Aachen University. Main focus of 2008 activities were the further design, development, deployment and advancement of the central learning management system L²P in cooperation with the Computer and Communication Center. Besides several weekly upgrades, new functionalities were successfully tested and introduced, for example an online supported exercise course, the possibility to request a copyright check for literature entries, and the visualization of LaTeX-formulas. Due to its operating expense, the previously used assessment modules of CLIX were replaced by the e-testing features of Moodle. Furthermore, supportive measures such as an expanded, target-oriented eLearning training program and first level support for all questions concerning L²P were helpful for newcomers 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 1700 per term). Within the two and a half years since its launch, L²P has been established as a stable and well-adopted eLearning platform. These numbers put RWTH Aachen University into the top universities in Germany concerning its adoption of a blended learning approach.

**SAiL-M: semi-automatic analysis of individual learning processes**

*Daniel Herding (funded by BMBF) and Ulrik Schroeder in collaboration with M. Zimmermann, Ch. Bescherer, Ch. Spannagel (PH Ludwigsburg), A. Fest, U. Kortenkamp (PH Schwäbisch Gmünd), M. Hiob-Viertler, 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 developed interactive tools that support the user in mathematical exercises, such as proving geometric theorems or transforming terms in set algebra. In cooperation with our partners in Schwäbisch Gmünd, we have integrated interactive visualizations based on the Cinderella Dynamic Geometry System. A Jacareto module makes it possible to evaluate the student’s learning process. The geometry tool, named TwoCol, has been introduced at PH Ludwigsburg during the summer term 2009.

### Jacareto and Protoreto

*Ulrik Schroeder, Daniel Herding together with Christian Spannagel (PH Ludwigsburg)*

Jacareto is a framework that offers the functionality necessary for capturing user-program interaction on graphical user interfaces written in Java. It has been successfully used

- to realize executable specifications of interactive systems using GUI prototypes;
- to integrate self-explanatory tutorials in help systems of software;
- to implement instructional scenarios focusing on the learning process;
- to realize usability studies of interactive systems.

In contrast to other capture & replay tools, Jacareto replays recorded interactions between a user and a software system on instances of the observed software itself. Consequently, the replay puts the software system into the state that the user reached before.

The protocol of the interactions is represented symbolically. Thus it can be automatically analyzed and structured, and to some extent also interpreted and statistically evaluated.

Protoreto is a prototyping tool that can be combined with Jacareto. Using its WYSIWYG editor, a user can create functional GUI prototypes even without programming skills. More complex systems can be realized by adding a few lines of script code. Jacareto can be used to capture the user’s interaction with a Protoreto prototype, for example during a user study. In the last year, Protoreto has been used at RWTH Aachen University as well as in private enterprises.

### Learning process oriented eAssessment and intelligent feedback

*Eva Altenbernd-Giani, Patrick Stalljohann and Ulrik Schroeder*

Presenting information does not suffice to ensure successful learning. Rather, the learner must deal with the material actively. For this purpose, exercises are offered among other things. To increase the number and frequency of the exercises offered to the learner, computers have been used for automatically correcting objective tests for a long time. These are such that the correct solution must be known in advance, and that the answers given by the learner are evaluable by a simple test procedure (e.g. single/multiple choice). These simple procedures allow using such objective tests in a variety of fields. In order to really benefit from such
tests, the learner should receive evaluated feedback concerning both his solution and his approach to reach the solution. However, the type and scope of feedback to objective and automatically evaluable tests often do not exceed a justification of either correctness or faultiness, and they mostly report only success or failure (correct/false). Determining the reason of failure is seldom possible and depends on the design of the test.

Special skills, such as programming, drawing a diagram or writing an essay, cannot be evaluated by such tests. Therefore, there were soon first approaches of eAssessment systems, with a focus on specific domains, which tried to at least semi-automatically correct exercises specific to these domains. In these systems, specialized correction procedures were implemented to identify typical errors and thus give better feedback.

In addition to correcting a learner’s solution and giving feedback, it is also reasonable to support him in the process of reaching the solution. To achieve this, the learner may solve exercises in teams, with the additional help of tools supporting collaborative work. Moreover, one can use tools that allow to monitor the learner’s progress while solving an exercise, and to give hints when the learner gets stuck or is heading in the wrong direction.

In this project, we aim for a workflow-based framework that will allow creating arbitrary, domain independent exercises together with their respective correction procedures. The framework should also offer manual correction phases at specific points in the correction procedure, which are referred to as “tutor-in-the-loop” steps. Furthermore, we develop specific tools that give feedback and hints to a learner solving an exercise.

Gender- and diversity-sensitive, user-centered design for help and support systems in eLearning environments

Anne-Christien Pielka (funded by a gender research grant within the excellence program of RWTH Aachen University) and Ulrik Schroeder

The intent of the research project is to develop a method of a gender- and diversity-sensitive, user-centered design for the construction of help and support systems implemented in eLearning-portals or software. Such an adapted help and support system ought to enhance the usability of the complete system. In combination with integrated measures of qualification it also communicates gender- and diversity-sensitive competencies. Concrete object of research is the learning and teaching portal L²P of RWTH Aachen University. This system is suitable for empirical surveys of gender and diversity studies because of its functionality and its heterogeneous user groups. In consideration of interdisciplinary approaches, methods and consolidated findings, particularly of communication science, it should constitute deduced criteria to specify different user groups by means of gender- and diversity-sensitive aspects. Furthermore the coherence between this criteria and the choice of existing communication structures of the different user groups will be analyzed. Of particularly interest are Web 2.0 communication structures.
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 during 2008/2009. 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 all of our 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. The first seminars start this April.

All learning units for the schools are didactically designed in such a way that pupils can discover, test and develop computer science, science and technology skills. This involves the development of skills such as perception, observation, testing and planning strategies. At the same time, team work and communication skills are trained and "social skills" will be fostered by the collaborative acquirement of knowledge 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 will 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.
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 40 workshops are arranged and will be held in 2009. Thus, up to 400 girls will attend the workshops this 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.

The intention of the ALI project is to develop high quality digital teaching and learning content for computer science education at high schools. Partners of the project included regio iT aachen, operating the eLearning platform to share the digital learning units among schools, as well as a number of computer science teachers of six Aachen high schools. The instructional concept chosen for the project are so called “Leitprogramme”, which are best suited for education with eLearning units, especially if the content has been designed by a different author than the teacher of the class. The purpose of this method is to allow pupils to learn at their individual pace in a relaxed environment.

The basic concept of Leitprogramme, which were developed at the ETH Zürich, consists of completely elaborated classes in written form. As far as content is concerned, they consist of chapters, each with a motivation of the topic and the objectives of the chapter, short explanatory sections with detailed examples and exercises with solutions for self assessment, and a concluding examination concerning the chapter allowing the teacher to assess the students’ learning progress. To allow for an individual learning pace, students with a fast learning pace are provided with additional material (“Additum”) which covers further interesting aspects that are not part of the regular curriculum. An essential factor of the empirical proven success of the Leitprogramm method is the mastery principle: learners can only tackle the next chapter after mastering the previous one. The average result of 36 studies
shows that students of classes employing this method can learn about 25% more or easier than with regular and good instruction.

The Computer-supported Learning Research Group advanced this method in this project to the blended learning method of “eLeitprogramme”. For this, the basic structure and properties of the Leitprogramme were adopted and enriched by advantages of eLearning, comprising multi-media elements as well as interactive tests which allow for automatic feedback concerning the exercises and the teacher’s control of the students’ learning progress.

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**eLearning 52.0**: Teaching older adults the usage of small screen devices
*Filippos Efstathiou and Ulrik Schroeder*

The purpose of this dissertation is the utilization of eLearning to specifically define and overcome acceptance barriers on the usage of small screen eHealth devices by older adults.

Mobile technologies nowadays offer a variety of services that can simplify everyday tasks. Communication, education, information, entertainment and even health services are some of the features supported by mobile technologies.

By means of small screen devices, the elderly can continue living independently at home, enjoying the advantages of mobile technologies. On the other hand, recent research shows that older people are not accepting those devices for various reasons. The hypothesis of this research is that eLearning technologies can be used in helping the elderly to familiarize with the devices, while we discover further diversity aspects hidden behind those acceptance barriers.

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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**

- Scientific director of CiL – Center for Innovative Learning Technologies at RWTH Aachen University
- Assistant chairman of GI expert group eLearning
- Program Committee member of 7th eLearning conference of computer science DeLFI 2009 in Berlin
- Program chair of the 3rd Workshop eLearning 2.0 during DeLFI 09 in Berlin
- International program committee member of CATE 2009 (12th IASTED International Conference on Computers and Advanced Technology in Education) – St. Thomas, USA
- International program committee member of the 9th IEEE International Conference on Advanced Learning Technologies, ICALT 2009, Riga, Latvia
- International program committee member of the 2nd International Conference eLearning Baltics, eLBa 2009, Rostock
- Program committee member of 3rd Workshop on pervasive University perU 2009 during Jahrestagung der GI 2009, Lübeck
- International program committee member of the 4th Int. Conference on Informatics in Secondary Schools – ISSEP 2010, Zürich
- Member of the committee for the education of secondary school teachers of RWTH faculty 1, which defined new curricula and regulations for teachers education in computer science
- Member of external PhD committee at the Computer Science Department of ETH Zürich
- Member of the steering committee for Campus-Management-Systems, RWTH Aachen
- Member of the committee defining the proposal for "Wettbewerb exzellenle Lehre", RWTH Aachen
- Member of various appointment committees
- Preparations of iTunesU launch for RWTH Aachen University
- 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 3rd workshop on eLearning 2.0, 7th German eLearning conference, DeLFI 2009
- Preparations and support for 2nd workshop on eLearning 2.0, 6th German eLearning conference in computer science, DeLFI 2008
- Development of CoDaCO, used as Web 2.0 application in the 3rd workshop on eLearning 2.0, 7th German eLearning conference, DeLFI 2009

**Eva Altenbernd-Giani**

- Co-organization of the “Girls Day” for Computer Science.
- Co-organization of the “Schnupperstudium” course “Wieso räumt der kleine Roboter Wall-E seit 700 Jahren die Erde auf?” for girls interested in Computer Science

**Thiemo Leonhardt**

- Project go4IT! / MINT and training for schools
- Project management Schüleruniversität Informatik 2009
• Didactical design of Schüleruniversität Informatik at RWTH Aachen University
• Co-organization of the “Girls Day” for Computer Science.
• Co-organization of the “Schnupperstudium” course “Wieso räumt der kleine Roboter Wall-E seit 700 Jahren die Erde auf?” for girls interested in Computer Science

Anna Dyckhoff

• Coordination and organization of the “Girls Day” for Computer Science.
• Coordination and organization of the “Schnupperstudium” course “Wieso räumt der kleine Roboter Wall-E seit 700 Jahren die Erde auf?” for girls interested in Computer Science
• E-mentoring program “Cybermentor”
• Preparations and support for workshop on eLearning at GU Tech Oman, December 2008
• Participation in Joint European Summer School on Technology Enhanced Learning 2009, funded by B-IT

Philipp Rohde

• “Entwicklung von SharePoint-Lösungen”-course of instruction for Univ. Paderborn/Univ. Bielefeld in cooperation with RWTH International Academy, Paderborn, July/August 2009
• Member of Microsoft Business Division Advisory Council, Microsoft Corp., Redmond, USA
• Executive Briefing Center, Microsoft Corp., Redmond, USA, March 2009
• Member of „Arbeitsgemeinschaft Campus-Management-Systeme“, RWTH Aachen University
• Member of „Arbeitsgruppe für die Ausschreibung des Stifterverbandes und der Kultusministerkonferenz zum „Wettbewerb exzellente Lehre““, RWTH Aachen University
Talks and Publications

Talks

Mostafa Akbari: Learning networks offline and online, Learning (in) Networks, Conference "Interdisciplinary approaches to technology-enhanced learning" (IATEL) 2009, Darmstadt, June 2009

Mostafa Akbari: Analyse von sozialen Netzwerken am Beispiel Twitter, Barcamp Cologne 3, Cologne, June 2009


Mostafa Akbari, Christian Spannagel: Netzwerke und Communities online und offline, Educamp, Ilmenau, October 2009


Philipp Rohde: Workshop "eLearning in NRW", Univ. Duisburg-Essen, December 2008

Philipp Rohde: Workshop with Virtuelle Saar Universität, Aachen, January 2009

Philipp Rohde: ZIM-Workshop with Univ. Düsseldorf, Düsseldorf, April 2009

Philipp Rohde: 2. ordentliche Vollversammlung der Professoren der Fakultät für Bauingenieurwesen im Sommersemester 2009, Aachen, May 2009

Ulrik Schroeder: Workshop with TATA group, Software R&D center Düsseldorf, November 2008

Ulrik Schroeder, Hiltrud Westram: Gender-sensitive didactics in introductory programming courses (for girls), December 2008

Ulrik Schroeder, Philipp Rohde, Anna Dyckhoff: 3-day workshop on eLearning at GU Tech Oman, December 2008

Ulrik Schroeder: Blended Learning – Overview and Strategies, CDS Workshop, March 2009

Ulrik Schroeder, Philipp Rohde: eLearning implementation with SharePoint (L²P), Microsoft Executive Briefing Center, Redmont, USA, March 2009

Ulrik Schroeder: Invited talk at Dagstuhl Seminar about Introductory Programming Courses, April 2009

Ulrik Schroeder: eLearning & Campus Management, Workshop with CAS Karlsruhe, April 2009

Ulrik Schroeder, Philipp Rohde: eLearning Strategie und Implementierung, Düsseldorf, April 2009

Ulrik Schroeder: Invited talk at International Conference on Web-Based Learning – ICWL 2009, Aachen, August 2009

Ulrik Schroeder, Norbert Hähnel: eLearning and social software, DeLFI, Berlin, September 2009


Ulrik Schroeder, Philipp Rohde: Meeting of TU-9 CIO, Aachen, October 2009

Publications


Mostafa Akbari, Anne Pielka, Thiemo Leonhardt, Ulrik Schroeder: Change in technical research - a case study. In: Going Diverse: Innovative Answers to Future Challenge. International Conference in Gender and Diversity in Science, Technology and Business 29-30 October 2009 at RWTH Aachen University, Germany, p. 280-282

Eva Altenbernd-Giani, Anna Lea Dyckhoff, Andreas Hackelöer, Anne-Christien Pielka und Philipp Rohde: "Ja, Nein, Jein" - Erweiterte elektronische Tests auf Basis von Microsoft SharePoint. 4th Microsoft Academic Days 2008


Philipp Brauner, Thiemo Leonhardt, Martina Ziefle, Ulrik Schroeder: The effect of tangible artifacts, gender and subjective technical competence on teaching programming to seventh graders. To be presented at ISSEP 2010, Zürich, Jan 2010

André Calero Valdez, Martina Ziefle, Andreas Horstmann, Daniel Herding, Ulrik Schroeder: Effects of aging and domain knowledge on usability in small screen devices for diabetes patients. To be presented at USAB 2009, Linz, Nov. 2009


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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 Stanford University, ETH Zürich, UCSD, Apple Computer, and others.

We are a member of the international RUFAE network that conducts research on user-friendly augmented environments, and of the DFG-funded UMIC Excellence Cluster in Ultra-Highspeed Mobile Information and Communication. We also offer courses and research opportunities within the Media Informatics Master’s Programme at the Bonn-Aachen International Center for Information Technology (B-IT). This center, established in 2002 and located in Bonn, offers highly selective International Master’s Programmes in Applied Information Technology as well as summer/winter schools to qualified Computer Science students. We are also a member of the B-IT Research School that offers PhD-level compact classes with international speakers to our PhD students.

**Awards**

At ACM CHI 2009, the premier international conference for human-computer interaction, Markus Reul became 3rd in the Student Research Competition with his topic on “Bringing Usability to Industrial Control Systems” that he worked on during his diploma thesis.

At ACM UIST 2009, the Symposium on User Interface Software and Technology, Malte Weiss, Gero Herkenrath, and Jonathan Diehl won 2nd place in the student innovation contest in the category “Best Implementation” with BallMeR, an action-packed game based on a pressure-sensitive multi-touch keyboard.

Christian Mattar, who did his final thesis at our chair, received the Springorum medal for graduating with distinction from RWTH Aachen University, at a ProRWTH event in the Audimax on June 19, 2009. In his thesis, Christian developed “Table Lemmings”, a tabletop game that explored casual collaboration on multitouch table surfaces and became a successful exhibit for the Dutch Industrien museum.
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.

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**HCI Design Patterns: Capturing User Interface Design Guidelines for Interactive Multimedia Systems and Environments**

*Jan Borchers*

HCI Design Patterns are a format to capture golden rules, design guidelines, and design rationale when building interactive systems. Building on our past work in this area, we have established a collaborative web site for the growing international community of researchers working on this topic (http://www.hcipatterns.org/), which we host as heads of the IFIP task group on this topic.

In 2003, we worked with international partners both at the CHI 2003 Patterns Workshop and online, to create a structural specification for HCI Design Patterns. The result, PLML (the Pattern Language Markup Language, pronounced pell-mell), is expressed as a Document Type Definition (DTD) in XML, and can be found on our web site. Several pattern languages, including our own HCI Design Patterns for Interactive Exhibits, have been converted by their authors into PLML and been made available online for general use.

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
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 (see below) is a novel technique for video interaction. Based on the concept of ‘direct manipulation’ which embodies several traits of Organic Interfaces, Dragon allows users to navigate in video scenes more easily and precisely than previous approaches like the timeline slider.

TWEND (see below) is a malleable input device that serves as a first prototype for bendable mobile devices. Controlling a device like, e.g., an eBook reader via bending gestures is not only natural and intuitive but also saves valuable space on the devices surface that otherwise would have been occupied by physical controls.

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DRAGON: A Direct Manipulation Interface for Frame-Accurate In-Scene Video Navigation

Thorsten Karrer, Malte Weiß, Jan Borchers

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DRAGON is a direct-manipulation interaction technique for frame-accurate navigation in video scenes. This technique benefits tasks such as professional and amateur video editing, review of sports footage, and forensic analysis of video scenes.

By directly dragging objects in the scene along their movement trajectory, DRAGON enables users to quickly and precisely navigate to a specific point in the video timeline where an object of interest is in a desired location. Examples include the specific frame where a sprinter crosses the finish line, or where a car passes a traffic light.

Through a user study, we have shown that DRAGON significantly reduces task completion time for in-scene navigation tasks by an average of 19–42% compared to a standard timeline slider. Qualitative feedback from users is also positive, with multiple users indicating that the DRAGON interaction felt more natural than the traditional slider for in-scene navigation.

The DRAGON interaction technique is illustrated in the figure shown below: The user has clicked on the car at the diamond marker, and is now free to drag the car along its trajectory in the video. As she moves the car, the video scrolls through time accordingly. Notice how evenly spaced positions on the car’s trajectory correspond to a non-linear temporal spacing on the timeline slider. DRAGON was presented at several conferences, such as ACM’s CHI and MobileHCI, and at UMIC events.
The goal of the project is to find new interaction methods for mobile devices. Traditional input methods suffer from certain problems in this context. First, there is a real estate problem between space used for input and space used for output. Screen sizes and number of input buttons are limited to keep the device small. Touch screens counter this, but can lead to occlusion problems. Tilting introduces a new interaction style by facilitating not just the fingers, but sometimes it can be hard to correctly interpret the users intention with this (just try to read something on the iPhone while lying in your bed...). A bendable device also makes use of the users wrists, i.e., just like tilting it makes use of an additional part of the dexterous system. Because the hands are already “in position” holding the device, no further space for input areas is needed.

TWEND consists of a hardware prototype that enables users to perform bending gestures and a Mac OS X software framework that maps these gestures to system events or provide other applications with raw sensor data.

An example application following this approach is an e-book reader. It shows how the continuous bending input can be used to easily manipulate a virtual book. When turning pages, their movement is directly mapped to the bending state of the prototype device, creating a natural and easy to understand mapping.

Inspired by this we built a demonstrator that further explored the book metaphor in the context of bending. This device consists of a bendable controller shaped like a book that is used to turn virtual pages that are projected directly onto that controller. The system was an exhibit on board of the MS Wissenschaft that cruised Germany from June to October, and is now on display in the UMIC Center.
Tactile Motion Instructions for Physical Activities
Daniel Spelmezan, Jan Borchers

In many sports, students do not receive feedback on their performance while performing exercises. For example in snowboarding, instructors cannot be with students while going down the slope. Due to this spatial separation, coaches typically provide feedback at the end of the run. Instead of waiting until the instructor can talk to the trainee, the trainee should get immediate feedback on his technique to better differentiate between correct and wrong movements. In this project we investigated how tactile motion instructions can help students to correct and adjust posture in real-time. These instructions are delivered with small vibration motors located across the body and form a simple language that conveys messages such as *shift your weight to the left foot* followed by *flex your legs* and *turn your body to the right*. These messages can also help people to prevent injuries during daily activities, for example when they incorrectly pick up objects from the floor with straight legs.
Our wearable system is based around a mobile phone and a custom-built sensor/actuator box. This small box can be used to automatically supervise posture or simple movements during physical activities and to provide tactile motion instructions that alert users to incorrect body movements. Tiny sensors inserted into clothes detect posture, such as straight legs or incorrect weight distribution. Actuators on the user’s body provide immediate tactile feedback that subtly communicates hints for corrections. Our results obtained in this project can be applied to teach different sports techniques, to assist and to maintain overall healthcare, and to support patients during rehabilitation in unsupervised situations.

SLAP: Silicone Illuminated Active Peripherals
Malte Weiß, Julie Wagner, Yvonne Jansen, Jan Borchers

Physical user interface components such as buttons, sliders, knobs and keyboards have many advantages: thanks to their haptic nature, they are easy to operate without looking, and their shape guides the user's input gestures. However, they are often expensive, and it is hard to change their labeling on the fly.

Computer interfaces have largely replaced these devices with virtual on-screen controls, such as push buttons, scrollbars, rotary knobs and soft keyboards. Virtual controls are very flexible, easily changed dynamically - but they lack the physical, haptic texture and feedback of their real-world counterparts.

Our Silicone Illuminated Active Peripherals, or SLAP widgets, are physical widgets made from silicone rubber and acrylic that combine the advantages of physical and virtual devices on multi-touch tables: Our SLAP buttons, sliders, knobs and keyboards have the physical shape of real devices to provide the right haptic feedback, but are still easily relabeled using a tabletop rear projection. At the same time, they are particularly low-cost, and easy to put to use.
SLAP widgets are transparent. This means we can always show the current labeling using the table's rear projection underneath the widget. For example, we can change the labels on our keyboard from normal characters to shortcut commands when the modifier key is held down. This makes it easier to use command shortcuts and other special keyboard mappings. But SLAP widgets are still physical, simplifying their eyes-free use. SLAP was on display at ACM’s CHI conference in April 2009.

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**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.
**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.

**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.
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 coulis 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

Physical Computing

We have experience in interaction design and in building interactive systems. End-users of our systems often manipulate and interact with real physical objects. The user interfaces that we develop therefore have to include software as well as hardware aspects. Creating these interfaces involves several prototyping cycles and extensive tests. To shorten the turn around cycle for projects in research and education, we have established a workshop room and a project space for our staff and our students. The project space is where we build and test interactive research systems, such as multi-touch tables and exhibits. The workshop room has a milling machine that can produce printed circuit boards (PCB) and will further include a 3D printer that creates three-dimensional models.

World Usability Day

In November 2008, we organized the third World Usability Day in cooperation with P3 Solutions at the Ford Research Centre. The main purpose of the event was to provide an introduction to the topic and create an awareness of the problem of inadequate usability. We covered the fundamentals of designing for usability including an introduction to cognitive psychology, the historical development, the user-centered design process, and methods of prototyping and evaluation.

In November 2009, we organized the fourth World Usability Day in cooperation with P3 Solutions at the AGIT Technologiezentrum. The topic of this year’s event focused on “Design in the Context of Mobility”.

Dorkbot

Since Mai, 2009, we are hosting Dorkbot, an international network of people doing interactive art and electronic hacks. Dorkbot is a fun meeting of hackers, designers, and artists working on interactive technologies (http://hci.rwth-aachen.de/dorkbot).

CocoaHeads

Since April 2008, we are hosting CocoaHeads, an international group devoted to discussion of Apple’s Cocoa Framework for programming Mac OS X. During monthly meetings, members present on their projects and offer tutorials on various programming topics (http://hci.rwth-aachen.de/cocoaheads).
AATC/e

In early 2009, our group became an Apple Certified Training Center for Education at RWTH Aachen University. We regularly organize Apple courses usually right before the start of the semester in October or March. 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 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 several MacBook Pros for our staff. The Media Space contains five 40” mobile interactive LCD screens, an eight-channel networked surround audio setup with four discrete amplifiers and dedicated Firewire audio interface, high-fidelity videoconferencing and a variety of non-standard input and output technologies (infrared batons, various sensors, Bluetooth devices, etc.). We create this environment to facilitate experimentation with time-based multimedia for our students and staff.

In 2008 and 2009, we worked as reviewers for CHI, UIST, Ubicomp, TOCHI, and various other conferences and journals in Media Computing and HCI. We also host the hcipatterns.org home page as heads of the IFIP task group on this topic.

iTunes U

iTunes U is a site for free course videos from by 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)
Talks and Publications

Talks


Designing the Urban Tourist Experience: From Serious Gaming to Locative Narratives. Prof. Dr. Jan Borchers, iDiscover Inspiration Day, Gallo-Roman Museum & University of Hasselt, Belgium, October 26, 2009.


20 Years of HCI Design Patterns: From Values to Formats, and Back Again. Prof. Dr. Jan Borchers, Invited talk, First International Summer School on Theories of Creative Design for Innovation in Science and Technology, Marie Curie Project DESIRE, Palazzo Feltrinelli, University of Milano, September 20-26, 2009.


A Language of Tactile Motion Instructions. Daniel Spelmezan, MobileHCI, Bonn, Germany, September 18, 2009.

Tactile Motion Instructions. Prof. Dr. Jan Borchers, Invited talk, PhD School (Graduiertenkolleg) "Advances in Digital Media", Dept. of Computer Science, University of Bremen, September 17, 2009


Lust und Frust – Benutzerfreundliche Technik im Alltag. Prof. Dr. Jan Borchers, Uni im Rathaus talks, Aachen city hall, June 25, 2009.

Wieso geht das nicht? Der Weg zu benutzbarer Technologie. Prof. Dr. Jan Borchers, Invited talk, BayKomm Communications Center, Bayer AG, Leverkusen, May 10, 2009.

SLAP Widgets: Bridging the Gap Between Virtual and Physical Controls on Tabletops. Malte Weiss, CHI, Boston, USA, April 7, 2009.

Fly: a Tool to Author Planar Presentations. Leonhard Lichtschlag, CHI, Boston, USA, April 7, 2009.


Sweet Spot Products: Why I Love My GPS. Prof. Dr. Jan Borchers, Distinguished Seminar, Dept. of Computer Science, Queen Mary College, University of London, Feb 11, 2009.
Publications


Malte Weiss, Florian Schwarz, and Jan Borchers. *Actuated Translucent Controls for Dynamic Tangible Applications on Interactive Tabletops*. In Extended Abstracts of Tabletop '09, November 2009.


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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Overview

The Chair “Informatik 11 – Software für eingebettete Systeme”, or short, 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.
We developed the [mc]square model checker which model checks microcontroller assembly code. Currently, [mc]square checks assembly code of the following microcontrollers: ATMEL ATmega16 and ATmega128, Infineon XS167, and Intel C51. We are currently extending [mc]square to support the Renesas R8C\23 microcontroller. Beside model checking microcontroller assembly code, [mc]square is also able to model check instruction list programs for programmable logic controllers (PLCs) and abstract state machines.

In our approach a tailored simulator is used to build the state space of a program for model checking. The simulator creates an over-approximation of the behavior shown by the real microcontrollers. Using a tailored simulator enables users of the tool to make propositions about all features of supported microcontrollers. As the simulator creates state spaces automatically from the assembly code, no manual modelling by the user is necessary.

To tackle the state-explosion problem, we employ different abstraction techniques. The focus of our work is the application of abstraction techniques such as delayed nondeterminism, path reduction, dead variable reduction, and interrupt handler execution reduction within this simulator. In this simulator, hardware-dependent information is utilized to limit the state-explosion problem. To support these abstraction techniques, we use static analysis and abstract interpretation to annotate the program. The simulator uses these annotations to limit state-space sizes and to support implemented abstraction techniques. Additionally, [mc]square uses static analysis in order to detect problems such as stack collisions and writing to reserved registers. Symbolic execution is used in some abstraction techniques in order to reduce the instantiation of nondeterministic inputs and, thereby, further reduce the size of the state space.

We conducted several case studies to show the applicability of this approach for certain microcontroller and PLC programs taken, for example, from lab courses, diploma theses, or student exercises.

For each platform we need to create a specific simulator and adapt our abstraction techniques. While we showed that it is possible to implement a new simulator within six person months, it is a tedious and error-prone process. Therefore, we created a synthesis framework that is capable of automatically generating new simulators.
The aim of AlgoSyn is to algorithmically synthesize reactive systems, especially control software. This goal requires an integration of approaches from computer and engineering sciences. At the Embedded Software Laboratory, there are currently two AlgoSyn scholarship holders, Dominique Gückel and Paul Hänsch, who conduct research in the area of synthesis of state space generators for model checking and reachability analysis for hybrid systems.

Eliminating errors in software for microcontrollers before the software is shipped to the customer is crucial. For this purpose, a model checking tool called [mc]square has been developed at the Embedded Software Laboratory. [mc]square is an explicit, discrete, CTL model checker that creates the state space by using a simulator. The task of the simulator is to simulate the behavior shown by the real microcontroller when executing the software. While an advantage of this approach is that no manual preprocessing is required, it has the disadvantage that the microcontroller simulator has to be implemented before we can conduct any model checking. Until recently, these simulators have been implemented manually. Our experience shows that implementing such a simulator by hand can take between six months and one year for a full-time developer, depending on the desired accuracy of simulation and the complexity of the hardware.

The goal of our ongoing research within the scope of the DFG Research Training Group AlgoSyn is to reduce the time for implementing new platform simulators. For this purpose, we have created a hardware description language and synthesis framework that allows us to automatically generate simulators. The new language, called State space Generator Description Language (SGDL), aims at describing the instruction set and resources of a microcontroller. It allows the developer to create a description of the hardware which closely resembles the data sheet or instruction set manual. Additionally, an SGDL description is much shorter than a manual implementation of a simulator because it is not an executable program. Hence, it takes far less time to create such a description than it takes to create an executable platform simulator.

In the last three decades the hybrid automaton model gained in importance. Many safety critical applications can be found, e.g. in control theory. Even though a number of academic tools is available for reachability analysis of hybrid systems, none is known to cope with higher dimensional non-linear systems. But most hybrid systems in real life scenarios that go beyond our imagination, putting us in need of formal verification, are both, high dimensional and non-linear.

For the present, the goal is to find new ideas that might help to overcome the current limitations on reachability analysis and to implement them in an automated tool. Finally, the long-term goal is concerned with algorithmic synthesis, more precisely the controller synthesis for hybrid systems.

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**UMIC: Model Checking Adaptive Protocol Stacks**

Carsten Weise, in cooperation with Raimondas Sausnakis (LuFG I4)

Adaptive protocol stacks will replace the monolithic protocol stacks in future mobile applications, allowing to adapt to the everchanging contexts in the mobile world. This leads to
problems in the consistency and functionality of the adaptive protocol stacks. Modelchecking has been identified as one method to tackle these growing problems.

However, model checking the code of the protocols turns out to be infeasible with today's tools. Instead, the project concentrates on testing approaches which have a much lower complexity. Klee is a tool for symbolic execution of test cases, and has been applied to several case studies to find errors in protocol software. The first results are very promising. The approach using Klee will be developed further, as Klee itself does not support distribution. A tool called KleeNet that supports distribution is under development.

UMIC: Scalable Software Architecture for Massively Distributed Mobile Systems
Carsten Weise, Jianmin Li

The project investigates the patterns for software architectures for massively distributed mobile systems (MDMS). After identifying major important features for MDMS software architectures in 2008, in 2009 the focus was in developing MDMS reference implementations. In order to investigate such applications thoroughly, an open architecture of the mobile device is mandatory. While such open architectures were rare in 2008, with the emerge of the iPhone and the Google android platform, software development for mobile devices has become much simpler. A simple application, originally developed for the Openmoko platform, has been ported to android, and will be implemented for the iPhone as well. Further, we have investigated the differences between different mobile device development frameworks like J2ME, Qt Mobile, iPhone and Android.

UMIC: Software Quality Initiative
Carsten Weise, Dominik Franke, 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. For this purpose cooperation through all UMIC research areas is needed to find out which quality issues occur in which area and where similarities can be found. On this basis we want to determine approaches and methods that fit to the quality requirements of the different research areas like static analysis, formal verification and software simulation.

The Software Quality Initiative is a UMIC path-finder project. In discussion with all UMIC stakeholders a project proposal shall be defined to improve the software quality for mobile applications.
This project focuses on the application of formal methods to model and manage QoS for Network Mobility.

The field of network mobility is gaining ground in telecommunications because of the evolution of broadband technologies and the increasing applications that demand broadband access, e.g. connectivity in public transportation and IMS. Network Mobility is the field that considers sets of mobile devices moving together as one entity with one or more access points which are called mobile routers. These networks are standardized under the IETF-RFC3963 specification also known as NEMO Basic Support, while QoS challenges are described in IETF-RFC4980. NEMO BS is an extension to MIPv6 described under IETF-RFC3775. Mobile routers can possess multiple Radio Access Technologies (RATs) and have to perform real-time operations, e.g. handover, managing binding updates, merging/splitting mobile networks and managing QoS. The intelligent management of mobility, data streams of different QoS requirements and the available RATs makes the formalization of this problem a necessity due to its complexity. The importance of this study comes from the industry focus on network operator’s IP services, especially IMS. NEMO BS provides a solution for this system and at the same time requires investment in research to improve QoS.

This work consists of two main parts; building the formal model and simulating the NEMO protocol. These parts are to be run in parallel to achieve interdependability between each other. This means that simulation measurements will be used to support theoretic hypothesis made by the formalized description of the QoS problem. On the other hand, formal tools have to be implemented in order to be able to incorporate extensions which in turn will allow making predictions of the behavior of the modeled system in a similar way to simulations.
This means that these tools will be designed to be able to generate quantitative as well as qualitative conclusions.

Heterogeneous Timing Constraints for Applications in Embedded Environments

John Schommer, Carsten Weise

In many applications hard and soft real-time computations are working concurrently. For hard real-time problems 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 such applications high-level languages are more suitable (the features can be programmed more efficiently) because these applications are very software intensive. But these languages are not necessarily real-time capable. Developing a heterogeneous application, which is suited in both domains, is difficult. We research methodologies, architectures, principles, and even process calculi, which allow facing different timing problems within an application. The work is based on our experience in a recent industrial cooperation, where under the increasing cost-pressure, the hastened development cycles, and a higher change-rate of the solutions it becomes reasonable to search flexible, maintainable, evolvable, modifiable and more economic ones for the described problem. We started analyzing existing technology regarding the described problem with focus on benchmarking several real-time operating systems and middleware.

Integrating timed testing into an industrial testing process

Ralf Mitsching, Carsten Weise, in cooperation with Henrik Bohnenkamp (I2)

In a cooperation between academia and the industry, we have run a case study for timed testing in the context of an industrial testing project. The case study revealed several open problems when integrating a model-based testing approach into an industrial test process.

In order to deal with this problems, we started developing our own tool chain. In collaboration with Henrik Bohnenkamp of chair of computer science 2, we have set the primary focus on an open source platform for applied research on timed testing.

The final goal of this project is to provide a prototypical tool chain that satisfies the requirements of an industrial testing process.

Simulator for a Rail Testing Environment

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 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 testlab, has been successfully developed. The project continues with the construction of a complete test harness for the railway controller.

Design Patterns for Safety Critical Embedded Systems
Ashraf Armoush

The design of safety-critical embedded applications requires an integration of commonly used software and hardware design methods. It is considered as one of the applications that could benefit from the concept of design patterns.

The main objective of this research is to construct an extensive catalog of design patterns which helps designers to build safe embedded systems for safety-critical applications with the help of a structured, effective, simple, and quickly accessible collection of successful solutions.

We have investigated the applicability of the concept design pattern for safety-critical embedded systems. We have then proposed a new pattern template for safety-critical design patterns. This template includes the classical representation in addition to fields for implications and side effects on non-functional requirements. The considered requirements include safety, reliability, modifiability, cost, and execution time. In our research, which is supported by DAAD, we have collected fourteen proven design techniques for hardware and software, and we have developed a new software pattern called Recovery Block with Backup Voting (RBBV). Furthermore, we have developed a new reliability a safety assessment method for design patterns which describes the reliability and safety improvement relatively to a basic system.

In order to illustrate the proposed reliability and safety assessment method, we have conducted a test case that includes five software design patterns sharing the concept of software diversity. In this case, we have developed a Monte Carlo based simulator to demonstrate the proposed safety and reliability metric.

To provide a decision support for users in the intended catalog, we have categorized the possible applications into six specific problems in addition to a general design problem. Moreover, we have classified the possible available resources and application requirements to be used as guidelines to find applicable solutions for each design problem.
Safety & Reliability of Automotive Embedded Systems

Eva Beckschulze

More and more automotive embedded systems fall in the category of safety-critical systems. These require the careful consideration of techniques to avoid, detect or tolerate faults in hardware as well as in software. The FAT-project funded by the Research Association of Automotive Technology (Forschungsvereinigung Automobiltechnik, FAT) is about safety and reliability in automotive applications. While the focus in the previous project was on hardware architectures we will now concentrate on techniques to increase software safety. A topic of current interest in the automotive industry is the so-called software partitioning. It allows the co-existence of software components using the same resources (e.g. memory) while requiring freedom of interference. In terms of software faults this means to prevent the propagation of a software fault in one software partition to any other software partition. One benefit of software partitioning is the possibility to change one software partition without the need for any re-verification of unmodified software partitions. Our goal is the investigation of new static analysis techniques to detect software faults that might result in failure propagation.

In this context, we currently develop a new tool for static analysis of C code. We will implement well-known and new static analyses and the ability to check the MISRA-C guidelines for the development of safety-critical systems. The tool will be specifically tailored to consider the peculiarities of microcontroller C code.

Model-based Development of Embedded Systems

Jacob Palczynski, Andreas Polzer

In the last year we successfully finished the BMBF-funded project ZAMOMO dealing with the "integration of model-based software engineering with model-based controller design". The project goal was to bring together the different views, methodologies, models, tools and processes of the two disciplines of control engineering and computer science. The project was focused on the exemplary application of automotive engine control systems.

The consortium consisted of the Institute of Automatic Control IRT, the Embedded Software Laboratory 111 (both RWTH Aachen University), the Fraunhofer Institute for Applied Information Technology FIT (St. Augustin), VEMAC GmbH & Co. KG (Aachen) and AVL Deutschland GmbH (Mainz-Kastel).

Within this project the Embedded Software Laboratory developed methods to increase the efficiency of model-based developing of embedded systems. The approaches focused on the simulation model and rapid control prototyping system.

In the first part of this project we developed a modelling hierarchy for systems to be controlled. Our approach was to look on the controlled system's behaviour in a qualitative way. The behaviour is represented by the dependency of input and output signals, we
generalise the behaviour by describing signals by sequences and dependencies of the characteristics. The information on the behaviour is refined by adding more accurate information on time and function. Semi-automatic transformations between the layers of the hierarchy support the developer.

In the second part we developed an architecture for a rapid control prototyping (RCP) system, and the development of new methods of modelling controlled systems.

A RCP system's task is to support the validation of modelled controller by automatic code generation and conveniently hardware. Thus we first analysed constraints, functional and non-functional requirements for the RCP system. Based on these, we developed an architecture which is able to deal with different hardware. VEMAC's customers make use of the new architecture when using VEMAC's RCP system VeRa. Thus this collaboration is a good example for successful innovation.

The results we obtained within this projects are the foundations for continuing our research of model-based development of embedded systems. One focus lies on the problem of managing variability. The variability is caused by the fact that a system often has to be adoptable for a family of somehow similar systems.

This causes a lot of complexity which has has to be managed by the developer. To this end we develop methods and approaches to support developers to manage variability and reduce complexity. The methods are based on model transformations. We are able to use the models from industry like Matlab/Simulink models and apply methods to derive special variants, to create views to reduce complexity, and combining different artefacts to avoid inconsistencies.

We cooperate with a industrial partner and the Irish Software Engineering Research Center LERO. In this context the researcher Andreas Polzer had a two month stay in Ireland to intensify the work and develop new approaches.

The second focus lies on the problem of safeguarding automatically generated code. In embedded systems development, software functionality is often modelled with tools like Matlab/Simulink and code is generated automatically with additional tools. The question arises if the generated code behaves in the same manner as the model and if not, to what extend the behaviour differs. We expect that experience in behaviour abstraction of continuous systems, i.e. controlled systems, gained in ZAMOMO will prove to be useful.

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.

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**Energy based control of a platoon of vehicles with a topological changing communication network**

*Ibtissem Ben Makhlouf, Hilal Diab*

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.

Within our project funded by the German Research Council (DFG) and in collaboration with the control engineering institute (IRT) in Aachen, a Lagrange energy based controller is designed for a platoon of vehicles, in which each vehicle sends its position, its velocity and its acceleration to the next following one via a communication network.

Communication networks generally introduce delays and drop packets. However, these communication faults are typically not taken into account while designing the controller. The objective of our project work is to analyze the effects of the communication faults on the safety of the vehicles within the platoon. The Platoon, controller and network are modeled using the framework of hybrid automata. The discrete events are introduced by the communication network. The continuous part of the hybrid automaton consists of the dynamics of the platoon and its controller. The problem of safety verification is then reduced to a reachability analysis of a hybrid system.

A hardware implementation of the whole system is realized. We designed four 1:14 reduced scaled platoon of trucks. Each truck is equipped with sensors and actuators 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.

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**Design of Heterogeneous Software-intensive Embedded Systems**

*Daniel Merschen*
In the context of preparing a special research area we investigated different research areas which we consider to combine. These research areas cover the concept of rich components as proposed by Damm et al. 2005, services and service cooperation in mobile ad-hoc-networks as developed by Pfeffer et al. 2008 and scenario-based programming which we plan to use to enable end-user-development of mobile applications which make use of different services in mobile networks.

A rich component as Damm defines it is a component of a whole system which can give guarantees to other components if a special set of assumptions holds. The whole concept grounds on a layered design space, i.e. a design space which contains different layers where each layer is a kind of abstraction for upper layers. Each layer consists of components which have an interface to components of the lower or upper layer as well as an intra-layer interface to components of the same layer. These rich components will be used as abstractions for services in mobile ad-hoc-networks.

Services are offered by different participants of such a network to other participants with the target of enabling everybody to solve more complex problems in cooperation with others, so to say enabling a kind of Web 2.0 on device layer. Of special interest will be to evaluate how heterogeneous embedded devices can communicate with other participants of the network if they were not originally developed to communicate with each other. A further challenge in this context will be how interfaces of services change if the end user modifies them and how other services will understand the new semantics of the changed service interface. For the integration of end-user-development we plan to investigate if the Play Engine of Harel and Marelly from 2003 is suitable for end users who are no experts in application development. A further central question to be answered by the special research area will be to evaluate requirements to and to design a software architecture for embedded systems which will be able to dynamically adapt to the user's needs, so to say to develop a design for designers with few experience in the area of software development. As mobile networks of embedded systems are of great importance for safety-related applications above mentioned architectures will have to suitable in this context. Therefore we strive to integrate formal methods to verify if such an architecture fits the above mentioned needs.

As a grounding application scenario we currently develop an Android application on a mobile Android phone in the context of practical course for students which we will use to control a model car by tilting the phone to the front and back respectively left and right. Therefore mobile phone and model car communicate via wireless LAN. Of special interest is how the ideal architecture for this scenario will look like and how this architecture will have to be modified to enable the user to dynamically modify the application at runtime, and how services offered by other mobile phones in the environment can be integrated into the application during runtime.
Industrial-strength software analysis and verification has advanced in recent years through the introduction of model checking, automated and interactive theorem proving, and static analysis techniques as well as correctness by design, correctness by contract, and model-driven development. However, many techniques are working under restrictive assumptions, which are invalidated by complex (embedded) system software such as operating system kernels, low-level device drivers, or microcontroller code.

The aim of this workshop was to bring together researchers and developers from both academia and industry, who are facing real software and real problems to find real, applicable solutions. By "real" we mean problems such as time-to-market or reliability that the industry is facing and is trying to fix in software that is deployed in the market place. A real solution is one that is applicable to the problem in industry and not one that only applies to an abstract, academic toy version of it. This forum discussed software analysis/development techniques and tools; it also served as a platform to discuss open problems and future challenges in dealing with existing and upcoming systems level code.

The workshop, which was held in the SuperC building at the RWTH Aachen University from 22.06.2009 until 24.06.2009, was attended by 48 international researchers. It featured three invited talks and 19 regular talks.

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**Project Carolo-Cup 2009**

*GalaXIs-Team, Andreas Polzer*

In 2009 the second student competition called Carolo-Cup was taking place in Braunschweig. As in the last year a student team supported by the Embedded Software Laboratory attended this challenge (Yves Duhr, Philipp Fischer, Stefan Kockelkoren, Julian Krenge and, Hugues Tchouankem). The team called GalaXIs (www.galaxis.rwth-aachen.de) has scored the second place just behind the team CDLC from Braunschweig and was decorated with 5000 Euro.

The main task 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 provide students an insight into interdisciplinary problems while developing automotive applications. There the students have to transfer their knowledge from their studies to practical problems.
Other Activities

Invited Talks


Program Chair

• Prof. Dr.-Ing. Stefan Kowalewski

• Dr. rer. nat. Bastian Schlich
  http://www.embedded.rwth-aachen.de/ssv09/
Publications


B. Schlich, Model Checking of Software for Microcontrollers, ACM Transactions in Embedded Computing Systems (TECS), 2009, To appear


**PhD Thesis**


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
  Dipl.-Inform. Michael Lülfesmann
  Dipl.-Ing. Monika Petera
  Dr. Arno Rasch (until 11/2008)
  Dipl.-Inform. Andre Vehreschild (until 12/2008)
  Dipl.-Inform. Johannes Willkomm
  Dipl.-Inform. Andreas Wolf
Overview

A recurring theme of the research activities at the Institute for Scientific Computing is the interplay of methods from computer science with mathematics and engineering or natural sciences. Problems occurring in practice are often too complex to be solved with techniques from a single discipline. The enormous requirements with respect to data handling and computational power can be accommodated only with an interdisciplinary approach. Here, the central roles of computer science are to keep the complexity at a manageable level by making use of problem-inherent structure, and to provide appropriate software tools that allow users from technical or scientific disciplines to easily benefit from algorithms derived this way.

Our research addresses various topics of high-performance computing, including computational differentiation, parallel computing, and efficient numerical methods.

Computational differentiation comprises the ensemble of techniques that, given an arbitrarily complex program computing some function $f$ (a large simulation code, say), yields another program that computes the derivative $f'$ along with $f$. These techniques rely on Automatic Differentiation (AD), which in turn is based on the fact that any program is built up from elementary operations, such as addition or multiplication, for which the derivatives are known. Starting with these "elementary" derivatives, the chain rule of differentiation is applied over and over again to obtain the derivative of the whole program. The associativity of the chain rule allows the elementary derivatives to be combined in many different ways, all leading to the same final result, but at widely differing costs. Finding the program that computes $f'$ at minimum cost is conjectured to be an NP-hard problem.

One particular area of research at our institute is the development or refinement of heuristics for reducing the cost of derivative computations with AD. In addition to optimized application of the chain rule, mathematical knowledge can be used to make the evaluation of the derivatives more efficient in terms of memory and operations. We also strive to transfer the AD theory into tools that enable practitioners to differentiate large programs involving complex control structures. Examples for such tools include the ADIFOR, ADIC, and ADiMat systems that are able to augment Fortran 77, C, and MATLAB programs, respectively, with derivative code.

Cooperation with other institutes throughout the university is enhanced by the fact that Prof. Bischof is also the head of the Computing and Communication Center (CCC) of the RWTH which offers cutting-edge computational power and advanced visualization techniques (such as Virtual Reality) to RWTH researchers.

Members of the Institute for Scientific Computing teach several courses related to High-Performance Computing (HPC), which is offered as Vertiefungsfach in the Computer Science curriculum.

- Einführung in High-Performance Computing (Introduction to High-Performance Computing) is the basis for more specialized courses, such as
- Parallele Algorithmen zur Vorkonditionierung linearer Systeme (Parallel Preconditioning Techniques for Linear Systems),
- Parallele Algorithmen und Software für iterative Methoden (Parallel Algorithms and Software for Iterative Methods),
- Computational Differentiation,
- Automatic Differentiation in MATLAB,
• *Virtuelle Realität* (Virtual Reality) offered in cooperation with the Computing and Communication Center,
• Algorithms for Simulation and Optimization of Physical Processes,
• Software Tools for Computational Science,
• Combinatorial Scientific Computing.

In addition, seminars and practical courses are offered, giving a deeper understanding of HPC-related issues. More information on our teaching activities is available at

http://www.sc.rwth-aachen.de.
Research Projects

Over the past years, the Institute for Scientific Computing has been fortunate to receive support from the Deutsche Forschungsgemeinschaft (DFG) within the Excellence Initiative, two Collaborative Research Centres (SFB), a Research Training Group (GRK), and a Priority Programme (SPP).

The Excellence Initiative aims to both promote top-level research and improve the quality of German universities and research institutions, thereby making a significant contribution to strengthening science and research in Germany in the long term, improving its international competitiveness and raising the profile of the top performers in academia and research. This national initiative involves three lines of funding: (a) graduate schools to promote young researchers, (b) clusters of excellence to promote world-class research, and (c) institutional strategies to promote top-level university research. The Institute for Scientific Computing is involved in the graduate school "Aachen Institute for Advanced Study in Computational Engineering Science" (AICES) and the cluster of excellence ‘Integrative Production Technology for High-Wage Countries’.

Computational Differentiation in Numerical Flow Analysis
A. Rasch, A. Vehreschild, C. Bischof, M. Bücker

This project of the Collaborative Research Centre (SFB) 401, "Modulation of flow and fluid--structure interaction at airplane wings", is aimed at developing efficient techniques for computing partial derivatives for Navier--Stokes Computational Fluid Dynamics (CFD) solvers. Such partial derivatives are needed, for instance, in sensitivity analysis and in design optimization. Due to strong non-linearities of the solution, as well as very high memory and runtime requirements of the simulation software, the traditional approach of approximating the derivatives with divided differences is not appropriate in these applications, in particular in three dimensions.

Therefore we rely on Automatic Differentiation (AD) tools for obtaining the derivatives along with the simulation results. Using the ADIFOR tool, we augment the TFS CFD solver, developed at the Aerodynamics Institute (AIA) of the RWTH, with code for computing partial derivatives, in particular the derivatives of the computed velocity or pressure fields with respect to fluid and geometrical parameters. The availability of such accurate derivative information is crucial if the TFS code is used within some optimization framework, e.g., for the estimation of turbulence parameters and wing shape optimization.

Furthermore, Automatic Differentiation is employed to obtain the analytic flux Jacobian for an implicit Newton-Krylov method which is used in the recent flow solver QUADFLOW currently under development within SFB 401. In contrast to numerical approximation of the Jacobian, the use of AD-generated code for the Jacobian calculation generally leads to increased performance and robustness of the overall computational method. Since in principle, only Jacobian-vector-products are needed by the iterative method implemented in QUADFLOW, we plan to avoid the explicit assembly of the whole Jacobian and generate code for computing Jacobian-vector products, yielding significant savings in memory.
consumption. This will also allow the transition from the currently used first-order-discretization in space to a second-order discretization scheme with improved convergence behavior.

An Environment for Parameter Identification and Sensitivity Analysis
M. Petera, C. Bischof, M. Bücker

This project is part of the Collaborative Research Centre (SFB) 540, "Model-based experimental analysis of kinetic phenomena in fluid multi-phase reactive systems". Several projects in the SFB 540 aim at developing a better understanding of complicated processes through the use of already existing simulation packages or newly developed software in the context of an inverse problem formulation. In order to support this process, we are developing an environment for parameter identification, which allows the coupling of simulation codes with algorithms for the solution of inverse problems with little effort. Tools for the automatic differentiation of programs are an important ingredient, as they allow the exact and efficient computation of derivatives of existing programs and thus increase both the robustness and speed of solvers for inverse problems. Another contribution is the automatic generation of marshalling code which effects the interfacing of the world of simulation with that of numerical solvers for inverse problems. In particular, we plan to develop such an environment around the models for dripping processes on films that are employing the commercial FLUENT CFD solver, and the SEPRAN solver, developed at Delft University of Technology, that is used in the modelling of boundary processes. The development of numerical methods that are specifically tailored to these problems is infeasible due to the complexity of the codes employed.

ADiMat—Automatic Differentiation of MATLAB Programs
A. Vehreschild, C. Bischof, M. Bücker

The MATLAB problem solving environment is widely used in the natural and engineering sciences. Its popularity is mainly due to its wealth of high-level data types and powerful mathematical operators, as well as to its flexibility and ease-of-use. The goal of this project is the design and implementation of an automatic differentiation tool for MATLAB. The ADiMat tool allows augmenting MATLAB programs with additional statements such that derivatives are computed along with the original function. ADiMat implements a hybrid approach combining source transformation and operator overloading techniques in order to achieve high performance while allowing for MATLAB's dynamic type system.
Reliable Parameter Estimation for Reactive Flows in Hot Aquifers
A. Wolf, C. Bischof, M. Bücker

This project deals with the numerical simulation of reactive transport in porous media using the simulation package SHEMAT (Simulator for HEat and MAss Transport). SHEMAT is an easy-to-use, general-purpose reactive transport simulation code for a wide variety of thermal and hydrogeological problems in two or three dimensions. The goal of this project is to develop a parallelization of SHEMAT based on the OpenMP standard for shared memory computers as well as to establish a methodology to reliably estimate model parameters using automatic differentiation. This project is funded by GEOPHYSICA Beratungsgesellschaft mbH and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Parallel Simulation of Reactive Multiphase Fluid Flow Models
O. Fortmeier, C. Bischof, M. Bücker

This project which is a joint work with the Chair for Numerical Mathematics is part of the Collaborative Research Centre (SFB) 540, "Model-based experimental analysis of kinetic phenomena in fluid multi-phase reactive systems". The main topic of this project is the development of a parallel solver (DROPS) for the incompressible Navier-Stokes equations that can be used for the numerical simulation of certain two-phase fluid flow models which are considered in this SFB. The focus of our work is on the development of a hybrid parallelization strategy combining the advantages of OpenMP and MPI. Research topics include parallel grid refinement, load balancing, and parallel iterative algorithms to solve sparse systems of linear equations.

Robust Shape Optimization for Artificial Blood Pumps: Hematological Design, Large-scale Transient Simulations, and Influence of Constitutive Models, Sensitivity Analysis
M. Lülfesmann, C. Bischof, M. Bücker

This project is part of the Priority Programme 1253 "Optimization with Partial Differential Equations" financed by the DFG since July 2006. It is a joint work with the Chair for Computational Analysis of Technical Systems. In the context of shape optimization of blood pumps, we propose to address the issue of objective functions which can be correlated with the accumulation of blood damage and the influence of constitutive model on the optimal shapes. The entire optimization tool chain, based on analytically-derived sensitivities and
adjoints, will be subjected to sensitivity analysis with the help of automatic differentiation. It is expected that criteria for detecting inadequacies in constitutive modeling will be exemplified, e.g., by extreme sensitivity of the optimal shapes to model parameters.

Novel methods for exploration, development, and exploitation of geothermal reservoirs - a toolbox for prognosis and risk assessment

A. Rasch, C. Bischof, M. 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.
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:

- Arno Rasch, vtmw, August 31, 2009
- Matti Stenroos, Helsinki University of Technology, June 7-9, 2009
- Volker Rath, Complutense University of Madrid, June 8, 2009
- John Field, IBM T.J. Watson Research Center, June 5, 2009
- Horst Simon, Lawrence Berkeley National Laboratory, March 23, 2009
- Per Christian Hansen, Technical University of Denmark, January 11-12, 2009
- Arno Rasch, vtmw, January 24, 2009
- Monica Bugeanu, POLITEHNICA University of Bucharest, December 11-12, 2008
- Alexandru Calotoiu, POLITEHNICA University of Bucharest, December 11-12, 2008

Christian Bischof is speaker of the Working Group "Parallelism" within the Forum Informatik and organizes – jointly with Th. Lippert (Forschungszentrum Jülich GmbH), U. Lang (University of Cologne) and U. Trottenberg (Fraunhofer Institute for Algorithms and Scientific Computing) – the Kolloquium über Parallelverarbeitung in technisch-naturwissenschaftlichen Anwendungen, a series of symposia concerned with parallel processing in engineering and scientific applications. This series, initiated in 1993 under participation of K. Indermark and F. Hoßfeld, has since then established itself as a forum for discussion and information exchange among the Northrhine-Westphalian institutions concerned with parallel processing.

The following workshops were co-organized by our institute:

- 8th European Workshop on Automatic Differentiation, Oxford, UK, July 17, 2009. (Co-organized by Martin Bücker)
- 7th European Workshop on Automatic Differentiation, Oxford, UK, November 24-25, 2008. (Co-organized by Martin Bücker)

In addition, Christian Bischof served on the program committee for:

- Gordon Bell Prize Award Committee, Supercomputing 2008 held in Austin, USA, November 15-21, 2008.

Martin Bücker served on the program committee for:

- 3rd Workshop on Language-Based Parallel Programming Models (WLPP) held in conjunction with the 8th International Conference on Parallel Processing and Applied Mathematics (PPAM'2009), Wroclaw, Poland, September 13-16, 2009.
- 12th IEEE International Conference on Computational Science and Engineering (CSE09) held in Vancouver, Canada, August 29-31, 2009.
• 10th IEEE International Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC-09) held in conjunction with the 23rd International Parallel and Distributed Processing Symposium (IPDPS-2009), Rome, Italy, May 25-29, 2009.
Talks and Publications

Talks


Publications


Institute for Scientific Computing RWTH-CS-SC-08-10, RWTH Aachen University, Aachen, 2008.


Software and Tools for Computational Engineering

Staff

- **Faculty**
  Uwe Naumann

- **Secretary**
  Gabriele Meessen

- **Research Assistants**
  Boris Gendler
  Ebadollah Varnik
  Hakima Lakhdar
  Markus Beckers
  Michael Förster
  Michel Schanen
  Viktor Mosenkis

- **Long-term Visitors**
  Jan Riehme, Dmitrij Gendler (U. of Hertfordshire, UK)

- **Student Researchers**
  Callum Corbett
  Christian Ewald
  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 \( \tilde{y} \in \mathbb{R}^m \) 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, C. Ewald

The aim of the project AaChen Platform for Structured Automatic Manipulation of Mathematical Models (AC-SAMMM) is to provide a tool that allows the calculation of specified symbolic expressions involving any kind of derivative based on automatic differentiation using code transformation for a structured model represented in any equation-oriented modeling language. In contrast to other AD tools, the platform will be parameterized such that the user can specify the desired derivatives in an easy manner, independently of the model itself and of the model representation language used. This way, a general purpose AD-tool will be provided that allows to support the solution of basically any kind of simulation and optimization problem formulated in a wide range of well-known equation-oriented modeling languages. Such a tool is highly desirable for scientist worldwide and is thus expected to strengthen the reputation of RWTH Aachen University as one of the leading technological universities in Europe.

Collaborators: Prof. Dr. W. Marquardt, AVT Aachener Verfahrenstechnik Prof. Marquardt,

Funded by: ERS boost fund (http://www.exzellenz.rwth-aachen.de)

JURASSIC

E. Varnik, M. Förster, U. Naumann

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 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 gradient of the cost function using tape-based forward and reverse mode AD. This feature is currently available in JURASSIC release 2.3. Further effort aims to minimize the memory consumption of the AD based solution.

Collaborators: ICG-1, Forschungszentrum Jülich

Funded by: JARA-SIM seed fund (http://www.jara-excellence.de)
The CompAD project aims to put AD into the NAG Fortran compiler. We are currently in the third phase of the project (CompAD-III). For further details please see http://wiki.stce.rwth-aachen.de/bin/view/Projects/CompAD/WebHome

**Collaborators:** The Numerical Algorithms Group Ltd., University of Hertfordshire, UK

**Funded by:** EPSRC

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**Subgradient Propagation for McCormick Relaxations**

*U. Naumann, C. Corbett, V. Mosenkis, M. Beckers, M. Maier*

McCormick relaxations of factorisable functions are applied by colleagues at MIT's Process Systems Engineering Laboratory and Dept. of Mechanical Engineering to a range of global optimization problems. The ability to propagate subgradients for the generally not differentiable underestimators has been added to the NAG Fortran compiler. Current work at STCE is focused on extending these methods by a working version of an adjoint mode based on AD.

**Collaborators:** Prof. A. Mitsos, Phd., MIT, USA

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**Sensitivity Analysis in Telemac/Sisyphe**

*J. Riehme, U. Naumann*

The aim of this collaboration with the German Federal Waterways Engineering and Research Institute, Karlsruhe, is to apply the differentiation-enabled NAG Fortran compiler to Telemac, a numerical modeling system for free surface hydrodynamics, sedimentology, water quality, waves and underground flows.

**Funded by:** German Federal Waterways Engineering and Research Institute, Karlsruhe
The aim of this research is minimizing the number of operations during the accumulation of Jacobian matrices. Different techniques like vertex-, edge-, and face-elimination are used. Jacobians are given in form of linearized directed acyclic graphs (DAGs) resulting from the application of AD.

As the general problem of Optimal Jacobian Accumulation is known to be NP-complete we are looking for good and fast heuristics. Recently we have proved some search space reducing criteria for this problem. These criteria can also be used in another problem which arise in this context, namely finding a graph representation of the Jacobian with minimal number of edges. Such a graph will need a minimal amount of memory for the representation of the same Jacobian.

This problem is called Minimum Edge Count problem. For the transformation of the graph we use the same elimination techniques as for the Optimal Jacobian Accumulation.

Funded by: DFG

We are currently investigating on how to integrate MPI in the adjoint AD mode. This would enable adjoint AD to be used on MPI parallelized code. A more general approach is taken in order to incorporate these insights in various AD tools.

Collaborators: Dr. Jean Utke, Argonne National Laboratory, USA, Dr. Laurent Hascoët, INRIA, France

Uncertainty Quantification is a field that tries to analyze the imprecision in the outputs of numerical programs caused by measurement errors in the inputs. Under the assumption that we know about the input (error) distribution, probabilistic methods are used to get information about the distribution of the outputs. At the moment we aim to use AD to improve uncertainty methods.
Collaborators: Prof. B. Christianson, Phd., University of Hertfordshire, UK
Funded by: German Research School for Simulation Sciences

Data Flow Reversal

H. Lakhdar, U. Naumann

Debuggers, profilers, or adjoint code compilers may require the intermediate values generated by a computer program to be accessed in reverse order. The efficient reverse retrieval of these values within a memory of limited size has been shown to be intractable only recently. Our aim is to represent a formalization of the corresponding DAG Reversal problem based on call trees and to find check-pointing algorithms with minimum flop count for a given upper bound on the available persistent memory.

Large-Scale Derivative Propagation

E. Varnik, L. Razik, U. Naumann

The construction of computational graphs of numerical simulations at runtime leads to very large graphs. Derivative accumulation by elimination techniques may fail due to the graph size exceeding the available memory. A tool named DALG has been developed to overcome this problem by eliminating intermediate vertices and edges on the fly.
The sparsity pattern of derivative tensors consists of static (not dependent on runtime parameters) and hence constant and dynamic nonzero entries. This distinction permits a targeted exploitation of dynamic sparsity.

Adjoint Error correction in ICON

J. Riehme, K. Leppkes, U. Naumann

Adjoint Error correction aims to correct the total modeling error based on the gradient of the objective with respect to the model parameters. The adjoint of a shallow-water configuration of the general circulation model ICON is generated by the NAG compiler.

Collaborators: Dr. P. Korn and F. Rauser, Max Planck Institute for Meteorology, Hamburg
Funded by: Max Planck Institute for Meteorology
Talks and Publications

Talks
Several talks were given at different conferences / workshops by various members of the group.

Publications
E. Varnik and U. Naumann, *What color is the non-constant part of your Jacobian*, in Dagstuhl Seminar Proceedings, number 09061, 2009
J. Utke and U. Naumann, *Combinatorial problems in OpenAD*, in Dagstuhl Seminar Proceedings, number 09061, 2009
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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 things like complete plants, over mid-size things like machine tools and robots, down to microscopic scenarios arising in material science.

In recent years, Simulation Science has more and more attracted our attention. At RWTH Aachen, numerical simulation of technical and physical phenomena has traditionally been an important pillar in engineering research. With the excellence initiative, Simulation Science has definitely become a main focus at the University. In Aachen and elsewhere, simulation is an indispensable and essential tool in production technology and the development of, e.g., airplanes, cars, combustion engines, turbines etc. Even in medical projects at RWTH, numerical simulation is going to play an important role, e.g., in the analysis of flow within artificial blood pumps, or in order to understand the air flow within the human respiratory organs. Researchers are going to simulate phenomena of such a high complexity that traditional methods of post-processing, like producing static images or at best animations, are no longer neither an effective nor an efficient approach to understand the simulation results. Instead, engineers demand interactive exploration of their data in 3-D space, what eventually leads in the use of VR technology. As such, the VR Group actively supports RWTH institutes and research groups in CCES, AICES, GRS, JARA-Sim, and the CoE “Integrative Production Technology 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 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.
Research Projects

Rhinomodell – Modeling the Aerodynamics of Nasal Airflow
B. Hentschel, T. Kuhlen, C. Bischof

The Virtual Reality Group participates in an interdisciplinary research project kindly funded by the DFG, investigating the airflow inside the human nasal cavity. The human nose has to satisfy a variety of different functions. Besides respiration it is responsible for moistening, tempering, and cleaning the air. These functions are expected to strongly depend on the complex internal geometry of the nasal cavity. Impaired nasal respiration especially under normal breathing conditions, i.e., in everyday life situations, is a common and widespread disease, which makes nose surgery one of the most frequent operations in the western world. Unfortunately, the success rate, i.e., the number of people having no problems after surgery, is by no means satisfactory. To enhance this situation, researchers from the fields of fluid mechanics, medicine and computer science cooperate in an interdisciplinary research team. The main goal of this effort is to devise objective criteria which on the one hand quantify the quality of a given nasal cavity’s flow field and on the other hand help to predict the outcome of a surgical intervention. In this project, the Virtual Reality Group is designing new, interactive visualization methods which are custom tailored to the investigation of the nasal cavity. Work is split up into four main strands:

In a first step the complex nasal geometry had to be visualized. Unlike in most other simulation output analysis settings where the shape of the simulated domain is some form of artificially created geometry, the highly complex, natural shape of the cavity poses major problems inhibiting an efficient navigation. A combination of CT-data displays used as a “map” of the nasal cavity and direct 3D interaction techniques has been used to solve this task.

A second field of work arises from the fact, that in order to understand the influence of the nose’s main anatomical components, flow simulations have been performed for different nasal geometries. A manual, purely image-based comparison of the results would have been very tedious and time consuming. Therefore, a set of visualization techniques has been devised that are used to assess the differences of the various data sets more efficiently. These techniques facilitate a direct comparison on the raw data level, either using a set of similarity metrics to show a global image of the data set similarities or by providing the user with 3D point probes which allow to locally assess any two data fields at the same time.

Third, in order to integrate the expertise from different research fields, the development of the virtual annotation system IDEA (Interactive Data Analysis and Annotation) has been started. This system combines an underlying model which links meta-information – the annotations – to respective parts in the scene. The annotation data is saved to a data base along with the annotated scene data for later restoration and follow-up analysis.

Finally, the fourth part of the project deals with the integration of quantitative data into the analysis process and the interaction therewith. Here, concepts from information visualization are transferred to a 3D immersive setup. Ultimately, this will lead to a comprehensive set of methods which allow the interactive specification, extraction, quantification, and follow-up
assessment of arbitrary data characteristics. Based on these, aerodynamics engineers will be able to easily identify areas where certain combinations of values are present in the data and to cross-link this data to medical statistics on the nasal respiration. Ultimately, this cross-referencing should lead to the establishment of the aforementioned objective criteria, which facilitate an evaluation of any given nasal geometry.

Figure 1: A user interactively explores the flow field inside a human nasal cavity using a large number of interactively traced particles.

Interactive Visualization of Blood Flow in a Ventricular Assist Device
I. Tedjo-Palczynski, B. Hentschel, M. Wolter, T. Kuhlen

Within the Jülich Aachen Research Alliance (JARA), we have developed an interactive visualization for simulated ventricular assist devices in cooperation with Prof. Marek Behr, Chair for Computational Analysis of Technical Systems (CATS).

A ventricular assist device (VAD) is a mechanical blood pump to support a patient’s weakening heart, which can help a patient to survive the waiting time until a suitable heart transplant is available. The long-term goal is to enable a permanent use of VADs, and thus obviate the need for a heart transplant. One of the main concerns in the advancement of the current VAD generation is blood damage (hemolysis), in which the blood cells’ content leaks into the surrounding blood fluid.

To analyze the cause of blood damage and facilitate the optimization of the VAD design, CATS developed computational methods to simulate human blood flow. The computation considers not only standard flow features, but also the impact of the flow on the blood cells which enables a prediction of the rate of hemolysis.

As the computation quantifies the impact of the flow on the blood cells by their deformation, the visualization depicts this feature by morphing, semi-transparent ellipsoids. The main axes
of the ellipsoid are not only shown to illustrate the deformation, but also to enable the observation of the so-called tank-treading of the blood cell. This is a natural protection mechanism of red blood cells in a shearing flow. To give an overview of the whole deformation process, the visualization application provides a static view, which is inspired by the multiple exposure technique in photography. This static overview can be used as a means for navigating through the time dimension. By picking one of the ellipsoids along the pathline, which is also a time line, the user jumps directly to the time step corresponding to that position of the blood cell.

Figure 1: Direct interaction with the data, as shown here, allows an intuitive navigation in space and time. Here, a user picks a particle instant in order to navigate to a specific point in time.

**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:
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.

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.

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.

Further insight and understanding of the process as a whole using leading edge Virtual Reality technology to visualize and adequately 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 utmost importance to be able to find and identify interdependencies and causalities between several simulation datasets. This forces us to integrate all simulation results from a processing chain into a single visualization context running at interactive frame rates. Being able to understand the whole process for the various simulation experts makes it mandatory for our framework to preserve and reconstruct the time and space coherency between datasets thus reflecting the real process as closely as possible.

Interactive Visualization for Prognosis and Risk Assessment of Geothermal Reservoirs

I. Tedjo-Palczynski, T. Kuhlen

This visualization project is part of the BMBF funded joint research project MeProRisk (novel MEthods for exploration, development, and exploitation of geothermal reservoirs – a toolbox for PROgnosis and RISK assessment). The goal of the visualization is to help detecting geothermal deposits, improving the underlying geological model, and finding coherencies between the geological properties, e.g. between permeable zones and temperatures.

Due to scattered and limited source of geological measurements the generation of reliable geothermal datasets is a current topic in the geothermal research. Thus, it is crucial to investigate the possibilities to include and emphasize the estimated uncertainty of the data in the visualization.
Displaying the visualization in an immersive environment should not only provide a better visual depiction of the volume dataset than the currently widely-used desktop visualization applications, but also enable the use of 3D user interfaces to support the analysis of the complex geological structures. In the further development phase of this project the interaction is going to be extended to enable the parameter editing of the underlying geological model.

RASim - Regional Anaesthesia Simulation
S. Ullrich, 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.

Figure 1: Visualization of extracted anatomical tissues in hip region with modeled peripheral nerve cords.

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.
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.

Figure 1: Real-time modification of a natural sound source in a virtual concert hall.

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.

VisPME - Visualization in Parallel Manycore Environments
T. Rick, T. Kuhlen
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.
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.

In this project funded by the Interdisciplinary Pathfinder Projects Initiative, 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.

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.
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 Jülisch, we have recently established ivNet (immersive visualization network) as a structural and methodical measure under JARA with the goal to integrate advanced visualization and exploration methods into the scientists’ daily work. To achieve this goal, high-end 3D workplaces which fit into an office environment, are connected via Grid technology to each other and also to remote, parallel file servers and post-processing servers. Such an infrastructure will allow for an intuitive and collaborative exploration of even very complex phenomena between researchers in Aachen and Jülisch.

In a lot of smaller cooperations with RWTH institutes and industry, we provided methodical support, helping our partners to visualize their data by means of state-of-the-art methods and beyond. For this purpose, we have been developing the software framework ViSTA (Virtual Reality for Scientific and Technical Applications) for more than ten years now. ViSTA is based on Open Source standards and is freely available to our research partners.

Torsten Kuhlen is the CEO of the Virtual Reality Center Aachen (see www.vrca.rwth-aachen.de) and in addition the speaker of the “Fachgruppe Virtual & Augmented Reality” within the “Gesellschaft für Informatik”. In 2008, he co-organized the yearly workshop of this GI section and was a member in the program committees of several national and international conferences like the IEEE VR.
Talks and Publications

Talks


Torsten Kuhlen: *Tutorial on Interactive Flow Visualization in Virtual Environments* at IRTG “Visualization of Large and Unstructured Data Sets Applications in Geospatial Planning, Modeling, and Engineering”, Kaiserslautern University, May 2009.


Sebastian Ullrich: Simulator for Regional Anaesthesia in Virtual Environments with Electric Nerve Stimulation. 18th International Conference on Artificial Reality and Telexistence (ICAT), Yokohama, Japan, December 2009.


Publications


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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 four 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.

In addition, many security mechanisms rely on dependable time synchronization. However, direct attacks against time synchronization protocols are rarely considered during the design of security protocols. This is particularly dangerous in the context of wireless networks, where time synchronization is based on the correct receipt of vulnerable broadcast messages. We address this problem by developing new secure time synchronization protocols.

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 targeted at mobile devices. Finally, we also work on the collection and analysis of (mobile) malware and in particular support the MW-Collect Alliance.

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 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:

2009:

• Member of the program committee: 5th LCN Workshop on Security in Communications Networks (SICK’09)

• Member of the program committee: The 25th ACM Symposium on Applied Computing, 22 – 26 March 2010, Sierre, Switzerland, Track on Information Security Research and Applications

2008:

• Member of the program committee: European Conference on Computer Network Defense, 2008
Talks, Publications, and Patents

Talks


Publications


Patents Granted


Advanced Studies in Computational Engineering Science

Staff

- **Faculty**
  Prof. Paolo Bientinesi, PhD

- **Team**
  Matthias Petschow,
  Roman Iakymchuk,
  Diego Fabregat.
Overview

Paolo Bientinesi joined RWTH Aachen in summer 2008 as Young Research Leader at the Aachen Institute for Advanced Studies in Computational Engineering Science (AICES). In October 2008 he was appointed as Junior Professor in "Algorithm & Code Generation for High-Performance Architectures" in the Fachgruppe Informatik. His research interests cover the fields of numerical analysis, high-performance & parallel computing, and automation. Research in these fields is motivated by real-world scientific problems and deals with the development of fast and accurate numerical algorithms specifically tailored for the fastest computing architectures.

Ongoing collaborations

- Christian Lessig, University of Toronto: Data parallel eigensolvers.
- Robert van de Geijn, University of Texas: Analysis of linear algebra algorithms.
- Enrique Quintana-Ortí, Universidad Jaume I: Symmetric eigenvalue solvers on multicore processors.
- Jeff Napper, VU University: Cloud computing for scientific computations.
- Dr. Edoardo Di Napoli, RWTH Aachen: Physical eigencomputations.

Research

The computing world has been revolutionized by the advent of multicore processors: they have become the standard engines for the entire range of computing platforms, from commodity computers to supercomputers. At the same time the community is investing in the employment of graphics processing units and other emerging processors to further improve performance of scientific applications. Both these advances result in clear constraints towards high-performance numerical computations: algorithms and libraries have to be re-designed, or even re-discovered, to fully exploit unprecedented forms and amounts of parallelism.

Derivation and Analysis of Linear Algebra Algorithms.

The techniques that were first introduced as part of Bientinesi's Ph.D. dissertation to derive and analyze algorithms for dense linear algebra are extended and generalized. The following topics are under investigation.

1) Systematic and modular stability analysis: the methodology to derive algorithm was extended to capture how roundoff errors propagate as the computation unfolds.

2) Automatic performance prediction: the cost of a target linear algebra algorithm is estimated while minimizing the number of algorithm executions.

3) Derivation of iterative solvers: we are seeking an extension of the derivation methodology to be applicable to sparse matrices and Krylov iterative methods.

4) Automatic derivation of parallel and domain specific libraries: as part of a recently started project, we aim for automatic generation of high-performance linear algebra ‘blocked’ and ‘by block’ algorithms.
5) Cost and performance models for Cloud computing: while the Cloud paradigm comes with a number of perks, it appears that Clouds are not yet well designed for high-performance computations. We are analyzing the new paradigm.

**Eigencomputations.**

In collaborations with scientists from RWTH and other international institutions, we have studied a number of different aspects of eigencomputations. One of the objectives is to extend the Algorithm of Multiple Relatively Robust Representations (MRRR), at the heart of symmetric eigensolvers, to target both multicore and massively parallel architectures. The resulting eigensolver will scale up to thousands of computational cores. As part of this project we are also studying the acceleration of the reduction of a symmetric matrix to tridiagonal form, the most expensive stage in the computation of eigenvectors. The employment of GPUs for the efficient computation of eigenvalues and eigenvectors is another objective of this research. Finally, we have established a collaboration with physicists to investigate how physical and mathematical properties can be made knowledge to be incorporated into the solvers, improving accuracy and/or performance.
Other Activities

Services

Throughout the year Bientinesi organized a number of events. Here we mention the three most salient ones.

• November '08: Short-course on ‘Introduction to PETSc”; taught by Dr. Victor Eijkhout, research scientist at the Texas Advanced Computing Center. The course had more than 40 attendees.

• July '09: ‘Workshop on Scientific Writing’, held by Prof. G.Gopen, professor of rhetoric at Duke University, NC. The event was attended by more than 70 scientists and graduate students.

• September '09: ‘High-Performance Computing and Numerical Linear Algebra” symposium and proceedings, within the 7th International Conference of Numerical Analysis and Applied Mathematics (ICNAAM 2009). Crete, Greece.

Awards

In 2009 Bientinesi was the recipient of the J.Tinsley Oden Faculty Research Fellowship for research collaboration with the Institute for Computational Engineering and Sciences at the University of Texas at Austin.

In April he received the 2009 Karl Arnold Prize from the North Rhine-Westphalian Academy of Sciences and Humanities for outstanding research work of a young scientist.
Talks and Publications

Talks:


Paolo Bientinesi: *Linear Algebra on Multicore Architectures*. School on High-performance Computing in Geophysics, September '09, Novosibirsk State University, Novosibirsk, Russia.


Publications


Laboratory for Parallel Programming

Staff

- **Faculty**
  Prof. Dr. Felix Wolf

- **Scientific Staff**
  Dipl.-Ing. Daniel Becker
  Dipl.-Inform. Dominic Eschweiler
  Dr. Markus Geimer
  Dipl.-Inform. Daniel Lorenz
  Dipl.-Phys. Christian Rössel
  Dr. Pavel Saviankou
  Dr. Brian Wylie

- **Doctoral Researchers**
  Dipl.-Inform. David Böhme
  Dipl.-Inform. Zoltán Szebenyi

- **Student Assistants/Researchers**
  David Krings
  Andreas Nett
  Divya Sankaranarayanan
Overview

Anchored at the German Research School for Simulation Sciences in Aachen and with part of the staff located at the Jülich Supercomputing Centre, the objective of the Laboratory for Parallel Programming is to make the optimization of parallel applications both more effective and more efficient. Facing increasing power dissipation, little instruction-level parallelism left to exploit, and almost unchanged memory latency, computer architects are realizing further performance gains by placing multiple “slower” processor cores on a chip rather than by building faster uniprocessors. To satisfy their growing demand for computing power, numerical simulations are therefore being required to harness higher degrees of parallelism available on systems such as the IBM BlueGene/P called JUGENE at the Jülich Supercomputing Centre. However, writing codes that run efficiently on large numbers of processors and cores is extraordinarily challenging and requires adequate tool support for performance analysis. Unfortunately, tools that normally assist developers in the optimization process often cease to work in a satisfactory manner when deployed on large processor counts. To improve the efficiency of large-scale applications and, thus, to expand their potential, our group develops scalable tools that collect relevant data on code performance and identify the causes of performance problems.

A key method we apply in our projects is event tracing, which is a well-accepted technique for post-mortem performance analysis of parallel applications. Time-stamped events, such as entering a function or sending a message, are recorded at runtime and analyzed afterwards with the help of software tools. Because event traces preserve the spatial and temporal relationships of individual runtime events, they are especially well suited for detailed inter-process analysis.

Acknowledgement. We would like to thank the following staff members of the Jülich Supercomputing Centre for their contributions to the work of our group: Wolfgang Frings, Marc-André Hermanns, Dr. Bernd Mohr, Morris Riedel.

University Courses

- Seminar Grid Computing (SS 2009)
- Multithreading (WS 2008/2009)
- Behandlung großer Datenmengen (WS 2008/2009) together with Prof. Bischof, Prof. Kobbelt, and Prof. Seidl
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 severe 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, allowing us to demonstrate performance measurements and corresponding analyses on up to 294,912 cores. Hybrid codes, which use a combination of message passing and shared-memory programming, are now supported both in runtime summarization and tracing mode. To accomplish the latter, we also extended the postmortem synchronization of timestamps that is needed on cluster systems and grids without a global clock. To become suitable for a broader range of applications, the replay-based simulator developed during the previous reporting period was extended to cover also non-blocking communication. It is now employed in a recently started framework aimed at identifying and assessing load imbalances responsible for the formation of wait states. Increasing Scalasca’s portability and also taking advantage of static filtering techniques, Scalasca was equipped with a flexible source-code instrumenter. The design of a more scalable component for the presentation 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 applied to tune a mold filing code of the company MAGMA GmbH in Aachen.

**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. During the past year, a runtime approach for the semantic compression of time-series call-path profiles was developed. Leveraging clustering techniques known from data mining, the method can be applied to large numbers of iterations without sacrificing important performance details and introducing major overhead. The other project investigates load and communication imbalance in parallel codes to better understand the formation of performance-degrading wait states. Building on earlier work by Meira, Jr. et al., a scalable method was designed that identifies program wait states 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.

**Virtual Institute – High Productivity Supercomputing (VI-HPS)**

*Funded by the Helmholtz Association and carried out in cooperation with RWTH Aachen University (Institute for Scientific Computing), TU Dresden, University of Tennessee, TU Munich (associated partner), and University of Stuttgart (associated partner).*

The mission of this virtual institute is to improve the quality and accelerate the development process of complex simulation programs in science and engineering that are being designed for the most advanced parallel computer systems. For this purpose, we develop and integrate state-of-the-art programming tools for high-performance computing that assist domain scientists in diagnosing programming errors and optimizing the performance of their applications. In these efforts, we place special emphasis on scalability and ease of use. Besides the purely technical development of such tools, the virtual institute also offers training workshops with practical exercises to make more users aware of the benefits they can achieve by using the tools. During the past year, two tuning workshops with hands-on sessions were organized in Jülich and Bremen, respectively. Our tool integration efforts resulted in improved interoperability between Scalasca and the Vampir time-line browser,
allowing Scalasca’s wait-state search and Vampir’s detailed time-line view to be used in combination based on the same set of trace files.

### 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, and GWT-TUD GmbH (associated partner)._  

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, Vampir, and Periscope. The latter two are developed by research groups in Dresden and Munich, respectively. In addition to increasing their scalability, making the three 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 peta-scale era.
Other Activities

We co-organized the Workshop on Productivity and Performance (PROPER 2009) at the Euro-Par conference in Delft in the Netherlands. Moreover, members of this group served on the program committees of the IEEE International Parallel and Distributed Processing Symposium (IPDPS 2009), the International Conference on High-Performance Computing (HPCC 2009), the Euro-Par Conference 2009, and the International Conference on Parallel Processing (ICPP 2009).

Tutorials


Talks and Publications

Talks


F. Wolf: Presentation during the panel "Software development and deployment challenges for the next generation computer architectures" at the HPCC 2009 Conference, Seoul, South Korea, June 26, 2009.


M. Geimer: *Performance Analysis of Parallel Programs using Scalasca*, AICES/MIT Spring School, RWTH Aachen University, Aachen, Germany, March 24, 2009.


B. J. N. Wylie: *Scalasca parallel performance analyses of SPEC MPI2007 applications, SC08 SPECMPI2007 BOF, Austin, TX, USA, November 18, 2008.*

M. Geimer: *The Scalasca performance analysis toolset, tool demonstration at JSC booth, SC’08, Austin, TX, USA, November 18, 2008.*


F. Wolf: *Scalasca Parallel Performance Analyses of PEPC*, University of Tennessee, Innovative Computing Laboratory, Knoxville, October 17, 2008.
F. Wolf: *How to make large-scale parallel applications more efficient*, Young Investigators Symposium, Oak Ridge National Laboratory, October 14, 2008.

**Publications**


Awards, Prizes, Honours

For the best Diploma at TU Braunschweig, Jan O. Ringert (Software Engineering) was named Honorary Member of the GI.

Bernhard Rumpe (Software Engineering) received the ‘Models’ conference’s ‘Ten Year Most Influential Paper’ Award for the paper ‘The UML as a Formal Modeling Notation’, co-authored by Andy Evans, Robert France, Kevin Lano, Bernhard Rumpe

Klaus Wehrle (Distributed Systems Group) was invited to serve on the examination board of the Federal Tournament in Computer Science (Bundeswettbewerb Informatik). The final round of the challenge was hosted by RWE IT Systems in Wanderath and Essen in September 2009.

Klaus Wehrle (Distributed Systems Group) was selected and invited by the New York Academy of Science to represent the European Science Community as one of two young researchers at the 6th Science, Technology and Society Forum, held in Kyoto from October 3rd to 6th. In the following, he was invited on a study tour organized by the Japanese Society Promoting Science and Research (JSPS).

Klaus Wehrle (Distributed Systems Group) was invited to participate in the interdisciplinary forum “Neue Verantwortung”, a think tank of young potentials from science, business, art and politics.

Klaus Wehrle (Distributed Systems Group) was elected member of the German Academy of Science and Engineering ACATECH (Deutsche Akademie der Technikwissenschaften). ACATECH represents the interests of German sciences and technology in Germany and abroad.

Łukasz Kaiser (Mathematical Foundations of Computer Science Group) received the E.W. Beth Dissertation Prize 2009 for his PhD thesis ‘Logic and Games on Automatic Structures’.

Michael Ummels (Mathematical Foundations of Computer Science Group) and Dominik Wojtczak (CWI, Amsterdam, The Netherlands) received the Best Student Paper Award at ICALP 2009, for their paper ‘The Complexity of Nash Equilibria in Simple Stochastic Multiplayer Games’.

A. Schmitz (Computer Graphics & Multimedia), T. Rick, T. Karolski, T. Kuhlen, L. Kobbelt (Computer Graphics & Multimedia) received the Best Paper Award at the Eurographics Symposium on Parallel Graphics and Visualization (PGV) for their paper entitled ‘Simulation of Radio Wave Propagation by Beam Tracing’.

M. Breitenstein, F. Reichlin, B. Leibe (Mobile Multimedia Processing Group) E. Koller-Meier, L. Van Gool received the ITG Innovationspreis 2009 for their paper ‘Automatisches Erkennen und Verfolgen von Personen in Videos – vom Video zum Bewegungsmuster’

A. Ess, K. Schindler, B. Leibe (Mobile Multimedia Processing Group), L. Van Gool received the Best Vision Paper Award at the IEEE International Conference on Robotics and Automation (ICRA’09), Kobe, Japan.

Bastian Leibe (Mobile Multimedia Processing Group) received an ‘Outstanding Reviewer Award’ at the IEEE International Conference on Computer Vision (ICCV’09), and at the European Conference on Computer Vision (ECCV’08)
Ira Assent (Data Management and Exploration) won the dissertation award of the GI chapter on databases and information systems sponsored by IBM Germany. The award for her dissertation on ‘Efficient adaptive retrieval and mining in large multimedia databases’ prepared at i9 was handed out on the 13th GI Conference for Database Systems in Business, Technology and the Web (BTW 2009). Ira Assent is an assistant professorship at the Department for Computer Science and Center for Data-intensive Systems (Daisy) of the University of Aalborg in Denmark since September 2008.

Sergej Fries (Data Management and Exploration) won the award for the best student contribution of the student program at the 13th GI Conference for Database Systems in Business, Technology and the Web (BTW 2009) sponsored by SAP AG. His contribution on “Determining the optimal branching factor of hierarchical anytime classifiers” was sponsored by SAP AG is based on his diploma thesis prepared at i9.

Michael Nett (Data Management and Exploration) got a scholarship for a 6-month research stay at the National Institute for Informatics (NII), Japan. During that time, he worked with Prof. Michael Houle on an interesting indexing problem.

At ACM CHI 2009, the premier international conference for human-computer interaction, Markus Reul (Media Computing) became 3rd in the Student Research Competition with his topic on “Bringing Usability to Industrial Control Systems” that he worked on during his diploma thesis.

At ACM UIST 2009, the Symposium on User Interface Software and Technology, Malte Weiss, Gero Herkenrath, and Jonathan Diehl (Media Computing) won 2nd place in the student innovation contest in the category “Best Implementation” with BallMeR, an action-packed game based on a pressure-sensitive multi-touch keyboard.

Christian Mattar (Media Computing) received the Springorum medal for graduating with distinction from RWTH Aachen University, at a ProRWTH event in the Audimax on June 19, 2009. In his thesis, Christian developed “Table Lemmings”, a tabletop game that explored casual collaboration on multitouch table surfaces and became a successful exhibit for the Dutch Industriomuseum.

Paolo Bientinesi (AICES) was the recipient of the J.Tinsley Oden Faculty Research Fellowship for research collaboration with the Institute for Computational Engineering and Sciences at the University of Texas at Austin.

Paolo Bientinesi (AICES) received the 2009 Karl Arnold Prize from the North Rhine-Westphalian Academy of Sciences and Humanities for outstanding research work of a young scientist.
Habitations and Dissertations
The connection between finite automata and logic was established in the 1960s for various types of automata to solve decision problems for certain restricted forms of second-order arithmetic. Besides their use for decidability proofs in logic, finite automata on infinite words and infinite trees have now become a major tool in the verification and synthesis of finite state systems. In this thesis we present some recent results in the theory of finite automata on infinite trees as well as some applications of these automata in the area of logic: We present a rather simple automata theoretic proof of a difficult result of Gurevich and Shelah on the undefinability of choice functions in monadic second-order logic over the infinite binary tree. This result and its proof can be used to show that there are regular languages of infinite trees which cannot be accepted by unambiguous automata. Unambiguous automata are an interesting subclass of nondeterministic finite automata because over finite words and finite trees they admit polynomial time algorithms for checking language inclusion, an important problem in verification.

For regular languages of finite words, finite trees, or infinite words there are canonical representations (e.g. minimal deterministic automata or algebraic objects like semi-groups) that are often used in algorithms or proofs. For automata on infinite trees no objects of this kind exist so far. We develop the notion of guidable tree automaton and show that each regular language of infinite trees can be accepted by such an automaton. Although guidable automata are not canonical because they are not unique, they possess good properties since they are in some sense most general automata that can simulate all other automata for the same language. We illustrate the use of these automata in a reduction from the parity index problem to the uniform universality problem for distance parity automata. Although the decidability of the latter problem remains open, our reduction provides a new approach to tackle the long-standing open problem of determining for a regular language of infinite trees the minimal number of priorities needed by an automaton for accepting this language.

We use automata theoretic tools to study the notion of finite set interpretation. Interpretations are a standard tool in logic to define one structure out of a given one while preserving decidability properties of the original structure. Finite set interpretations are used to transform structures with decidable monadic second-order theory into structures with decidable first-order theory. Using this method one obtains a rich landscape of structures with decidable first-order theory that subsumes, e.g., the classes of automatic and tree-automatic structures, which are used in computer science to represent infinite state systems in a finite way. We develop tools that allow to study definability of structures with finite set interpretations by reducing them to the well-studied problem of definability by monadic second-order interpretations over trees.
Virtual Reality (VR) environments define computer simulated worlds. The users' interaction with these worlds should be as intuitive as possible, using the visual, aural and haptic senses and natural body movements. In order to achieve this goal, VR software systems have to process inherently parallel but heterogeneous tasks under real-time conditions. The time for signal processing and reproduction is constrained by human perception thresholds. The reproduction systems often suffer from unavoidable latency, which leads to a violation of the real-time constraints and thus to perception perturbations. If the reproduction system suffers from unavoidable latency, compensation algorithms have to be used. In order to be effective, the compensation must be combined with efforts to minimize the VR system overhead.

This thesis presents a comprehensive approach to lower the overall VR system latency by a concurrent device and data processing architecture and its embedding in a generalized interaction concept. Low latency history recording and data exchange for multi-modal data types are among the key concepts of the approach. The architecture is presented in the context of the “Virtueller Kopfhörer” system, which is a representative of a demanding multi-modal environment that was developed as a joint research project between the Institute of Technical Acoustics and the VR Group at RWTH Aachen University. The reproduction environment is discussed with respect to its interface and latency as a distributed architecture. An adaptive tracking approach is presented for latency compensation. Finally, event-interleaved master/slave rendering is outlined as a low latency data- and swap-locking approach for CAVE-rendering based on commodity PC clusters.

**Evaluators:** Prof. Dr. T. Kuhlen  
Prof. Dr. M. Vorländer  
Prof. C. Bischof, PhD

Date of oral exam:: 5 February 2009
Efficient Adaptive Retrieval and Mining in Large Multimedia Databases
Ira Assent

Multimedia data ranging from images to videos and time series is created in numerous scientific, commercial and home applications. Access to increasingly large data volumes stored in multimedia databases is a core task to retrieve similar objects or to generate an overview of the entire content. Examples include retrieval of similar magnetic resonance images for diagnostic purposes, or automatic detection of customer segments for sales promotion. Meaningful retrieval and pattern detection require content-based methods that describe the relevant characteristics of multimedia objects. As opposed to manual keyword annotation techniques that are typically infeasible for large data volumes, content-based approaches use similarity models to process multimedia data. Similarity models specify appropriate features and their relationship for effective content based access. As most multimedia features require many different attributes, high dimensionality of multimedia features and huge database sizes are major challenges for efficient and effective retrieval and mining. In this work, very common feature types for multimedia data are studied: histogram and time series data. Histograms are used for a variety of features such as color, shape or texture. Time series data is prevalent for sensor measurements, stock data, and may even be applied to shapes and other features as well. For these data types, effective adaptable similarity models are usually computationally far too complex for usage in large high dimensional multimedia databases. Therefore efficient algorithms for these effective models are proposed. In this work, indexing techniques are used that allow for efficient query processing and mining by restricting the search space to task relevant data. Multistep filter-and-refine approaches using novel filter functions with quality guarantees ensure that fast response times are achieved without any loss of result accuracy.

Reviewers: Prof. Dr. Thomas Seidl, Computer Science 9 (Data Management and Data Exploration)
Prof. Christian S. Jensen, Ph.D., Aalborg University, Denmark

Date of oral exam: 26. February 2008
Methods numerically simulating the interaction of gases or fluids with complex surfaces (computational fluid dynamics, CFD) are able to perform calculations with increasing levels of detail due to the ongoing development of more powerful computers. CFD simulations are utilized during the design of e.g. combustion engines or airplanes, amongst many others. An increasing level of detail on the one hand allows for more accurate and meaningful simulation results proving very useful in industrial development and research. On the other hand, huge amounts of raw CFD data are generated and need to be repeatedly accessed during the subsequent interactive post-processing (e.g. isosurface extraction) by experts in the application domain. The efficiency of post-processing can be significantly increased by the use of virtual reality (VR) technology, letting users immerse into the visualized data sets and extracted features. Interactive post-processing is efficiently performed on data sets stored in main memory, which outperforms secondary storage by magnitudes regarding access times. Large CFD data sets not fitting into main memory thus require efficient secondary storage methods. In this thesis, methods are introduced which appropriately arrange CFD data on secondary storage and allow for an efficient access during post-processing. The efficiency of post-processing is improved by novel view-dependent query methods. The continuous extraction and visualization of partial results in the proximity and direct line of sight of the user allow for a “quick first impression” of the result set. The approaches are enhanced by dynamic aspects, reacting to a user freely roaming the VR environment with immediate alignment of query execution and 3 of the result data stream. For CFD data sets simulated over a span of time, prefetching methods allowing for a dynamic visualization of different time steps are presented. Furthermore, the index supported graphics data server IndeGS is presented, which offers the developed indexing and access methods and can be integrated into arbitrary virtual reality frameworks. IndeGS executes post-processing queries according to a multitude of user parameters and streams the result data to the visualizing component of the VR framework. Relational database management systems (RDBMS) offer comfortable means to integrate user-defined indexes. An improvement of the relational interval tree (RI-tree) is proposed and utilized to enable indexing and efficient view-dependent querying of CFD data in the context of interactive post-processing. This work is concluded with the introduction of novel nearest-neighbor query methods on high-dimensional data. The precalculation of nearest-neighbor information combined with a two-step dimensionality reduction allows for a very high query throughput on static indexes in main memory. This thesis is structured as follows: Part I gives an overview over the topics presented in this thesis. Part II and Part III introduce and evaluate the secondary storage indexing methods and view-dependent query techniques. Part IV presents the approaches to execute view-dependent queries with an enhanced RI-tree in RDBMS. Part V addresses dimensionality reduction methods for efficient nearestneighbor queries. This thesis is finally concluded and aspects for future research are presented in Part VI.

**Reviewers:**
Prof. Dr. Thomas Seidl, Computer Science 9 (Data Management and Data Exploration)
Prof. Christian Bischof, Ph.D., Computer Science 12 (High Performance Computing)

**Date of oral exam:** 24. Juni 2008
Service Management for Nomadic Users in Converging Networks
Stephan Diepholder

The development of new, innovative services is a key factor for the success of converging high-speed networks. On the other hand, most mobile applications utilise the end-systems’ capabilities only to a limited degree, and do not really take into account user requirements. Future applications need to overcome these limitations, by personalising both network-internal services as well as applications. ‘Personalisation’ refers to the adaptation of an application or service to the individual context of a user, taking into account both static and dynamic information, such as, for instance, age, job, location, and time of day.

The thesis analyses key components of a service management for nomadic users in future converging networks. Specifically, aspects like the development of services independent of specific end-systems, personalisation of services, dynamic adaptation to user behaviour, and the provision of services close to the user’s location will be discussed. Solution will be demonstrated and evaluated.

Evaluators: Prof. Dr. Otto Spaniol, Prof. Dr. Martin Mauve (Uni Düsseldorf)

Date of oral exam: 27 January 2009
Diagnosis, Synthesis and Analysis of Probabilistic Models

Tingting Han

This dissertation considers three important aspects of model checking Markov models: diagnosis --- generating counterexamples, synthesis --- providing valid parameter values and analysis --- verifying linear real-time properties. The three aspects are relatively independent while all contribute to developing new theory and algorithms in the research field of probabilistic model checking.

We formally define a counterexample in the setting of probabilistic model checking, transform the problem of finding informative counterexamples to shortest path problems and propose corresponding algorithms. We then investigate a more compact representation of counterexamples by regular expressions and finally extend the definition and counterexample generation algorithms to various combinations of probabilistic models and logics.

Secondly, we synthesize values for parametric continuous-time Markov chains pCTMCs wrt. time-bounded reachability specifications. The rates in the pCTMC s are expressed by polynomials over reals with parameters and the main question is to find all the parameter values (forming a synthesis region) with which the specification is satisfied. A symbolic (based on a closed-from expression) and a non-symbolic approach (based on interval arithmetic) are investigated with the respective error bound, time complexity as well as some experimental results.

Finally, we focus on verifying CTMCs against linear real-time properties specified by deterministic timed automata (DTAs). The model checking problem aims at computing the probability of the set of paths in CTMC C that can be accepted by DTA A, denoted PathsC(A). We consider DTAs with reachability (finite, DTA<>) and Muller (infinite, DTA-omega) acceptance conditions, respectively. PathsC(A) can be reduced to computing the reachability probability in a piecewise deterministic Markov process (PDP), which amounts to solving a system of integral equations. For single-clock DTA<>, it can be simplified to solving a system of linear equations, while for DTA-omega specifications, the problem is reducible to the reachability problem in the DTA<> case.


Date of oral exam: 25 September 2009 (U Twente); 16 October 2009 (RWTH)
Games are a classical tool for the synthesis of controllers in reactive systems. In this setting, a game is defined by: an arena, which is a graph modelling the system and its evolution, and a winning condition, which models the specification that the controller must ensure. In each state, the outgoing transition is chosen either by the controller (Eve), a hostile environment (Adam), or a stochastic law (Random). This process is repeated for an infinite number of times, generating an infinite play whose winner depends on the winning condition.

Our first object of study is the fundamental case of reachability games. We present a new effective approach to the computation of the values, based on permutations of random states. In terms of complexity, the resulting `permutation algorithm" is orthogonal to the classical, strategy-based algorithms: it is exponential in the number of random states, but not in the number of controlled states. We also present an improvement heuristic for this algorithm, inspired by the `strategy improvement" algorithm. - We turn next to the very general class of prefix-independent games. We prove the existence of optimal strategies in these games. We also show that our permutation algorithm can be extended into a `meta-algorithm", turning any qualitative algorithm into a quantitative algorithm. - We study then the complexity of optimal strategies for Muller games, focusing on the amount of memory that can be saved through the use of randomised strategies. Using the Zielonka tree, we show tight bounds on the necessary and sufficient memory needed to define randomised optimal strategies for any given Muller condition. We also propose a polynomial algorithm for the winner problem in explicit Muller games. The results of the former chapter yield immediately NP and co-NP algorithms for the values problem. - Lastly, we consider the finitary versions of parity and Streett games, where the regular conditions are supplemented by universal bounds on delays. We propose a polynomial algorithm for the winner problem on finitary parity games. For finitary Streett games, a reduction to Request-Response games provides an EXPTIME algorithm for qualitative problems, and we show that the problem is PSPACE-hard.

Supervisors: Prof. Dr A. Muscholl, Univ. de Bordeaux, Prof. Dr. W. Thomas, Aachen University (Co-Tutelle)

Day of oral exam: 29th October 2008
Learning Communicating and Nondeterministic Automata
Carsten Kern

The results of this dissertation are two-fold. On the one hand, inductive learning techniques are extended towards learning of nondeterministic (and universal, respectively) finite-state automata. On the other hand certain learning techniques are employed to infer distributed communicating automata (so called design models) semi-automatically. For both topics, theoretical results on the feasibility of the approaches as well as an implementation are presented, which, in both cases, support our theory.

Concerning the first objective, namely to derive a so-called online learning algorithm for nondeterministic finite-state automata (NFA), we present, in analogy to Angluin's famous learning algorithm L* for deterministic finite-state automata (DFA), a version for inferring a certain subclass of NFA. The automata from this class are called residual finite-state automata (RFSA). It was shown by Denis et al. that there is an exponential gap between the size of minimal DFA and RFSA. Even if there are also cases where the canonical (i.e., minimal) RFSA is exponentially larger than a corresponding minimal NFA, we show that the new learning algorithm is a great improvement compared to L* as the inferred canonical RFSA has always at most the size of the corresponding minimal DFA. Like L*, the new algorithm (called NL*) is applicable in many fields including pattern recognition, computational linguistics and biology, speech recognition and verification. From our point of view, NL* might especially play a major role in the area of verification.

The second objective is to create a method for inferring distributed design models, i.e., some kind of communicating automata, called communicating finite-state machines (CFMs), from a given set of requirements specified as Message Sequence Charts (MSCs). The main idea is to extend the L* algorithm to cope with valid and invalid system runs and, after some iterations, come up with an intermediate design model (a DFA) which exhibits certain features that make it distributable into communicating components (or processes) interacting via FIFO channels. Theoretical results on which classes of CFMs are learnable in which time-complexity bounds are presented. We also developed a tool implementation called Smyle, realizing certain theoretical results of this part of the thesis. Based on this learning formalism we also derived a software-engineering lifecycle model called the Smyle Modeling Approach in which we embedded our learning approach.

Committee: B. Jonsson, J.-P. Katoen, L. Kobbelt, B. Rumpe, B. Voecking

Day of oral exam: 31 August 2009
Embedded software design using abstract state machines and Business Object Notation

Daniel Klünder

The ever increasing presence of information technology along with the pervasion of hardware and software into everyday life boosts the need for engineering methods and tools for the development of high quality embedded systems. This trend is further amplified by the rising complexity of such systems and their usage for safety critical tasks. However, classical software engineering methods lack support for the peculiarities of embedded systems. This thesis therefore extends these methods with support for verification and requirements that arise through interaction with the physical world.

Abstract state machines (ASMs) are used for functional modeling and extended with an abstract notion for feedback control algorithms by utilizing non-deterministic choose. For their verification this thesis presents a novel approach to model checking ASMs that directly supports them by utilizing their notion of run. The simulator CoreASM is adapted to branch into all possible successor states and integrated into the model checker [mc]square. On the one hand, this enables the approach to present counterexamples and witnesses directly as sequences of ASM states, to be easily extendable, and at the same time supports the whole CoreASM syntax. On the other hand, it suffers from the simulator’s design that was built with the goals of comprehensiveness and extendibility in mind and hence is not optimized for performance in a model checker.

The Business Object Notation (BON) is used for structural modeling and extended with the representation of concurrent classes. Requirements that arise through the execution of the embedded system on a physical platform are represented in preconditions while those that arise through reactions to the physical environment are modeled in postconditions. The former is only useful for short methods. While ASMs can easily be transformed into an implementation, timed and concurrent BON models need an extra runtime environment for a semi-automatic translation. Therefore, simple concurrent object-oriented programming (SCOOP) is implemented on a real-time operating system and extended with the runtime checking of time assertions in postconditions. Because of the unpredictability of runtimes it is only practical for soft real-time systems and improves the system’s reusability at the expense of its resource usage. For evaluating the approach an adaptive cruise control which includes two closed loop controllers, interaction with the environment via sensors and actuators, time requirements, and safety critical functions is successfully implemented.

Evaluators: Professor Dr.-Ing. Stefan Kowalewski
Professor Dr. Ursula Goltz (TU Braunschweig)

Day of oral exam: 3 February 2009
Assuming $P \neq NP$, which is widely believed to be true, many important computational problems are not solvable in polynomial time. However, this does not imply that NP-hard problems are not exactly solvable at all. Both the concepts of moderately exponential time algorithms and parameterized complexity provide tools for solving many of these problems in reasonable time. In this thesis, we introduce the concept of intuitive algorithms. While intuitive algorithms can be either moderately exponential time algorithms or parameterized algorithms, we require that they follow an intuitive idea and are kept as simple as possible.

When we analyze algorithms only in terms of a worst case runtime bound, this approach is disadvantageous, as it is sometimes much harder to prove good bounds for simpler algorithms. In some cases, this might even be impossible. However, we will show that there are several aspects of intuitive algorithms that make the development of such algorithms worthwhile.

For example, their runtime is often not as bad as assumed. Especially on small instances, intuitive algorithms often outperform more complex algorithms, because the more complex algorithms tend to unfold their full potential on large instances. However, in practice large instances cannot be solved with exponential time algorithms at all. Furthermore, we often do to not know precise lower bounds on the runtime of exact algorithms. It is thus hard to decide, whether more complex operations only ease the analysis of a complex algorithm or if such operations really improve the running time. Moreover, intuitive algorithms tend to allow for efficient implementations. This allows us to solve real life instances of surprisingly large size. In contrast to this, implementations of complex algorithms can be rather slow. Finally, intuitive algorithms are often more aesthetic than complex algorithms. Overall, simpler algorithms often tell us more about problems.

Throughout this thesis, we will outline that intuitive algorithms can also be competitive when compared to traditional algorithms. To emphasize this, we will present several examples of intuitive algorithms that are either the fastest known algorithms or have only been improved recently.

List of Results

- For Max-2SAT and Max-Cut, we present intuitive algorithms with a runtime bounded by $O^*(1.128^m)$, where $m$ denotes the number of clauses or edges, respectively.
- For the Maximum Leaf Spanning Tree problem, we introduce an intuitive algorithm with a runtime bounded by $O^*(4^k)$ that works both on undirected and directed graphs. Here, the parameter $k$ denotes the number of leaves.
- We show that Partial Vertex Cover can be solved with a deterministic intuitive algorithm in time $O^*(1.396^t)$ and with a less intuitive randomized algorithm in time $O^*(1.2993^t)$, where $t$ is the number of covered edges.
- Moreover, we present an algorithm for Partial Dominating Set with a runtime bounded by $O^*((4 + \epsilon)^t)$, which is based on the technique of Divide & Color. Here $t$ denotes the number of dominated nodes.
- Finally, we present an intuitive algorithm for Independent Set with a runtime bounded by $O^*(1.2132^{|V|})$. 

Intuitive Algorithms
Joachim Kneis
The first and the last result thereby are moderately exponential time algorithms, while our algorithms for Maximum Leaf Spanning Tree, Partial Vertex Cover, and Partial Dominating Set are parameterized algorithms. The focus in this thesis lies on proving the claimed theoretical runtime bounds for these algorithms. However, we will also present implementations for each algorithm and argue that they can be used to solve surprisingly large instances.

**Evaluators:** Prof. Dr. rer.nat. Peter Rossmanith  
Prof. Dr. rer.nat. Dieter Kratsch

**Date of oral exam:** 23 July 2009
Modeling and Realization of Consistency Maintaining Tools for Simultaneous Document Development

Anne-Thérèse Körtgen

The results of development processes are stored in documents. They contain specifications/realizations of the system going to be developed from different perspectives and on different abstraction levels. Documents may overlap in their contents, whereby when the documents are edited simultaneously the descriptions of the system can get inconsistent, i.e. contradictory.

The subject of this thesis are general concepts and tools for maintaining consistency, also called integration, whereby the focus lies on syntactical consistency between documents from different abstraction levels. The work is based on the results achieved so far of the CRC IMPROVE concerning integration tools. To demonstrate the applicability of the new introduced concepts of this work, consistency problems of development processes in chemical engineering and between flow sheets which are developed in this area are studied.

Existing approaches resolve inconsistencies by transformation; most of them, like the approach of this work, use model and graph transformations whereby fine grained relationships of overlapping structures between documents are stored. But the procedures of repairing inconsistencies are not sufficient.

Additionally, the transformation languages which are used are not expressive enough for extensive and complex documents. Modularization and operationalization concepts but also further language constructs to specify complex graph structures are needed. Furthermore, the layout of the documents and that of the graph patterns included in the transformations are not considered, but the layout is important in flow sheets from the chemical engineering domain.

The thesis provides general concepts to maintain consistency and demonstrates the realizability by a prototypical implementation applied on examples from chemical and of software engineering. Various consistency recovering transformations, called repair actions, are created dynamically at runtime regarding the inconsistent relationships of two documents and the currently existing errors. Restructurings on a document performed by the user can be recognized by the dynamic processing. The created transformations define different alternatives how changes of the user may be propagated to the respective other document (perhaps changes can be made on both documents simultaneously) to retain a consistent state. The alternatives are presented to the user who decides how the inconsistency should be resolved.

The graph transformation language which is used for these purposes is extended for modularization, i.e. graph patterns and transformation specifications can be reused in other specifications. Either they are used completely for extension or partially within the left side of a transformation rule to serve as a so called context. By this between transformations extension or context relationships are established.

The extension relationships are considered in particular for determining appropriate repair actions in cases smaller correspondence relationships to the inconsistent one are still valid and can be retained. Context relationships between transformations are used to optimize the pattern search algorithm and allow dependency analysis between executable transformations. These dependencies are beneficial to the user to decide among multiple transformation options.
Additionally, the transformation language now allows specifying operational calls of other transformations by newly introduced imperative language constructs. Furthermore, there are extensions that allow specifying set-valued, repetitive and alternative graph patterns as well as expressing similarities of graph entities. The similarity comparison is performed with the use of string matching techniques and searching a synonym database.

The specification of transformation rules is a wasteful and complex task. To support this process this work suggests two approaches, where transformation rules can be induced from existing correspondence relationships either between (i) elements on the document level or (ii) types and attributes on the document model level. These correspondence relationships are established by a foregone correspondence analysis which is also performed by the consistency maintaining tool.

The analysis find – according to a generic rule set, which defines only coarse correspondence relationships – existing concrete relationships between documents or document models, respectively. For the document level, for each pair of specific document types a rule set has to be modeled, which in particular uses intensively the new language constructs for complex graph patterns. In contrast, for the document model level there is only one rule set for all document models which in particular uses the constructs to express similarity to find similar elements. Attribute correspondences between compound types are also defined within these rules.

The results of this work improve the realization process of integration tools. In that way, an integrator now can be configured at runtime. Further easy to use tools were developed to support rule modeling and the integration process. They can be integrated easily in existing document development environments. With the help of these tools the integration together with the newly introduced repair actions are put into praxis.

**Supervisor:** Prof. Dr.-Ing. Manfred Nagl  
**External Supervisor:** Prof. Dr. Wilhelm Schäfer  
**Day of oral exam:** June 25, 2009
Efficient Density-based Methods for Knowledge Discovery in Databases
Ralph Krieger

Today's data storage facilities allow recording of billions of transactions from business applications, scientific sensor readings, monitoring systems etc. Scientists developing new drugs, system administrators monitoring complex technical processes, and decision makers being responsible for complex social or technical systems require an overview and even a deeper understanding of their respective data. The knowledge discovery in databases (KDD) process has been designed to identify hidden patterns in large data resources. A central step of the KDD process is the data mining task. Major data mining tasks are clustering and classification. Density-based approaches have proven to be very effective for many data mining methods. However, the good effectiveness often comes at the cost of a high runtime complexity. This thesis presents new efficient density-based approaches for different data mining applications whereas the effectiveness of the new developed methods is always kept in mind. The first part of this thesis is concerned with new density-based clustering methods. Clustering is a data mining task for summarizing data such that similar objects are grouped together while dissimilar ones are separated. Density-based approaches have shown to successfully mine arbitrary shaped clusters even in the presence of noise. In multi-dimensional or high dimensional data, clusters are typically hidden by irrelevant attributes and do not show across the full space. As relevance of attributes is not globally uniform for all clusters, global dimensionality reduction approaches are not adequate. Subspace clustering aims at automatically detecting clusters and their relevant attribute projections. This work presents a new clustering model DUSC which guarantees a comparable and redundancy free subspace clustering result. As the number of possible subspaces is exponential in the number of dimensions subspace clustering is a computationally challenging task. The algorithm eDUSC developed in this work is based on a filter-and-refinement architecture which avoids repeated database scans. Further on, this work proposes a new visualization technique for subspace clusters and a specialized clustering technique for multi-dimensional sequence databases. The second part of this thesis proposes new density-based methods for classification. Classification aims at assigning a class label to unknown objects. Various approaches for classifying objects have been investigated in the last decades. Classifiers based on statistical approaches have been most intensively studied in the literature and results like asymptotical behavior and classification bias have been derived. To apply statistical classifiers the density of objects has to be estimated. In this work, a hierarchy of density estimators is proposed which makes the classification of objects possible anytime. Additionally, a new classification method using subspace clusters for higher dimensionalities is developed in this thesis. The proposed density-based clustering and classification methods are evaluated in terms of both efficiency and effectiveness in thorough experiments on real world and synthetic data.

Reviewers: Prof. Dr. Thomas Seidl, Computer Science 9 (Data Management and Data Exploration)
Prof. Dr. Bart Goethals, University of Antwerp, Belgium

Multimedia traffic is becoming more and more important in the Internet. Users want to have prompt access to interactive multimedia services like video or audio streaming. Existing transport protocols like TCP and UDP/RTP are not able to deliver the required service as needed. In addition to that Internet connections strongly differ regarding available bandwidth, delay and jitter. A new transport protocol is required to cope with these problems.

Four important features of future transport protocols have been identified in the past: tunability, adaptability, compatibility and flexibility. Tunability means that a transport protocol can be adapted to the available link characteristics. Adaptability stands for the ability of adapting the requirements of the application to the service offered by the network, while compatibility represents the possibility to deploy a new transport protocol in conjunction with existing protocols. Flexibility expresses the potential to use it together with both existing and future network infrastructures.

With these requirements in mind, a new transport protocol TPTR (Transport Protocol with Tunable Reliability) has been defined. It consists of three sublayers: Application Framing (AF), Windowing, Reliability, Timing and Flow-Control (WRTF), and Congestion Control (CC).

As a general framework a third generation wireless access network can be used. In this area many related concepts, like SIP for session management, are well defined, and the standards are also applicable to other types of access networks, also. The model of an UMTS radio link has been defined by the combination of an algorithm transmitting single packets and a queuing model. This defines the underlying network.

The data to be transmitted is encoded with different multimedia codecs. Modern video codecs impose dependencies between different parts of the data stream. Some parts can be decoded independently, and others are useless when the data they depend on is not available. A common baseline video codec in today’s systems is H.263, with the newest codec extension being H.264/AVC Scalable Video Coding (SVC). The codecs define the structure of the application data.

The transport protocol has to mediate between the network characteristics and the application requirements. Each of the sublayers has specific tasks: The AF sublayer adapts data coming from the application to a format suitable for the network, and supports the assignment of priority values. The WRTF sublayer does the main task and decides which packet to send when a transmission is possible; basis of the decision are both importance (priority) and urgency (timestamp) of the data. Last but not least the CC sublayer is responsible for link estimation; i.e. it determines when the next packet can be sent.

In the thesis concepts were both newly developed, like the decidability mechanisms, and reused, like the packet structure of RTP. For the AF the concept of decodability has been invented. It makes use of structural information of a video stream to determine the priority of its different parts. Its key characteristic is the fact that it does not rely on the availability of the original video stream before encoding because this may not be available. The done performance evaluation shows that the new concept performs similar to existing approaches which need such information. Furthermore, the concept mathematically supports existing heuristics.
The main work has been done at the WRTF sublayer. The simplest way to transmit real-time data is doing so in presentation order according to timestamps (EDF – Earliest Deadline First). Given that the data has different importance it may be transmitted out of order according to this information (while considering to keep enough space in the receiver buffer to send less important data later). This is called Priority Based Scheduling (PBS). This improves the transmission probability for important packets when the link bandwidth is not sufficient but may result in situations where less important packets are not transmitted timely.

These two basic concepts have been combined and generalised to a new scheduling algorithm GPBS/TR (Generalised PBS with Tunable Reliability) which is able to switch between these two operating modes depending on a function relating the priority to the timestamp. To explain the concept an intermediate step has to be made: PBS/TR is a scheduling algorithm for an integer number of priority classes. For each priority class a tuning parameter defines for how far in the future relative to the actual playout time PBS is used. This tuning parameter can be interpreted in two ways: On one hand, it defines how long data of a certain priority class can be played out during a link loss; on the other hand, the tuning parameter divided by the round trip time can be interpreted as the desired number of retransmissions which should be possible for that data. Based on these considerations, different network scenarios like optimal links, insufficient bandwidth, and packet or link loss can be considered either analytically or by simulations. Due to the fact that both EDF and PBS are special cases of the PBS/TR algorithm, the later performs at least as good as the former ones. However, even with a fixed set of configuration parameters which is not optimised for a certain link scenario, the PBS/TR algorithm diminishes the weaknesses of EDF or PBS, and performs well.

GPBS/TR removes the restriction to a fixed number of priority classes. The set of tuning parameters used to map a priority value to a time threshold is replaced by a function. This allows supporting floating point priority values, and this approach has been evaluated by simulations in conjunction with the scalable H.264/AVC SVC video codec. Different aspects like the dependence on the available bandwidth or the initial buffering delay have been also considered.

A method for scalability when there is no scalability support from the video codec is stream switching. A predictive algorithm extrapolating the receiver buffer fill in the future is able to reduce the number of necessary switches and to improve the perceived video quality.

Regarding the CC sublayer, no optimal solution can be given but research has highlighted the fact that this sublayer has to be kept modular, and that the algorithms should be exchangeable for proper support of different network infrastructures. One algorithm for UMTS networks called RF-TRC (RTCP-Feedback based Transmission Rate Control) has been extended to support out of order transmission. Its performance has been analysed, and the dependence on the network buffer configuration has been shown.

The proposed algorithms, concepts, and methods can be used in two ways: They can either be deployed together as a new transport protocol or be taken separately and interpreted as a toolbox for the short-term improvement of existing applications.

**Reviewers:** Prof. Dr. Otto Spaniol (RWTH Aachen University)  
Prof. Dr. Vladimir Getov (University of Westminster, UK)

**Date of oral exam:** 27 October 2009
Graph-based Reengineering of Telecommunication Systems

Christof Mosler

Up to 80 percent of resources allocated in the lifecycle of a software system fall upon maintenance and reengineering activities. This thesis concerns the reengineering of telecommunication systems. The E-CARES research project (Ericsson Communication ARchitecture for Embedded Systems) is a cooperation between Department of Computer Science 3 (Software Engineering), RWTH Aachen University, and Ericsson Eurolab Deutschland GmbH (EED) in Aachen. The aim is to provide concepts, languages, methods, and tools to improve the architecture and the real-time performance of software systems in the telecommunications domain. The current system under study is Ericsson’s AXE10, a mobile-service switching center (MSC) for the GSM network written in programming language PLEX. Such embedded systems are distributed and time-critical, which poses additional requirements on the reengineering process.

In the first phase of the ECARES project mainly the reverse engineering of telecommunication systems was regarded. In this thesis the original graph-based reverse engineering approach is extended to a complete reengineering solution. Thus not only the understanding of the existing system is in scope, but also system modifications and improvements are supported. The reengineering approach is performed on two abstraction levels. First, on the source code level the reverse and forward engineering steps are performed. Whereas during the reverse engineering the existing software is parsed, the corresponding structure graph generated and analyzed, in the forward engineering phase the new source code is generated. Second, between these two phases, during the redesign, the system architecture is modified in the structure graph. Hereby the processing of the source code in done mostly automatically by tools, and the actual redesign of the structure graph is interactively controlled by the engineer.

Evaluator: Prof. Dr.-Ing. Manfred Nagl
External Evaluator: Prof. Dr. Uwe Assmann
Date of oral exam: April 17, 2009
Zero Configuration Service Management for Dynamic Networks

Stefan Penz

Future mobile network systems will exhibit considerably higher topological dynamics than current wireless access networks. Mobile devices will connect directly among each other and form so-called mobile ad-hoc networks. These networks do not require any fixed infrastructure and can be established without configuration by the users. The properties of mobile ad-hoc-networks differ significantly from those of conventional wireless networks. In order to allow communication over a large distance, the network devices have to forward data packets of other users. This leads to a perceptible decrease of transmission quality. Furthermore, the network topology changes frequently. Due to the spontaneous nature of ad-hoc networks, users must be able to identify suitable providers for required network services without any configuration. This thesis describes a service discovery system that is tailored to the special requirements of mobile ad-hoc networks. This system is based on the Service Location Protocol which combines the necessary robustness of a distributed discovery mechanism with the traffic efficiency of a centralized service directory.

The long-term availability of a service provider cannot be guaranteed in mobile ad-hoc networks. Therefore, the service discovery system should support seamless handovers between different service providers. This requires the user to constantly stay informed about available service providers. To this end, the thesis proposes a service information system that manages and provides dynamic service provider information. The core of this system is a background process that serves as a central service information point for all user applications of the corresponding device. This process caches requested service information and refreshes it periodically. With this information, user applications are able to prepare for a service handover to an alternative service provider already during service usage.

The transmission quality plays an important role for service provider selection in mobile ad-hoc networks. Therefore, the service discovery system has been extended by a modular concept which allows the integration of different service information sources. Connection stability, i.e. the long-term availability of a communication path between a user and a service provider, is one of the most important transmission quality parameters. The thesis proposes a so-called Bridging Nodes Heuristic which evaluates the expected lifetime of a connection. On one hand, this heuristic is based on the observation that the connection stability decreases with increasing topological distance between the endpoints. On the other hand, the heuristic takes the number of devices into account that are able to bridge a broken connection. Both factors are aggregated to a single quality parameter that can be used to compare different service providers. Simulation experiments have shown that a provider selection based on the Bridging Nodes Heuristic leads to a significant increase of connection stability. By integrating the assessment procedure into the Dynamic Source Routing protocol very high traffic efficiency has been achieved.

Another important quality parameter is the transmission bandwidth that is available for a given communication path. Similar to the assessment of the connection stability, the thesis proposes a measurement system that computes a parameter for the available bandwidth from intermediary device information, i.e. the local utilization of the communication channel. Especially in mobile ad-hoc networks, the available bandwidth is subject to major fluctuations. Therefore, thorough simulation experiments were analyzed to create a statistical estimation method for future bandwidth availability. This method estimates the probability that a given minimum bandwidth will be available during an upcoming time interval. The corresponding assessment procedure is designed to minimize the necessary traffic effort.
Both assessment systems for connections stability as well as for available bandwidth were implemented as information sources for the service discovery system. This integration allows the user to request and retrieve all relevant service information via a single comfortable software interface. The refreshment procedure of the information system keeps the user informed about changes in transmission quality so that a service handover can already be initiated when the transmission quality decreases significantly. All in all, the service discovery system proposed in this thesis proves to be a comprehensive and flexible platform for the efficient retrieval and management of relevant service information in mobile ad-hoc networks.

**Evaluators:** Prof. Dr. Otto Spaniol, Prof. Dr. Christian Becker, University of Mannheim

**Day of oral exam:** 12. February 2009
Holistic confidentiality in open networks

Lexi Pimenidis

The aim of this work is to act as a foundational work for providing data protection in open environments. To this end, we give an overview of important parts and aspects of this research area. We display the research area in a bigger context and from a practical point of view. This position allows to see the big picture of current advancements and issues in the area of our topic. We also give an extensive discussion on the entities related to the use and deployment of anonymous communication systems and those affected by these networks. To this end, we show characteristics of each entities situation and examine their needs. This does not only refer to requirements directly connected to security but also those which influence security in a more indirect way. We include studies about the users of anonymization networks. The findings are summarized in an analysis for multilateral security. A novel attacker model for anonymous communication systems is developed. The motivation for this is to overcome the limitations and ambiguities in the existing theoretical works. After we have described the properties which should be fulfilled by a classification, we continue with a list of properties inherent to attackers. Furthermore, we describe their motivations and finally provide a taxonomy which fills the gap between theoretical attacker models and real networks.

Evaluators: Prof. Dr. Otto Spaniol, Prof. Dr. Dogan Kesdogan (Uni Siegen)

Date of oral exam: 10 February 2009
We present an abstraction and verification framework for pointer programs operating on unbounded heaps. To this end, we introduce an abstraction method for pointer-manipulating programs employing context-free hyperedge replacement graph grammars to model the data structures and compute the abstraction mappings.

By means of partial concretization steps we avoid the necessity for explicitly defining the effect of pointer-manipulating operations on abstracted parts of the heap: it is obtained “for free” by combining partial concretization, the concrete pointer operation, and re-abstraction of the transformed state.

Besides the possibility to check for pointer safety, assuring the absence of null dereferences, and shape safety, the preservation of the data structure, we establish an expressive pointer logic that is based on LTL. It allows to specify safety as well as liveness properties for the executions of the system. We show that the corresponding model checking problem can be reduced to an LTL model checking problem enabling the application of existing, highly optimized model checkers.

Committee: J.-P. Katoen, B. Koenig, T. Seidl, B. Voecking

External Evaluator: Prof. Dr. Jean-Éric Pin

Date of oral exam: 23 September 2009
Global Gene Expression Profile Mining in Stem Cells and Their Progeny
David Ruau

Today’s biology relies heavily on technological advances made during the last 30 years. At the same time, the way of analyzing a biological question changed and nowadays we aim at understanding globally the system under study. DNA microarray technology allows events to be measured at a genome wide scale leveraging the need for an educated guess approach. Global gene expression profiling is the most frequent application of DNA microarrays and is used to study different cell types in diverse experimental setup. In this work, I have (1) subjected DNA microarray data to different mining approaches for the identification of gene signatures in stem cell differentiation and reprogramming, and (2) developed a workflow for semantic annotation of microarray data from public repositories. Dendritic cells (DC) were treated with TGF-β and subjected to global gene expression profiling. DC are derived from hematopoietic stem cells. They initiate immunity and induce antigen-specific tolerance making these cells major candidates for cell-based therapies. Our study revealed key regulatory factors in the answer of DC to TGF-β1. Chromatin structure determines gene expression and thereby cell identity and cell fates. Thus, specific drugs that alter DNA methylation and histone acetylation modify the chromatin structure and were found to broaden the developmental potential of neural stem cells. Microarray analysis revealed the induction of pluripotency and pluripotency associated genes by drug treatment and this is suggested to account for the altered potential of these cells. Pluripotent stem cells, including embryonic stem cells (ESC), are able to generate all cell types present in the adult body, however the isolation and cultivation of such cells raised some ethical and technical concern. For this reason alternative methods have been developed to generate ES-like cells from somatic cells or adult stem cells. The medical and research applications of such cells are extremely promising. Gene expression profiling of induced pluripotent stem (iPS) cells, either generated using two or four reprogramming transcription factors (Oct4 and Klf4 or Oct4, Klf4, Sox2 and c-Myc), revealed a genomic signature similar to ESC. The gene array technology underlying such studies generates an enormous amount of data that is usually stored in database made available to the community. However the descriptions available for the experiments are made in free text. Thus, retrieving and associating microarray experiments is subjected to a comprehensible labeling from the submitter. Linking different sources of data requires description made in a vocabulary on which everybody agrees such as biomedical ontologies. Ontology organizes knowledge of a particular domain in a define network of relationships. In this work I developed a workflow for semantic annotation of microarray public repositories. Gene Expression Omnibus (GEO), the biggest public repository of microarray data, was subjected to the workflow and annotated using different ontologies. The method relies on text mining, outlier detection and an algorithm for label propagation of labeled objects to unlabeled objects, in order to increase the labeling coverage. The algorithm adapts the label propagation to the specificity of the biological sample type measured. Integrative bioinformatics studies that merge different data types to discover new relationships between diseases, phenotypes and gene expression profiles will benefit from standardized annotation of the experiments.
Reviewers: Prof. Dr. Martin Zenke, Chair for Cell Biology, RWTH Aachen University, Prof. Dr. Thomas Seidl, Computer Science 9

Date of oral exam: 25 May, 2009
Abstract: Embedded systems based on different types of hardware platforms are nowadays increasingly used in safety-critical applications. These different hardware platforms lead to fundamental differences in design, particularly regarding the corresponding software.

In this work, potential influences of hardware platforms on safety properties were gathered and open issues were identified. The most relevant of these open issues were evaluated for popular embedded hardware platforms (microcontroller, CPLD/FPGA). In detail, the impacts of hardware platform selection on software diversity, encapsulation, reviewability, reusability and the development according to ISO26262 were chosen for investigation. Furthermore, the approach of software diversity was compared with a fault removal approach. The evaluation was realized in form of six experiments conducted for this work. During these evaluations, the following similarities and differences were observed for the considered hardware platforms.

Despite the diversity between the hardware platforms, failures observed in the software versions, which were developed for these different platforms, contained high numbers of dependent (coincident) failures. Although failure dependency between two versions was reduced by the use of diverse hardware platforms, this effect was low. Most dependent failures were identified as implementation independent so that improvements of the software diversity by hardware diversity were limited. Thus, a comparison of software fault tolerance with a fault removal approach based on tests and reviews was conducted. As a result, different types of failures were mitigated by these alternative approaches. On the other hand, differences between microcontrollers and FPGAs were observed. First, certain advantages of FPGAs with respect to encapsulation and reuse of real-time functions could be demonstrated. Moreover, differences regarding the reviewability of software versions written for FPGAs and microcontrollers were observed. Finally, the development according to ISO26262 revealed only minor differences between the investigated hardware platforms but between the different safety concepts of device supervision and function supervision.

Evaluators: Prof. Dr.-Ing. Stefan Kowalewski  
Prof. Dr.-Ing. Klaus Müller-Glaser (Karlsruhe Institute of Technology)

Day of oral exam: 8 October 2008
The most fundamental decision problem in computer science is the halting problem, i.e., given a description of a program and an input, decide whether the program terminates after finitely many steps or runs forever on that input. While Turing showed this problem to be undecidable in general, developing static analysis techniques that can automatically prove termination for many pairs of programs and inputs is of great practical interest.

This is true in particular for logic programming, as the inherent lack of direction in the computation virtually guarantees that any non-trivial program terminates only for certain classes of inputs. Thus, termination of logic programs is widely studied and significant advances have been made during the last decades. Nowadays, there are fully-automated tools that try to prove termination of a given logic program w.r.t. a given class of inputs. Nevertheless, there still remain many logic programs that cannot be handled by any current termination technique for logic programs that is amenable to automation.

Another area where termination has been studied even more intensively is term rewriting. This basic computation principle underlies the evaluation mechanism of many programming languages. Significant advances towards powerful automatable termination techniques during the last decade have yielded a plethora of powerful tools for proving termination automatically.

In this thesis, we show that techniques developed for proving termination of term rewriting can successfully be applied to analyze logic programs. The new techniques developed significantly extend the applicability and the power of automated termination analysis for logic programs. The work presented here ranges from adapting techniques to work directly on logic programs to transformations from logic programs to a specialized version of term rewriting. On the logic programming side we also present a new pre-processing approach to handle logic programs with cuts. On the term rewriting side we show how to search for certain popular classes of well-founded orders on terms more efficiently by encoding the search into satisfiability problems of propositional logic.

The contributions developed in this thesis are implemented in tools for automated termination analysis - mostly in our fully automated termination prover AProVE. The significance of our results is demonstrated by the fact that AProVE has reached the highest score both for term rewriting and logic programming at the annual international Termination Competitions in all year since 2004, where the leading automated tools try to analyze termination of programs from different areas of computer science.

Evaluators: Prof. Dr. Jürgen Giesl; Prof. Dr. Michael Codish

Date of oral Exam: December 8, 2008
Empirical Studies for the Application of Agile Methods to Embedded Systems
Dirk Wilking

Agile Methods are a collection of software engineering techniques with specific differences to traditional software engineering processes. The main differences consist of rapid, cycle based development phases setting the focus of attention on feedback of the source code being developed. The results taken from user feedback, software reviews, or other forms of software evaluation are used as a basis for changes which comprise for example corrections of the user interface or the adaption of the software architecture. Based on single techniques taken from Agile Methods, their application to embedded systems software engineering is empirically evaluated in this thesis.

The experiments and studies which have been conducted comprise the techniques of refactoring, short releases, and test driven development. The results hint to inconclusive effects. For example it could be shown that a constant effort for functional work is achieved by using the short releases technique, but its impact on the resulting software remains difficult to assess. For refactoring a reduced consumption of memory was found, but this effect was created by an overhead for applying the refactoring technique itself. The effect of agile techniques appears to be inferior to individual software development ability of participants in terms of factor strength. Consequently, the second part of the thesis aims at creating variables for the purpose of experiment control. Variables comprise C language knowledge and viscosity measuring a participant's level of reluctance to change a fragment of source code.

An additional experiment consists of the replication of the N-version programming experiment by Knight and Leveson. The original experiment of independence between two program failures has been extended by an additional factor of hardware diversity. By using different hardware platforms, it has been expected to create mutual independent failures which is not approved by experimental observations.

Evaluators: Prof. Dr.-Ing. Stefan Kowalewski
Prof. Dr.-Ing. Ulrik Schroeder

Day of oral exam: 13 November 2008
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  Dipl.-Inform. Willi Geffers

- Technical Staff
  Marion Brandt-Röhrig, M.A.
  Viktor Keil
  Stefanie Scholten
  Karl-Heinz Thevis

- Trainees
  Janina Jansen
  Christian Königs

- Student Workers
  René Birekoven
  Sebastian Kaufmann
  Damian Lukowski
  Behnam Nikzad
  Ahmad Obeid
  Wolfgang Refisch
  Ilhan Ucar
Overview

Since 1985 the System Administration Group (Rechnerbetrieb Informatik, RBI) operates several computer labs and provides technical support for the Department of Computer Science at RWTH Aachen University. The principal task of the RBI is to install, maintain, and evolve the local network and several central services, including file servers, a database server, mail server, and web server. Students, faculty, and staff have free unlimited access to the computer labs operated by the RBI.

The computer labs are used in computer science courses and for student and faculty research projects. Especially for novice users a user helpdesk is offered during business hours. The labs are provided with PCs running the Debian GNU/Linux operating system. The computers are equipped with various hardware extensions and software to support the students in doing their exercises and projects. All computers are part of the local area network and provide unrestricted access to the campus backbone and the internet.

Equipment

Computer Laboratories

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 mail server provides email service for the students and cluster users.
- Furthermore the RBI provides the primary web server of the department.
- A database server contains the database of the computer science library and handles all inquiries.

Local Area Network

Since 1986 the Department of Computer Science runs a computer network according to the IEEE 802.3 standard. 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. fileservers and database servers, we use gigabit ethernet either over twisted pair or over optical fiber. New chairs realize their local network completely based on optical fiber.

A wireless LAN has been installed in all public areas of the department and most chairs and research areas. Currently the wireless LAN is based on the IEEE 802.11 b/g standard and operates at a maximum speed of 54 Mbit/s.

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:

during terms:  
mon: 9 am - 7 pm  
tue - thu: 9 am - 9 pm  
fri: 9 am - 6 pm

else:  
mon - thu: 9 am - 7 pm  
fri: 9 am - 5 pm

For detailed information and current changes please note the announcements on the billboards or check http://www-rbi.informatik.rwth-aachen.de for a listing of all RBI labs’ hours of operation, including exceptions due to holidays and breaks.

Computer Science Library

The RBI maintains the entire hard- and software of the computer science library. This includes the workstations and PCs of the library staff and library users as well as the database server. The database contains the entire stock of books and journals of the library. The RBI develops and supports dedicated software for cataloging and querying the database.
Computer Science Library
RWTH Aachen

Staff

- **Head:**
  Dipl.-Bibl. Renate Eschenbach-Thomas

- **Team:**
  Mehrnaz Alirezaie (since 01.01.09)
  Jonas Becker (until 30.04.09)
  Nadine Behnke (until 31.07.09)
  Florentine Gruhn
  Rainer Hallmann (volunteer gardener until April 2009)
  Ingo Hengstebeck (until 30.06.09)
  Richard Hoffmann
  Alexander Mertens (until 31.12.08)
  Tatjana Repenko (since 01.08.09)
  Nina Scharenberg
  René Scherer (since 01.07.09)
  Dilmin Ürek (since 01.04.09)
  Martina Witt (until 31.07.09)
  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 34700 monographs and conference proceedings recorded in an online public access catalogue (OPAC)
- “Handapparate”: Required readings for the courses, compiled by professors for their students, accessible on special shelves
- All diploma theses of our department recorded in a separate database
- Complete stock of the Springer “Lecture Notes in Computer Science” up to Volume 3000 as well as “Informatik-Fachberichte / Informatik Aktuell” 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 C’t, PC Magazin, free X, Der Spiegel, Die ZEIT, . . .
- Annual reports from domestic and foreign universities
- Service for department staff: Books and articles not available on site are procured from the central university library or from international library supplies

Literature search training in online databases and catalogues for computer science students in connection with their proseminars and seminars; individually prepared exercises for each participant and his/her topic

- Website containing plenty of information on our stock and interesting computer science links
- 3 internet workstations and 60 comfortable work places; separate student group work spaces
- 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

- Again from student fees we were able to extend our stock of text books for the standard courses of computer science, called "Handapparate".
• As a continuous trend over the past years, we observe that the number of students, visiting the library for reading and studying, increases. Often all 60 seats are occupied. Very popular is also the possibility to stay until 10 p.m. in one special room.

• With the gardening of our popular Open-Air Reading Room (“Lesegarten”) we fortunately are supported by a volunteer gardener.

• In July 2009 our new website went live. It provides a more transparent overview of the services of the library: Visit

  http://www-bib.informatik.rwth-aachen.de
Staff
Fachschaft Mathematik, Physik, Informatik
Kármánstraße 7, 3rd level (postal address: Fachschaft I/1, Templergraben 55, 52056 Aachen)
e-mail: fs@fsmpi.rwth-aachen.de
WWW: http://www.fsmpi.rwth-aachen.de/
Tel. 0241 80-94506

Opening hours during lecture period: Mon-Fri 12-14 h
during lecture free period: Tue & Thu 12-14 h

Meetings of the Fachschaft: Mon 19 h in the rooms of the Fachschaft
Plenary meetings: at the beginning of each semester

People who volunteered at the Fachschaft during the last year:

- Adam Stephanides
- André Goliath
- Andrea Hutter
- Andreas Ganser
- Angélina-Géraldine Bieler
- Anna Nelles
- Beatrix Blank
- Bettina Schmiedt
- Brigitte Boden
- Christian Fuchs
- Christoph Rackwitz
- Daniel Schmitz
- David Altmann
- Dominic Jabs
- Dominik Masur
- Felix Reidl
- Fernando Sanchez Villaamil
- Florian Lütkecosmann
- Florian Schandinat
- Hedwig Lipp
- Hendrik vom Lehn
- Hossein Shafagh
- Ines Färber
- Ingmar Gebhardt
- Ingolf Segger
- Jacob Schmiedt
- Jan Bußmann
- Janine Repke
- Jens Forster
- Jolande Fooken
- Julian Meichsner
- Laura Neisius
- Lukas Middendorf
- Manuel Rispler
- Marcel Straub
- Mareike Ahl
- Martin Henze
- Martin Weusten
Overview

The Fachschaft (group of student representatives) represents the interests of all students of mathematics, physics and computer science at RWTH Aachen University.

At the beginning of each semester a plenary meeting is held where every student of mathematics, physics or computer science is invited. This is where the major topics concerning the upcoming semester and the work of the Fachschaft in general are discussed. Furthermore the students responsible for the accomplishment of the aspired goals and tasks are elected there.

We have weekly meetings where current concerns are discussed and work is coordinated. Any student of mathematics, physics or computer science is welcome to participate, to express his or her opinion and to take part in all decisions.

Service

The Fachschaft has regular opening hours to offer support to students by students concerning their course of study but also on issues not directly related to university topics. We have a collection of former exercises and transcripts of exams to be copied in our rooms.

Since January 2008 we offer these services once a week in a room in the Computer Science building as well.

Work in committees

Most of the work done by the Fachschaft is not that obvious. We represent the students in a lot of committees, especially Fakultätsrat (faculty board), Fachkommissionen, Prüfungsausschüsse (examination boards) and Berufungskommissionen (search committees). Additionally we attend all committees deciding on how to spend the tuition fees.

We are not only looking out for students' interests, but also aim to cooperate with professors and staff.

Students' garden

Since this summer, the students' garden at the Computer Science building has been opened again. When the weather is fine, students can sit outside enjoying their breaks. Active members of the Fachschaft voluntarily have an eye on the garden.

Introduction of new students

To introduce the new students to their new environment, the ErstsemesterInnen-AG, a working group of the Fachschaft, arranges tutoring groups. These groups consist of several beginners and two advanced students as their tutors, who invite the freshmen to get to know each other.

Furthermore, a weekend at a youth hostel and a welcome party are organized. Every year the ErstsemesterInnen-AG publishes a magazine containing information for people planning to study mathematics, physics or computer science at RWTH Aachen University.

The goals of these activities are:

• Building social contact after leaving behind the former environment.
• Helping to cope with the first steps at university (learning on one’s own responsibility and in a team).
• Support in managing their studies.
• Basic approaches to reflect on their study situation.
• Information/Discussion on opportunities to take influence in the university (academic self-management).

Working groups

There is a number of working groups dealing with special tasks apart from the main topics.

**ErstsemesterInnen-AG:** Supports the beginners. See above.

**Interdisziplinäres Diskussionsforum:** The IDF (interdisciplinary discussion forum) organizes discussion events on topics beyond the area of mathematics, physics and computer science; e.g. the last event on privacy and online identity. Lexi Pimenidis (Chair for Computer Science 4) and Ralf Bendrath (TU Delft) were invited as speakers.

**Geier:** The Geier (engl. *vulture*) is a leaflet with newsworthy information and references to events. The Geier is published every two weeks.

**Video-AG:** The "Video-AG" working group records lectures and other events to make them available online. As of now, they have been recording:
  • Algebra" (linear algebra), Dr. Hanke, SS 2008
  • mathematics refresher course, SS 2008
  • "Berechenbarkeit und Komplexität" (analysis of computability and complexity), Prof. Vöcking, WS 2007/08
  • parts of "Diskrete Strukturen" (discrete math), Prof. Hiß, WS 2007/08
  • events of the Interdisciplinary Discussion Forum (IDF) of the Fachschaft I/1

The Video-AG is still looking for sponsors to make additional video cameras and other supporting equipment available to them, allowing them to record more lectures in higher quality.
Co-operations
Cluster of Excellence
“Ultra High-Speed Mobile Information and Communication” (UMIC)

Overview

“Ultra High-Speed Mobile Information and Communication (UMIC)” is the only cluster of excellence in the areas of Electrical Engineering and Computer Science approved under the excellence initiative of the German Federal and State government.

The focus of UMIC research is on mobile information and communication systems of the next decade. The service quality as perceived by the users must be at least an order of magnitude over that of today’s systems with lower cost. This goal can only be achieved by joint interdisciplinary research, taking all aspects into account from mobile applications to ultra-highly integrated implementation. Key pillars of the cluster research include

• Mobile Application and Services,
• Wireless Transport Platform,
• RF Subsystems and SoC (System on a Chip) Design.

The close interdisciplinary cooperation of the participating teams is essential for the success of the cluster (see figure below).

Research targets of “Wireless Transport Platform” are smart, mobile, broadband and low-cost systems, which provide adaptive configuration and seamless connectivity, balancing between conflicting targets like data-rate, radio range and power consumption by continuous joint optimization.
Matching requirements and features of applications and services on the one hand and of the wireless transport platform on the other hand is a key approach of the research area “Mobile Applications and Services”.

Design methodology and implementation are addressed by “RF Subsystems and SoC Design”. Major challenges to be addressed are the nanometre-CMOS integration of flexible radio frequency subsystems required for cognitive terminals and “Multi-Processor-System-on-Chip” (MPSoC) platforms, designed for maximum performance and energy efficiency, taking into account the features and issues of future silicon technology generations.

Research topics like performance and reliability of complex systems, privacy and security, energy efficiency, and software architecture affecting all pillars of the UMIC research are grouped within the research “Interdisciplinary Methods and Tools”.

Nucleus of the cluster research is the UMIC centre, hosting the interdisciplinary research teams headed by Junior Professors and UMIC Distinguished Researchers, the prototyping labs and a demonstrator space. More than 20 chairs and institutes from the Electrical Engineering and Information Technology Faculty and the Computer Science Department of RWTH Aachen are active members of the UMIC research cluster.

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

UMIC Day 2009

This year, the number of participants exceeded all expectations. Quite a few less lucky ones did not get a seat and had to watch the keynote presentation from the outside …… Henning Schulzrinne, Professor at the Columbia University, New York, talked about ‘Internet 2.0 – Hype or Hope’.
Joram Seewi presented a slightly less scientific equivalent to the keynote. He managed to astonish even the experts by visualising complex issues in mobile communication through juggling ....

The performance was followed by a relaxed champagne buffet.
Aachen Institute for Advanced Study in Computational Engineering Science (AICES)

AICES is a new doctoral program established in November 2006 under the auspices of the Excellence Initiative of the German state and federal governments in the funding line graduate schools. The program sets out to advance the computational engineering in three critical areas of synthesis: model identification and discovery supported by model-based experimentation, understanding scale interaction and scale integration, and optimal design and operation of engineered systems.

Since 2002, RWTH Aachen University has been establishing educational structures to meet the future research challenges in computational engineering science (CES). In 2004, the Center for CES has been established. Bachelor and Master programs in CES are now operating, and were joined by the AICES doctoral program in the summer semester of 2007.

AICES is spearheaded by 15 RWTH institutes from four departments including Computer Science and enjoys participation from Forschungszentrum Jülich and the Max Planck Institute for Iron Research in Düsseldorf. Today, approximately 18 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, 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. In 2009, two tuning workshops with hands-on sessions were organized in Jülich and Bremen, respectively. Another workshop in Munich/Garching is planned for early 2010.

More information

www.vi-hps.org

Contact

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The German Research School for Simulation Sciences is a joint venture of Forschungszentrum Jülich and RWTH Aachen University, combining the resources of the two institutions in a unique way. Distributed across two sites, one in Aachen and one in Jülich, the school is dedicated to research and education in the applications and methods of HPC-based computer simulation in science and engineering. It provides a Master’s and a doctoral program for outstanding graduate students and is aiming at training the next generation of computational scientists and engineers. Coursework and research opportunities are offered in topic areas ranging from state-of-the-art methods to the most advanced applications of computer simulation in the disciplines science and engineering. Substantial funding is provided by Bundesministerium für Bildung und Forschung (BMBF), by Ministerium für Innovation, Wissenschaft, Forschung und Technologie (MIWFT) des Landes Nordrhein-Westfalen and by Helmholtz Gemeinschaft Deutscher Forschungszentren.

In 2009, the school established four research groups (so-called laboratories) in the following fields:

- Applied Supercomputing in Engineering
- Computational Biophysics
- Computational Materials Science
- Parallel Programming

The Laboratory for Parallel Programming led by Prof. Wolf is affiliated with the Computer Science Department and specializes in performance-analysis methods for parallel programs. It offers courses related to parallel programming and simulation software engineering.

**More information**

[www.grs-sim.de](http://www.grs-sim.de)

**Contact**

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Germany  
e-mail: f.wolf@grs-sim.de
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 and
GRK 1298 “AlgoSyn”, speaker Prof. Thomas.

Helen Bolke-Hermanns links the two GRKs together: she is responsible for management and coordination.

The Graduiertenkolleg “AlgoSyn” is a highly interdisciplinary research project led by a group of ten professors representing five different faculties in our university. The aim is to develop methods for the automated design of software and hardware, and its main challenge is to make progress in integrating quite diverse approaches from computer science and engineering disciplines.

While methods of software validation and verification are by now well established, based on adequate formal models and tested in practical applications, the approach of automatic synthesis of software (and hardware) is as yet only developed in quite rudimentary form. On the other hand, in theoretical computer science as well as in engineering disciplines a rapidly increasing stock of techniques for the development of algorithmic synthesis is emerging, triggered by the demand to decrease development costs by invoking algorithmic procedures based on adequate formal models. The approach of program synthesis is only applicable in restricted scenarios, in particular in control systems and in reactive (multi-agent-)systems with low data complexity. Central issues in the area are the establishment of system models which allow an algorithmic solution of the synthesis problem, the combination of discrete and continuous parameters in hybrid systems (as this is also familiar from verification), and the exploration of the potential of applications. The aim of the Research Training Group is to unify the expertise from computer science, mathematics, and four engineering disciplines and to push forward the desired integration of methods.

There is a unit working on foundations comprising two branches, a central unit supplying methodological interfaces for implementations, and a range of application areas from four engineering disciplines. In a little more detail, the areas are:
• Algorithmic for agent-based, probabilistic, and hybrid systems
• Formal methods of reactive systems and game-theoretic methods
• Software development and modeling languages and
• Applications and demonstrators, in the fields of processor architectures, automatic control, process control engineering and train traffic systems.

The actual research activities always touch more than one of these subject areas, and a central objective is to intensify the interaction, by tuning models towards applications, and by making practical case studies accessible to a treatment in the existing formal and algorithmic frameworks.

For a full version of the proposal (in German language) please see:
http://www.algosyn.rwth-aachen.de/

AlgoSyn has 15 positions for PhD students and one additional postdoc position. There are also collegiates and research students who are attached to the Research Training Group. You can find the complete list of people involved on the website www.algosyn.rwth-aachen.de.

All positions have been taken by highly qualified students. The current (November 2009) grant holders include:
• Dipl.-Inform. Kai Dominik Bollue, Institute of Automatic Control, Prof. Dr. Abel
• 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.-Ing. Sebastian Klabes, Institute of Transport Science, Prof. Dr. Wendler
• Dipl.-Inform. Ulrich Loup, Hybrid Systems Group, Prof. Dr. Abraham
• Alexandru Mereacre, M.Sc., Chair Informatik 2, Prof. Dr. Katoen
• 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. Melanie Winkler, Chair Informatik 1, Prof. Dr. Vöcking
• Seven students left the ‘Graduiertenkolleg’ during the reporting period as scholarship holders. By now, they have successfully completed their theses, or are near completion.
• Dr. Lukasz Kaiser, Group Mathematical Foundations of Computer Science, Prof. Dr. Grädel
• Dipl.-Inform. Michael Ummels, Group Mathematical Foundations of Computer Science, Prof. Dr. Grädel
• Dipl.-Math. Lars Olbrich, Chair Informatik 1, Prof. Dr. Vöcking
• M. Sc. Gustavo Quirós Araya, Chair of Process Control Engineering, Prof. Dr. Epple
• M. Sc. Weihua Sheng, Chair for Software for Systems on Silicon, Prof. Dr. Leupers
• Dipl.-Inform. Stephan Swiderski, Chair Informatik 2, Prof. Dr. Katoen
Two Postdocs Martin Hoefer and Angelo Fanelli enriched the “Graduiertenkolleg” with their research work.

Graduiertenkolleg
‘Software for Mobile Communication Systems’

The ideas of Graduiertenkolleg “Software for mobile Communication Systems” are as follows:

New ways of exchanging data through different types of networks are continuously evolving. This includes particularly mobile communication, which has by now become more or less ubiquitous, thanks to an ever increasing level of user acceptance. This, in turn, is largely due to improved standards and a vastly expanded variety of services. Future application developments will more and more be based on user requirements rather than just feasibility. Here, the most important domains include electronic commerce, transport telematics, new forms of working, and other innovative concepts such as e-learning, e-government, and e-home. For these new applications to be acceptable, new underlying technologies and services are a sine-qua-non. Moreover, the increasing mobility of users will lead to an equally increasing role wireless networks will play in communication infrastructures. Yet, users expect application functionalities to be independent from the underlying communication network. Considerable additional research will be needed to actually meet this requirement. Within the framework of the Graduate School research will focus on three areas: ‘Applications’, ‘Middleware and New Services’ and ‘Network Infrastructure’. New applications will be specified, implemented, and tested. Middleware architectures and associated new services will on the one hand be designed to meet user and application requirements. On the other hand, they will be capable of adapting to different underlying communication architectures and infrastructures. Work will focus on those applications and services which lend themselves to access via wireless networks.

For a full version of the proposal (in German language) please see: http://www-i4.informatik.rwth-aachen.de/Kolleg

All positions have been taken by highly qualified students. The current (November 2009) grant holders include:

- 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
Five students left the ‘Graduiertenkolleg’ during the reporting period. By now, they have successfully completed their theses, or are near completion.

- M. Sc. Juan Miguel Espinosa Carlin, Chair Informatik IV, Prof. Dr. Spaniol
- Dipl.-Inform. Sebastian Max, Chair Comnets, Prof. Dr. Walke
- M.Sc. M. Sc. Elena Meshova, Chair Mobilfunknetze, Prof. Dr. Mähönen
- Dipl.-Inform. Stefan Schiffer, Chair Informatik IV Lab, Prof. Dr. Lakemeyer
- M. Sc. Milan Zivkovic, Chair Theoretische Informationstechnik, Prof. Dr. Mathar

A special event was the Cooperation meeting with B-IT Research School, Graduiertenkolleg ”Software for Mobile Communication Systems“ and Graduiertenkolleg “AlgoSyn” in Bonn, September 2009, where joint seminars and courses were prepared.
Transfer Center 61/
Collaborative Research Center 476
‘IMPROVE’
Speaker: Prof. Dr.-Ing. M. Nagl

The Collaborative Research Center IMPROVE was established after a successful peer review in the spring 1997 by German Research Foundation (DFG) on August 1, 1997. Speaker was Prof. Dr.-Ing. M. Nagl, Computer Science 3, speaker substitute Prof. Dr.-Ing. W. Marquardt, Process Engineering).

IMPROVE was also successfully peer reviewed in May 2000 and April 2003, each giving additional three years funding. In spring 2006 the Transfer Center 61 was established after another successful peer review mid 2006 for further three years.

**Topic and Aims**

The topic of CRC 476 IMPROVE is computer science support of cross-company development processes in chemical engineering. Development processes are regarded in their early phases (conceptual design and basic engineering). The long-term goal was the investigation and definition of an integrated process and product model for development processes in chemical engineering.

Based upon this model model tools have been developed, which are part of an integrated design environment and which, again, can be synergetically integrated. The development environment also uses existing tools to avoid the reimplementation of already existing and estimated functionality. The development environment is based on a software architecture, taking the above mentioned process and product models into account, but also the a-posteriori integration of existing tools. Ideas and concepts developed in the CRC are practically tested and evaluated by using a reference scenario (development of a polyamide-6 plant).

**Status of Transfer Center 61 within CRC 476**

After the fourth successful peer review in 2006 a new Transfer Center “New Concepts and Tools for Chemical Engineering Practice” as the fourth phase of the CRC was established. Six subprojects were accepted. Another transfer project was – being financed from another source – loosely coupled with the Transfer Center. Furthermore, another DFG-project will continue its cooperation with the CRC/Transfer Center.

There is a series of workshops together with industry, organized by Prof. Marquardt and Prof. Wozny, which is held on an annual basis. Furthermore, an international workshop is scheduled for 2009 which is going to present the research results of TC 61 in relation to other big research projects.
Subprojects

- Transfer Project T1: Process Engineering (LPT) [http://www.lpt.rwth-aachen.de](http://www.lpt.rwth-aachen.de)  
  Ontology-Based Integration and Management of Distributed Design Data  
  Industrial partners: Degussa AG Engineering, Ontoprise GmbH

- Transfer Project T2: Process Engineering (LPT) [http://www.lpt.rwth-aachen.de](http://www.lpt.rwth-aachen.de)  
  Computer-Assisted Work Process Modeling

- Transfer Project T3: Labour Research (IAW) [http://www.iaw.rwth-aachen.de](http://www.iaw.rwth-aachen.de)  
  Simulation-supported Workflow Optimization in Process Engineering  
  Industrial partners: Bayer Business Services AG, Bayer Technology Services AG, ConSense GmbH, InfraServ GmbH & Co. Knapsack KG

- Transfer Project T5: Software Eng. (Inf. 3) [http://www-i3.informatik.rwth-aachen.de](http://www-i3.informatik.rwth-aachen.de)  
  Tools for Consistency Management between Design Products  
  Industrial partner: innotec GmbH

- Transfer Project T6: Software Eng. (Inf. 3) [http://www-i3.informatik.rwth-aachen.de](http://www-i3.informatik.rwth-aachen.de)  
  Dynamic Process Management Based Upon Existing Systems  
  Industrial partners: AMB Generali Informatik Services GmbH, innotec GmbH

- Transfer Project T7: Software Eng. (Inf. 3) [http://www-i3.informatik.rwth-aachen.de](http://www-i3.informatik.rwth-aachen.de)  
  Service-oriented Architectures and Application Integration  
  Industrial partner: AMB Generali Informatik Services GmbH

Book summarizing the results

A volume, containing all scientific results of the CRC up to the end of 2007 was published in April 2008. It is a comprehensive book demonstrating the advantage of a long-term project. Thanks go to German Research Foundation (DFG) for 12 years of financing.

The results are not only valuable for Chemical Engineering. Most of them are also applicable to Mechanical Engineering, Electrical Engineering, Software Development, Civil Engineering, or any discipline where complex results have to be designed/developed.


TC 61 Results as Special Issue

The results of the Transfer Center were presented at the 8th World Congress of Chemical Engineering at Montreal, Canada. All presentations got through the review process.

Even more, all presentations were encouraged to produce a paper for the Journal Computer & Chemical Engineering. If all these full-length papers pass the paper review process, there will be a special issue of this journal which can be regarded to be a final report of the Transfer Center.

The CRC 476 and the TC 61 are Success Stories

In total about 11,5 Mio € funding were spent for the CRC and the TC resulting in about 300 person years of research work.

About 400 articles in conferences and journals were produced by the members of both initiatives. More than 70 Ph.D. Theses resulted from the research in the period of these 12
years project. 11 young scientists of the CRC/TC got offers as associate or full professors at universities.

A long lasting cooperation with industrial companies provided the basis for technology transfer. There was a remarkable influence on industrial companies. However, industry is still not fully aware of the long-term importance of design process improvement and tool integration.

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http://www-i3.informatik.rwth-aachen.de/sfb476

Web sites for TC 61
http://www-i3.informatik.rwth-aachen.de/research/tb61/
The Bonn-Aachen International Center for Information Technology (B-IT) is a pioneering activity of the German Federal government and the state of North Rhine-Westphalia in their effort to establish excellence clusters across universities and research institutes in Germany. B-IT is a joint institute of RWTH Aachen University and Bonn University in cooperation with the Fraunhofer Institute Center Birlinghoven Castle and the FH Bonn-Rhein-Sieg in Sankt Augustin. B-IT aims at the internationalization and acceleration of study programs in Applied Informatics. Prof. Dr. Matthias Jarke serves as Founding Director together with Prof. Dr. A.B. Cremers, Bonn, and Prof. Dr. K. Witt, FH Bonn-Rhein-Sieg, Prof. Dr. Otto Spaniol is Study Coordinator of the Media Informatics program, Dr. Jürgen Rapp its study advisor.

**English-Language International Master Programs**

Supported by the 57 m€ 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. The Master Programs prepare students for successful international careers that require technical excellence and leadership, creativity and the ability to innovate. B-IT master programs 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 the optimization of existing undergraduate computer science curricula at University of Bonn and RWTH Aachen University for selected top students.

Well before the current debate on how to make Germany more competitive in the worldwide "battle for the best brains", B-IT has been active in attracting the best international Bachelor graduates in the ICT sector. Due to intense international networking, applicants from some of the best international undergraduate programs, e.g. from top Chinese universities such as Tsinghua, Nanjing, or Zheijiang, have been attracted to the program. B-IT students have been unusually successful in obtaining attractive competitive scholarships, ranging from university scholarships via industrial ones to the prestigious Erasmus-Mundus program of the European community. In total, the roughly 180 students at B-IT come from over 40 countries.

All study programs are now 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 around 90%, the currently highest at RWTH Aachen University. 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 University of Cambridge and Oxford as well as Stanford. Significant third-party funding acquired by B-IT faculty also offers local opportunities.
B-IT Research School

In spring 2008, a proposer team of the B-IT partners led by Professors Matthias Jarke (Speaker) and Armin Cremers (deputy speaker) were among the winners of the North-Rhine Westphalian Research School competition – one of only two computer science programs among the 17 winning teams. 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 two rounds in October 2008 and April 2009, the first 18 doctoral scholarships to candidates from 11 countries were awarded from over 250 applications all over the world. Six of the scholars are graduates from the B-IT master programs.

Faculty and scholarship holders celebrated the first general assembly of the B-IT Research School in September 2009 with a keynote talk by Prof. Martini, University of Bonn, about his analysis of the infamous Conficker worm.
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

• Univ.-Prof. Dr. rer.nat. Otto Spaniol (Chairman of the board)
• Univ.-Prof. Dr.-Ing. Dirk Abel
• Univ.-Prof. Dr.-Ing. Gerd Ascheid
• Univ.-Prof. Dr.-Ing. Christian Brecher
• Univ.-Prof. Dr.-Ing. Stefan Kowalewski
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• Univ.-Prof. Dr.-Ing. Jens-Rainer Ohm
• Univ.-Prof. Dr. rer. pol. Kai Reimers
• Univ.-Prof. Dr.-Ing. Dipl.-Wirt.Ing. Thomas Gries, University Representative of the
  Interdisciplinary Forums
• Univ.-Prof. Dr.med. Rolf Rossaint, Vice Rector for Structural Development and Research
Management

• Dr.-Ing. Gero Bornefeld, Dipl.-Phys. (Manager Interdisciplinary Forums)
• Dr. Regina Oertel (Coordinator Interdisciplinary Forums)

Members

Industrial Partner
REGINA e.V. – Kompetenznetz IT/Informatik Aachen

Strategic Process
In the course of RWTH Aachen University’s application for the Excellence Initiative, the advancement of the interdisciplinary research was emphasized as one of the two measures sharpening the university’s scientific profile. So far, the Interdisciplinary Forums have made a remarkable contribution to this. However, there is a recent need for reorientation to be able to contribute with innovative measures and to identify future topics, as for example by means of the Exploratory Research Space.

Workshop
In order to identify strategic guidelines and concrete activities for the next few years, each of the forums held a meeting for half a day under the professional moderation of PD Dr. Giuseppe Strina in November 2008. The forum member’s resonance was distinctly positive.

Strategic Papers
The findings from each workshop developed into strategic papers in which the guidelines for the next years were specified. On the background of its 20-year existence, the forum has determined its purposes (mission) in a changing academic environment, its “target audience” and the services that need to be provided for these clients in the future.
Moreover, the forums established a vision for the future, settling the question of how they should develop internally in the long term (vision).

The current status of the vision regards the Forum Information Technology as 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 (cp. chapter 1).

Corporate Strategy of the Forums

In a joint consideration of the strategic findings of all forums, it became obvious that there is an overall consensus across the forums with regard to their most important tasks for the future, and similar ideas of how to realize them developed.

According to these ideas and subsequently to the workshops comprehensive formats were identified by the speakers of the forums.

These formats shall be developed by each forum and realized in pilot projects in 2009. These formats contain for example scientific high-class scientific conferences (according to the model of the Gordon Research Conferences), guest lectures by speakers of highest scientific reputation, university-internal interdisciplinary studies and the so-called “Scientific Speed Dating”: Several smaller internal and informal meetings on specific topics are planned, where a multitude of short presentations give an overview of the operations at RWTH Aachen University in this field.

Lecture Series Forum Information Technology in Winter Semester 2008/09

The lecture series Forum Information Technology in winter semester 2008/09 attracted great interest. On an average, more than 120 people attended the three lectures. Due to the 20-year existence of the Forum Information Technology, the first two lectures were under this motto and right before the main presentation they were opened by a content-related introduction concerning the history of the Interdisciplinary Forums at RWTH Aachen University. These introductions were generously given by Professor Spaniol and Professor Hossfeld. Subsequently to the second lecture, a champagne reception on the occasion of the 20-year existence was held. The third lecture was carried out in cooperation with the Cluster of Excellence UMIC, as it has been last year.

Lecture 1: The Brain as a System of Translational Research in Psychiatry and Neurology

The first lecture on November 17th, 2008, was presented by Professor Schneider (JaraBrain), director of the Department of Psychiatry and Psychotherapy, University Hospital Aachen.

Neuro-scientific research with imaging proceedings in direct comparison with other scientific disciplines can be estimated as relatively young.

The establishment of new and more simply applicable methods, as for example the functional magnetic resonance tomography, has decisively influenced the development of neuroscience and the exploration of the
brain. While just after the wide prevalence of the imaging methods the emphasis was on the identification of single brain areas that are linked to a function or impaired due to a psychiatric or neurological disease, this focus increasingly shifts to the identification of neuronal networks. The brain progressively is understood not as a coexistence of specialized functions, but as a system that consists of an organized and structured collaboration of different areas.

This systematic approach is especially indispensable when findings from the fundamental research are to be realized in therapeutic options for patients with psychic or neurological diseases. The translation from fundamental research to clinical application is the essential aim of the imaging research in psychiatry and neurology.

**Lecture 2: Quantum Computing and Quantum Communication with Quantum Optical Systems**

On January 19th, 2009, the second lecture took place, and for the first time, the lecture was held in the Ford-hall, SuperC in Aachen. Professor Dr. Peter Zoller, Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, presented his lecture on the topic of “Quantum Computing and Quantum Communication with Quantum Optical Systems.”

The presentation gave an overview of different aspects of quantum information processing with quantum optical systems. Addressed subjects were quantum computing and quantum simulation with cold ions, atoms and molecules, quantum repeaters with atomic ensembles and hybrid systems, consisting of solid body elements and atomic systems.

**Lecture 3: Swiss Experiment – From Wireless Sensor Networks to E-Science**

The lecture on Mobile Communication by Professor Dr. Karl Aberer (Lausanne) on January 26th, 2009, was introduced by Professor Ascheid. The complementary program was organized by UMIC since the lecture was offered in cooperation with the UMIC Distinguished Lecture Series. The title of the presentation was “Swiss Experiment – From Wireless Sensor Networks to E-Science” and familiarized the audience with how the development of novel sensing devices and wireless sensor network technologies provides a whole new opportunity for global environmental studies and environment-related decision making.

The “Swiss Experiment” is a newly initiated multidisciplinary project aimed at building a comprehensive and large-scale platform. This platform shall serve to support field investigations of ecological processes which are based on new sensor and data management technology. Professor Aberer first gave an overview of the environmental problems that are in
the focus of the Swiss Experiment and presented opportunities of supporting environmental scientists by the recent advances in communications and information systems.

He discussed in particular the approach to support data and information management throughout experimental campaigns. These include the advancement of distributed data stream management based on Global Sensor Networks, for data storage and analysis, map-based visualizations based on SensorMap and for information sharing using a WIKI-based semantic platform.

Subsequently, Professor Aberer presented initial results and identified future challenges in connection with the development of a truly comprehensive information management support for environmental sciences.

**Virtual Reality Center Aachen (VRCA)**

In 2009, about 42 professors of RWTH Aachen University are organized as full members as well as 18 companies as sustaining members in the Virtual Reality Center Aachen (VRCA). The Fraunhofer FIT, Sankt Augustin, the Jülich Supercomputing Centre, the Academic and Research Department Car Body Technology at FH Aachen as well as the Institute for Protestant Theology, Bayreuth University, represent four external facilities as associated members of the VRCA.

Due to the multidisciplinary and collaborative work on research projects and regardless of the boundaries of the single faculties, the specific competences of the respective project partners complement one another in an ideal way.

Currently, over 50 research projects are being conducted, the majority of which being financed by third-party funds. These projects are documented in a separate VRCA report which will be released in autumn 2009.

**BMBF Foresight Process**

From 2007 to 2009, the Interdisciplinary Forums were partners 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). This Foresight Process was aimed at glancing at the future of research and technology with a perspective of 10 to 15 years plus x in order to

- identify new fields of attention in research and technology
- name and derive comprehensive activities for research and innovation fields
- analyze in which technology and innovation fields strategic partnerships can be realized
- derive priority domains of activity for research and development.

**Future Areas of BMBF Process**

Based on a multitude of research methods, the main findings of the Foresight Process are available now. The essential findings – in terms of the as prospectively important identified research fields – were presented on the closing meeting of the Foresight process in Bonn. These findings shall be presented in the following.

1. **Decoding the Process of Aging**

By means of a systemic and interdisciplinary approach, gerontology investigates the reasons and mechanisms of aging. The difference between aging and age is of utmost importance for studies in the field of gerontology: Aging describes a lifelong process which is determined by
continuously proceeding changes in the organism and proceeding transformation; age, on the other hand, represents a stage of life on its own.

At which age this phase of life is reached is not only dependent on the changes in the process of aging, but can also be seen as an effect of societal conventions.

It is to be expected that findings from the cellular and molecular developmental biology will offer new insights into cognitive, psychomotor and emotional processes.

The following questions will need to be sorted out in the next years and decades:

• How does the individual aging process proceed, and how can it be influenced?
• Is it solely the lifespan that is extended, or can we also improve the ‘health span’?
• Which economic and social impacts does longevity have, especially with the aim of stretching the health span to a relevant degree?
• How do working processes and age images change as a result of an extended life and health span (individually, operationally, and socially)?
• Can repair mechanisms be discovered and therapeutically used on DNA level (e.g. for cancer treatment)?
• Which mechanisms of learning can be identified by neuro sciences?
• How can lifelong learning be kept up, and how can these mechanisms be used in all phases of life? (e.g. learning products in early childhood; geragogy to support learning in old age).

2. Infrastructures for the Living Environments of the Future

Living environments are subject to a structural change all around the world. However, many recent technologies and research approaches are geared to the previous forms of settlement and life, which can only be changed with an immense cost and resource expenditure in the short and medium term. Therefore, a research perspective is required which orients on possible future sustainable living environments on the one hand and accounts for challenges of a greater flexibility of spatial use as well as the infrastructure in general on the other hand. The development of such a perspective demands interdisciplinary cooperation and networking of different areas of research and technology.

Central aspects of this field of research are:

• innovations for a greater flexibility of settlement and infrastructure in consideration of its future remodeling and revitalization (areas of activity: energy, supply and disposal, information and communication, water, integrated traffic and logistics systems, contemporary architecture, building research) despite the traditionally long term investment and utilization spans
• technologies and concepts for a sustainable supply (local attendances, small-scale materials cycles)
• innovative concepts to enhance the personal and technical safety (Security and Safety) in the living environment.

3. Complexity, Models and Simulations

By now, virtual system analyses and experiments are not only indispensable for the formulation of hypotheses on complex circumstances in physical, chemical as well as biological fields of research, but also in technical and social science fields of research.
The major challenge is to exchange findings among adjoining or even independent disciplines by means of appropriate translation processes.

Due to an adequate combination of recent findings, new simulation methods have been developed for existing and recent problem areas.

Examples for research questions and developmental areas are:

- How and by means of which models can ecological connection be simulated, thus to be able to better understand and address them?
- In which ways can phenomena of self organized complexity, for instance the performance of living cells or whole organs, be modeled or stimulated so that further breakthroughs in the medical diagnosis and therapy can emerge?

4. Man-Technology-Cooperations

Numerous recent research projects in various areas focus on innovations which are associated with shifts of established boundaries between man and technology. Where established research perspectives structurally end, the new perspective of “Man-Technology-Cooperations” starts its research. It moves on from established disciplinary boundaries of today and takes into consideration recent configurations of man and technology in its broad complexity.

It examines technical and non-technical aspects of boundary innovations in its overall context. The dynamic interaction and the complex interwoven transition of man and technology become the focus of observation.

Central areas of research are:

- the relocation of man within closing-in technological shells in the face of more and more humanlike machines
- “mechanical people”, meaning technologies which are affiliated with human characteristics like autonomy, intelligence, decision-making competence and emotions
- symbioses of man and machine where human and technical abilities complement each other smoothly to accomplish certain ends
- man-machine-cultures which socially tie new forms of interconnections of human action and technical processes.

5. Gaining Micro-Energy from the Environment

Everyday we use – if consciously or subconsciously – a multitude of different devices that demand energy to function properly. These increasingly diminish in size and are integrated in systems, some of them are even integrated in human beings.

More and more applications are aimed at functioning autonomously, decentralized or mobile, beyond established energy infrastructures and energy sources. Technologies for power and electricity supply that use small amounts of energy from the environment (energy harvesting) can help to make our life more comfortable and secure in a multitude of applications. At the same time, they can also help to spare natural resources and save the environment.

Examples are:

- the permanent energy supply of heart pacemakers
- the permanent measuring and transfer of body functions like heart rate and blood pressure
- pressure sensors in car wheels or the wireless transfer of the measured data
• measuring and transfer of measured data of air pollutants in rooms which serve for a need-based ventilation control.

6. ProducingConsuming 2.0

Future added value will have to face considerable, partly even conflicting changes: climate change, scarcity of resources, internationalization of production and markets as well as diversification of forms of life and consummation patterns to begin with. The research area ProducingConsuming 2.0 connects recent technological and organizational concepts in these areas with hot spots that are crucial for the future in order to develop potentials for the prospective viability in new dimensions.

Rather than dealing with the optimization of single elements in value-added processes, the focus will be on the systemic change of the overall framework. Innovative methodical approaches to the study of systemic changes are a central component in this field of research.

Examples for the research tasks in connection with the hot spots are:

• sustainable specification of new innovation patterns like “Interactive Added Value”
• relocation, decentralization and automation of added value elements – adjusted development of concepts and technologies
• production in the context of concepts for innovative spatial use (e.g. in cities with locally adjusted materials cycles)
• governance of systemic transformations in the field of producing and consuming (e.g. the development of creative potentials for the realization of innovative added value paradigms)
• embedding of biological production of the second generation in future added value networks.

7. Time Research

The factor “time“ is not yet understood sufficiently and therefore represents the shortage factor in many developments: For example, we need to address the question of the temporal order of complex processes with the aim of making applications faster, more efficient, cost-effective and more intelligent as well as parallelizing and synchronizing processes. A further and very dynamic future field of analysis in connection with time research is chronobiology in which first findings with regard to precisely timed medication have been achieved.

Moreover, it might also help to reduce the side effects of irregular working hours and night work or define optimal times, for example for the process of learning.

Central aspects of research are therefore the understanding and systematic controlling of the factor “time” with the aid of time efficiency research, precise time measuring (e.g. for GPS-applications in precise agriculture, remote maintenance of machines) and metering time period (e.g. 4D precision).

That way, existing technologies could be optimized as well as it may lead to the development of completely innovative “time technologies”.

Five research areas attract great attention:

• ultra-precise and ultra-short time measuring – a new area of time measuring due to optical clocks
• 4D imaging – real-time structure investigation and microscopy up to the subatomic area
• Atto(seconds)electronics – control of processes on an atomic time scale
• biological clock / chronobiology
• synchronization, parallelization and efficiency.

8. Area of Activity: Energy Concert

The major aim of the Energy Concert is the precocious strategic grouping of contributions from different research fields for the sustainable generation and utilization of energy.

Therefore, a future oriented and structured observation of the scientific landscape is proposed. This “Meta-Roadmapping” shall serve to identify synergy potentials and inconsistencies and to propose appropriate strategic activities as needed. That way, a well tempered energy orchestra will emerge which can adjust its repertoire to various framework conditions readily and effectively.

Possible fields for such an energy related “strategic alignment” are:
• materials science / nanotechnology / electric mobility
• energy efficient production engineering / biological production
• intelligent house / photonics.
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)
Activities in 2008-2009

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 2008/2009:

- Management Get-togethers: voice recognition, spam-mails, Europe’s fastest supercomputer, process-oriented knowledge management, mobile and adaptive Internet, industrial espionage, exchange of experiences about recruitment, mobile TV-mobile trends, schooling and further education by the chamber of Industry and Commerce Aachen, presentation of the UMIC-Cluster (Ultra-high-speed Mobile Information and Communication systems, embedded systems: When we leave the control of everyday objects to computers, Galileo above – Aachen creates the opportunities, integrated and international merchandise: more contacts-less money, virtual infrastructure: more appliance- less server, RWTH Aachen Campus- a new quality of cooperation between the university and industry…

- Round-table Discussion: Paradigm shift - go for future for all
- 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.
Transfer of personnel from universities to regionally based companies

Research institutions such as RWTH Aachen University, Aachen University of Applied Sciences, and the Research Centre Jülich, as well as the major development laboratories of industrial companies provide the Aachen region with a density of research and development which is almost unique in Europe. The IT sector is one of the most promising focal fields.

REGINA is engaged in developing strong links between research and industry. The aim is to educate highly qualified young talents as future employees in regional IT companies, so that expertise is rooted in the Aachen region in the long term. This effort is supported by REGINA's own Internet-based job-placement exchange, which not only advertises jobs for graduates but also training, work-experience opportunities, and postgraduate internships. Finally, grants for graduate students have been donated by REGINA companies.
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 Arabic 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 2008-2009, this concerned PD Dr. Matthias Westermann (Informatik 1) and Dominik Lübbers (Informatik 5). 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.

The initial IT student population has started very small in 2008, with only four students, but has been growing to 6 in the second intake 2009, and 17 students are preparing for the 2010 intake in the Foundation Year.

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.
Overview

TGGS is a joint institution established by RWTH Aachen University and her Thai partner KMUTNB (King Mongkut’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)
The mission of the Fraunhofer FIT Institute for Applied Information Technology in Sankt Augustin and Aachen (Director: Prof. Dr. Matthias Jarke) 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. After three years of strong growth in third-party funding from 4.6 m€ to 7 m€ per year, 2008 saw a consolidation at this historically high level. About 100 researchers, 15 technical and administrative personal, and 50-60 student assistants work in the institute. 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).

*The first mobile underwater augmented reality system for diver training, recently developed by FIT.CSCW, caused a lot of attention in the media*
FIT.CSCW (Prof. Wolfgang Prinz, PhD) investigates the field of Cooperation Support Systems. In the reporting period the department was working a number of EU-funded projects. ECOSPACE is an integrated project (IP) coordinated by FIT.CSCW. The project goal is the development of reference architecture, a collaboration middleware and services, as well as new cooperation tools to enable seamless and instant collaboration among knowledge workers, beyond organizational boundaries. CoSpaces, another IP, focuses on innovative collaborative work environments for individuals and teams in design and engineering. The third IP, C@R investigates collaboration technologies for rural areas. The vision of the IPCity project (another IP coordinated by FIT.CSCW) is to provide citizens, visitors, as well as professionals involved in city development or the organization of events with a set of technologies that enable them to collaboratively envision, debate emerging developments, experience past and future views or happenings of their local urban environment, discovering new aspects of their city. Two BMBF funded projects on a collaboration and task management platform for distributed development and engineering processes (SAGE) and on a toolbox for the development of service oriented applications for collaboration environments (MITSOA) were successfully finished in 2009.

The Summer Olympics inspired Bayer Business Services (BBS), a German company with 89 offices worldwide, with an exciting idea: A symbolic baton travels round the earth, from one office to the next, from employee to employee, and gathers greetings, ideas, or stories in a multimedia album that is open to the company staff worldwide. Under the banner “We are a people company, be part of it”, the project was to build bridges between the BBS offices, enhance social interaction and thus improve communication within the organization. Fraunhofer FIT developed the conceptual design and technical realization of this project. The main challenge initially was how to motivate the company staff worldwide to be spectators and symbolic runners in the relay, i.e. to contribute to the album. Focusing on the latter, we decided to translate the idea of a symbolic baton into a tangible tool that is an attractive piece of technology and at the same time makes it easy to create messages for the album. For the hardware we settled on a VAIO ultra-mobile PC from Sony. It is optimized to enable non-specialist users to create short multimedia or text messages. In regular intervals the finalized messages are uploaded to a shared workspace that delivers the contributions to the web page of the relay. The relay was started in July 2008 at the summer party of Bayer Business Services in Berlin. By the end of the year staff from twenty-five offices had contributed to the relay. The messages by the employees presenting themselves and their colleagues, the business focus of their office, local or regional highlights already are a very impressive collection of facets of a global company. Six months after the project start demand for the Baton is still lively. Comments by the staff confirm that the virtual relay has indeed enhanced social interaction within Bayer Business Services.
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. In the FUSION project on minimally-invasive liver therapy http://www.somitfusion.de, we have prepared for conducting a clinical study of the developed navigation system for treatment of liver tumors. We have designed and implemented a novel automated microscope with extensive software support, the TopoScan system, which will be used at the University Hospital Düsseldorf (Prof. Dr. D. Häussinger) in a joint clinical research project. In the IMIKRID project we have realized a miniaturized diagnostic device that can detect molecular markers in blood in small amounts. Together with Helmut Hund GmbH, we have developed a system for detection and classification of pollen that is being installed in a monitoring network by the German weather service (DWD) as the worldwide first fully automatic system in this domain. With full rollout of the system throughout Germany, significant relief for the ca. 12 million pollen allergetics can be expected through localized and timely prediction.
MACE links architectural archives in Europe into a coherently accessible information network for research, teaching, and practice; in the Biennale 2008 in Venice/Italy, MACE demonstrated collaborative access to this information network through a multitouch table.

FIT.ICON (Prof. Dr. Reinhard Oppermann) develops context-adaptive and mobile systems for eLearning and mobile work. Jointly with Informatik 5, they are main partners in the ROLE 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. Contextualization in mobile work settings is also the main topic of the MICA project that demonstrates novel mobile user interface solutions in RFID-based warehouse worker scenarios. A number of European integrated projects are ongoing, addressing metadata for architectural learning (MACE), self-organizing photo collections (aceMedia), and middleware for mobile, networked device integration (HYDRA). In 2008 a new research group CAPLE (Context and Attention in Personalized Learning Environments) was established. CAPLE focuses on utilizing the observations about and context of the learner to facilitate application and task independent support of individualized learning experiences. Information is plenty today, with a continuously growing number of information sources and new ways to interact with them. Consequently, learners need to focus more and more on managing digital information thus severely increasing the cognitive load of learners beyond meaningful states. In 2009, a major joint focus between FIT.ICON and FIT.PRO lies in the area of emergency management. For example, FIT has contributed user-centered design methods to the development of wearable firefighting systems in the largest civil wearable computing project worldwide, the EU Integrated Project wearIT@work; other current projects address topics such as rapid damage estimation after earthquakes and protection of energy networks.
Iterative game-based design is an important approach pursued in the development of novel technologies for critical applications to make firefighting professionals able to envision the technological future, and assess its chances and risks (wearIT@work project).

FIT.PRO (Prof. Dr. Thomas Rose) develops process management solutions for domains that can be characterized by the complexity of their decision processes. Doctoral theses on business models for eGovernment in public-private partnerships, and on workflow support for quality control in intensive care units have been completed in 2008. Usability of tools for process capture and business models for operating services is major topic of FIT.PRO. After successfully finalizing projects on methods and tools for identifying trends in the home textile industry (AsIsKnown), requirements engineering for control software in the automotive industry (Zamomo), and electronic risk management platforms (ERMA), we are currently devising methods and tools that allow domain experts in the emergency domain to “voice” their expertise. The latter is based on experiences gained in formally modeling rescue management procedures in the context on the event of mass casualties (Massenanfall von Verletzten und die überörtliche Varianten ÜMANV).

FIT organized a Software Symposium 2009 for the promotion of project findings and prototypical results developed in the BMBF Initiative SE-2006 for the generation of software-enabled innovations for the German industry. The forum has attracted a balanced mixture of participants from industry and academia and was held at the B-IT premises in Bonn.

Together with the University of Siegen, and in cooperation with Aachen’s UMIC Excellence Cluster and the B-IT Research School, FIT organized the annual international Mobile Human-Computer Interaction conference 2009 (MobileHCI09) where more than 350 participants from 28 countries presented and discussed latest results about novel applications and interaction techniques with mobile devices for users on the move.
Computer Science Technical Reports 2009

Electronic copies of all Technical Reports may be obtained through
http://www.informatik.rwth-aachen.de/Forschung/aib.php

2009-01  Fachgruppe Informatik: Annual Report 2009
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2009-03  Alexander Nyßen: Model-Based Construction of Embedded & Real-Time Software - A Methodology for Small Devices
2009-04  Daniel Klünder: Entwurf eingebetteter Software mit abstrakten Zustandsmaschinen und Business Object Notation
2009-05  George B. Mertzios, Ignasi Sau, Shmuel Zaks: A New Intersection Model and Improved Algorithms for Tolerance Graphs
2009-06  George B. Mertzios, Ignasi Sau, Shmuel Zaks: The Recognition of Tolerance and Bounded Tolerance Graphs is NP-complete
2009-07  Joachim Kneis, Alexander Langer, Peter Rossmanith: Derandomizing Non-uniform Color-Coding I
2009-08  Joachim Kneis, Alexander Langer: Satellites and Mirrors for Solving Independent Set on Sparse Graphs
2009-09  Michael Nett: Implementation of an Automated Proof for an Algorithm Solving the Maximum Set Problem
2009-10  Felix Reidl, Fernando Sánchez Villaamil: Automatic Verification of the Correctness of the Upper Bound of a Maximum Independent Set Algorithm
2009-11  Kyriaki Ioannidou, George B. Mertzios, Stavros D. Nikolopoulos: The Longest Path Problem is Polynomial on Interval Graphs
2009-12  Martin Neuhäußer, Lijun Zhang: Time-Bounded Reachability in Continuous-Time Markov Decision Processes
2009-13  Martin Zimmermann: Time-optimal Winning Strategies for Poset Games
2009-14  Ralf Huuck, Gerwin Klein, Bastian Schlich (eds.): Doctoral Symposium on Systems Software Verification (DS SSV’09)
2009-15  Joost-Pieter Katoen, Daniel Klink, Martin Neuhäußer: Compositional Abstraction for Stochastic Systems
2009-16  George B. Mertzios, Derek G. Corneil: Vertex Splitting and the Recognition of Trapezoid Graphs
2009-17  Carsten Kern: Learning Communicating and Nondeterministic Automata
2009-18  Paul Hänsch, Michaela Slaats, Wolfgang Thomas: Parametrized Regular Infinite Games and Higher-Order Pushdown Strategies