Annual Report 2011

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

This annual report provides a summary of the research and teaching activities of the Computer Science Department at RWTH Aachen University in the academic year from October 2010 to September 2011. We are happy to report about the large variety of research and teaching activities within the department. In this booklet you will find ample information not only about our research and teaching activities and our scientific successes, but also about social life and important developments in the department.

The Computer Science Department is especially proud about the large number of students that successfully graduated during the last academic year. By far the most students are enrolled in our Bachelor program in Informatics. Besides, we offer three different Master programs. Already since several years, we have attracted top Bachelor graduates from all over the world by our international Master programs in Software Systems Engineering and Media Informatics. Just two years ago, these two focused programs were complemented by a more general Master program in Informatics that is most attractive to our Bachelor graduates. On this year’s Computer Science Day, we expect to celebrate the first Master graduates of this program.

During the previous year, the researchers of the department achieved a large variety of scientific successes. This report contains descriptions of the research projects running in the different groups and lists their publications and presentations. When reading this report, it becomes very obvious that the research of the department is quite successful and visible on an international level. Various members of the department received awards for outstanding papers and theses, or were invited to give keynote presentations at highly ranked conferences. Instead of re-enumerating all kinds of distinctions and awards here, I would like to highlight one of them: Professor Hermann Ney has become a fellow of IEEE for contributions to statistical language modeling, statistical machine translation, and large vocabulary speech recognition.

It is worth mentioning that the members of the department are involved in organizing and running scientific workshops and conferences in different fields. A major event this year was the “Aachen Concurrency and Dependability Week” taking place at our university in September 2011. This event was organized by the group of Prof. Joost-Pieter Katoen (Informatik 2). It consisted of the conferences CONCUR, QEST and TGC, as well as 9 workshops and 6 tutorials. ACDW offered a highly interesting and varying program for 6 full days: Invited talks by top scientists, excellent tutorials on recent topics in quantitative analysis, and presentations of selected papers. About 300 researchers participated in this event.

In the last year, the department was able to establish two new professorships. Bastian Leibe accepted a professorship for Computer Vision and now leads the research and teaching group Informatik 8. Martin Hoefer became a Juniorprofessor in the area of Algorithmic Game Theory at the Chair of Informatik 1. Both of them will present their research areas at this year’s Computer Science Day.

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

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

Aachen, November 2011

Berthold Vöcking

Speaker, Computer Science Department
Faculty Life
The ‘Tag der Informatik’ at the RWTH Aachen is the traditional colloquium where the research groups of the computer science department present their research and teaching activities. This event gives everybody 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. The 2010 event took place on December, 3rd and was organized by the Chair of Computer Science 3 (Software Engineering). Traditionally it starts at midday with the come together in the lobby.

Welcome addresses were given by Rector Prof. Dr. Ernst M. Schmachtenberg, by Dean Prof. Dr. Gerhard Hiss, by the spokesman of the computer science department, Prof. Dr. Berthold Vöcking and by the rector of Alpes-Adria-University Klagenfurt and former president of the Gesellschaft für Informatik (GI) Prof. Dr. Dr. h.c. Heinrich C. Mayr.

After the introduction Chris Rupp of SOPHIST GmbH gave a talk called "Hellsehen für Fortgeschrittene oder Systemanalyse auf den Punkt gebracht" discussing modern forms of requirements engineering: How to capture and fulfill wishes and requirements of customers, even subconscious and non verbalized ones, using techniques and advancements in modern requirements engineering.

Like in the last year the “one minute madness” (OMM) has been an entertaining and informative part of the open day, which in general gave the audience an impression of the field of activity of the department of computer science. Presenters had 100 seconds (which is obviously slightly more than a minute, but has a lower potential for a catchy title) and one slide to tell the interested audience why their respective project is relevant, exciting, and fun.
The afternoon program was closed with a laudatio held by Prof. Dr. Dr. h.c. Manfred Nagl and a talk by Prof. Dr. Peter Russel before exactly 163 graduates received their graduate certificates. 81 of them were diploma, 31 bachelor, 22 master, 2 teaching degrees and 27 dissertations.

Furthermore, several awards and prizes were given to outstanding graduates by different sponsors. In detail aixigo AG sponsored the prize for Monica Verma, CSB-System AG for Roland Hildebrandt, DSA Daten- und Systemtechnik GmbH for Tilo Müller, Generali Deutschland Informatik Services GmbH for Tobias Arndt Ickler, Microsoft EMIC GmbH for Vira Falak Sher and Soptim AG for Christian von Eßen. Fabian Kürten was prized for the best bachelor degree with the Schöneborn-Preis.

The ‘Tag der Informatik’ ended with the traditional evening banquet for the graduates, their families, many current students and alumni, 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 150 students received their certificates at each summer party.

Said official ceremony was followed by the – less formal – party proper. A small(ish) buffet and plenty of drinks were on offer. The typical crowd of about 800 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.
Informatik Sommerfest
Im Informatikzentrum
Ahornstraße 55

1. Juli 2011

16:00 Beginn
16:30 Festakt
Verleihung der Zeugnisse
danach Geselliges Feiern
The InfoCup is the CoSc department’s traditional football tournament. In 2011, it was once again sponsored by Soptim AG. The event took place on 28 May. Eleven teams had registered.

The group phase comprised two groups with 6 and 5 teams, respectively. In Group A (6 teams) i6 started with two wins and could defend their 1st place. Team i8/MMP finished as runner-up.

Competition in Group B was particularly fierce, as all teams were very strong. Previous year’s winner i5 made the semis, as did i4/MNP with a last-round win against i5.

The teams from group B also dominated the semis. i4/MNP managed a last minute win against i8/MNP (1-0), and i5 prevailed against i6, but like last year only in the penalty shootout (2-0).

Unlike last year, i6 lost in the petite finale; i8/MMP made third place (4-3; again after a penalty shoot-out).

The finals was a reenactment of the 2009 edition, including the result. Like 2 years ago, i5 came off better in the hard played match (2-0).
The final table:
i5
i4/MNP
i8/MMP
i6
i11
Stdents’ Council
i3
i4
i2/HS
i10
i12

Players and onlookers let the day gently fade away with the traditional After-Soccer-Party, enjoying the barbecue and the cold beer.
Starting six years ago, the Department of Computer Science joined the support program Aachener Model for highly talented pupils from elementary schools in city and county of Aachen, which was continued since then. An external steering committee selected 16 children who attend the new program called Helle Köpfe in der Informatik – Bright Brains in Computer Science. During eight course meetings, faculty members of the Department of CS introduced the talented students to basic topics of computer science. They particularly stress on the insight that computer science is much more than simply working with computers.

The 2011 seminar addressed the following topics:

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

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

The experiences were very positive, and the programme will be continued in the next years.
Teaching
Contents and curriculum of the Computer Science Programme (BSc/MSc)

Short Description

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

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

Degree: Bachelor/Master of Science RWTH Aachen University (B.Sc. RWTH/M.Sc. RWTH)

Standard period of study: 6/4 semester

Required Qualifications

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

Overall Structure

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

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

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

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

Subsidiary Courses

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

Post-Graduate Studies

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

Subject-Related Specialty

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

Professional Areas

Computer Scientists may find employment in many different professional areas which all bear upon information technology. For example chip producers, telecommunication companies, software companies, consulting firms, and users of administration systems (banks, insurances, public service etc.) or automation technology (producing industry, automotive and airplane industry). Because of the increasing use of computer systems in all areas, presently the career opportunities of computer science graduates are excellent!
Contents and curriculum of the
Principles of Computer Science
as second major of the
‘Technik-Kommunikation’ 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 is standards, document testing, creativity, rhetoric, technical terminology, media/multimedia, sociology, psychology, foreign languages, and further training.

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

Required Qualifications

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

Overall Structure

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

Stage I

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

**Stage II**

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

**Professional Areas**

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

The subject of computer science at school

The aim of this curriculum is to give future teachers (in secondary school education) a firm basis for the school subject of computer science. This curriculum has been established 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 prerequisites for a successful study of computer science are similar as for the diploma curriculum: a certain acquaintance with abstract methods and constructions as they are learned and trained in mathematics. Moreover, the ability to communicate with others (and of course, in particular with children) is a necessary condition for future success as a teacher.
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 4 for German language classes. At present, about 80 students from 20 countries are enrolled in the programme.

Last year, the programme underwent a major revision, both in order to harmonize the course with the new Master in Informatics and to strengthen the focus on Software Engineering. The revised curriculum was accredited by ASIIN at the national level and by EQANIE at the European level. Incidentally, Software Systems Engineering was the first to ever receive the EQANIE label, together with our B-IT Master programmes Media Informatics and Life Science Informatics.

Building on the strengths of our department, the Software Systems Engineering focuses on the design and implementation of complex software systems, including their embedding in technical and socio-technical systems. The programme's curriculum covers the areas of theoretical foundations of software systems engineering, communication, data and information management, applied computer science, and software engineering. Students may take courses of no more than 35 credits in each of these areas but are required to take courses of at least twelve credits in theoretical foundations of software systems engineering as well as at least 16 credits in software engineering. This includes a mandatory four credits course on the management of large software system engineering projects and courses in the amount of twelve credits to be chosen from a specific set of lectures called Core Subjects both in software engineering and in theoretical foundations of software systems engineering. During the programme students further need to take two seminars and a lab course. The Master's examination consists of course-related exams, the two seminars, the lab course, an oral core exam on courses of twelve to 18 credits and the Master's thesis. The thesis typically takes the final six months of the programme and can be undertaken in cooperation with industry or at the university.

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

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

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

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

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

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

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

**Career Opportunities**

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

**Language of Instruction**

The Programme will be taught completely in English

**Duration of the Programme**

Two years

**Beginning of the Programme**

October

**Deadline for application:**

March 1st the same year the programme starts

**Further information**

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

RWTH Aachen University
Chair Informatik 4
Media Informatics Team
52056 Aachen, Germany
E-Mail: msc-mi@b-it-center.de
Webpage: [http://mi.b-it-center.de/](http://mi.b-it-center.de/)
### Courses Taught in 2011

#### Summer Term 2011 – Diploma, undergraduate

<table>
<thead>
<tr>
<th>Course</th>
<th>Instructor(s)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proseminar: Echtzeitsysteme</td>
<td>Abraham, Jansen, Loup, Nellen, Chen</td>
<td>PS (2)</td>
</tr>
<tr>
<td>Multimodal Media Madness</td>
<td>Borchers, Herkenrath, Heller, Bohne</td>
<td>VP (V1+P3)</td>
</tr>
<tr>
<td>Mensch-Maschine-Interaktion</td>
<td>Borchers, Möllers, Karrer</td>
<td>PS (2)</td>
</tr>
<tr>
<td>Proseminar: Fortgeschrittene Programmierkonzepte in Java, Haskell und Prolog</td>
<td>Giesl, Brockschmidt, Emmes, Fuhs, Otto, Ströder</td>
<td>PS (3)</td>
</tr>
<tr>
<td>Mathematische Logik</td>
<td>Grädel</td>
<td>V (3)</td>
</tr>
<tr>
<td>Mathematische Logik (Diskussion)</td>
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<td>Klausur Mathematische Logik</td>
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<td>Lineare Algebra I für Informatiker</td>
<td>Hanke, Hiß</td>
<td>V (3)</td>
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<tr>
<td>Klausur Lineare Algebra I für Informatiker</td>
<td>Hiß, Hanke</td>
<td>U (2)</td>
</tr>
<tr>
<td>Datenbanken und Informationssystem</td>
<td>Jarke, Quix, Krempels, Geisler, Terwelp</td>
<td>PS (2)</td>
</tr>
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RFC Communication Systems: Multi-hop Wireless Networks  | Thißen, Wehrle  | VÜT  
Klausur Parallele Programmierung II  | Wolf,  | Kl  
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**Summer Term 2011 – BSc**

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Proseminar: Echtzeitsysteme | Abraham, Jansen, Loup, Nellen, Chen | PS (2)  
Modellierung und Analyse hybrider Systeme mündliche Prüfung | Abraham | MPT  
Multimodal Media Madness | Borchers, Herkenrath, Heller, Bohne | VP (V1+P3)  
Mensch-Maschine-Interaktion | Borchers, Möllers, Karrer | PS (2)  
Seminar: Kombinatorische Modellierung im wissenschaftlichen Rechnen | Büncker | S (2)  
Einführung in High-Performance Computing | Büncker, Bientinesi, Fortmeier, Willkomm | VT (3)  
Einführung in High-Performance Computing | Büncker, Bientinesi, Fortmeier, Willkomm, Lülfesmann | U (1)  
Prüfung Einführung in High-Performance Computing | Büncker, Bientinesi | Kl  
Medizinische Bildverarbeitung | Deserno, Köbbelt, Ney, Rossmanith, Seidl, Spitzer | ST (2)  
Proseminar: Fortgeschrittene Programmierkonzepte in Java, Haskell und Prolog | Giesl, Brockschmidt, Emmes, Fuhs, Otto, Ströder | PS (3)  
Termersetzungssysteme - Aktuelle Themen und Erweiterungen | Giesl, Brockschmidt, Fuhs, Otto, Emmes, Ströder | S (2)  
Seminar: Logik, Komplexität, Spiele | Grädel | S (2)  
Mathematische Logik | Grädel | Tut (2)  
Klausur Mathematische Logik | Grädel | Kl  
Mathematische Logik | Grädel | V (3)  
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Mobile Internet Technology | Gross, Wehrle, Thißen, Bitsch Link, Alizai | VÜT (3+1)  
Prüfung Mobile Internet Technology | Gross, Wehrle, Thißen, Bitsch Link, Alizai | Kl  
Datenkommunikation und Sicherheit (vormals: Sichere verteilte Systeme) - Klausur | Gross, Wehrle, Thißen, Christoph | Kl  
Lineare Algebra für Informatiker | Hanke, Hiß | F  
Lineare Algebra I für Informatiker | Hanke, Hiß | U (2)  
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Klausur Lineare Algebra I für Informatiker | Hiß, Hanke | KIT  
Klausur Lineare Algebra I für Informatiker (Wdhlg.) | Hiß, Hanke | KIT  
Algorithms for Complex Networks | Jarke, Klamma | ST (2)  
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Datenbanken und Informationssysteme | Jarke, Quix, Krempels, Geisler, Terwelp | PS (2)  
Datenbanken und Informationssysteme | Jarke, Quix, Krempels, Geisler, Terwelp | VT (3)  
Klausur Datenbanken und Informationssysteme | Jarke, Quix | KIT  
Softwarepraktikum: Implementierung heuristischer Algorithmen für Brettspiele | Katoen, Heinen, Nguyen | PT (3)  
Foundations of Multi-Core Memory Models | Katoen, Noll | S (2)  
Current Research Topics in Computer Graphics, Geometry | Kobbelt, Leibe, Möbius | S (2)  

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| Master-Mentorenprogramm: Software &amp; Kommunikation | |
| Master-Mentorenprogramm: Daten- &amp; Informationsmanagement | |
| Master-Mentorenprogramm: Angewandte Informatik | |
| Modellierung und Analyse hybrider Systeme | Abraham, Chen | VÜT (3+1) |
| Modellierung und Analyse hybrider Systeme mündliche Prüfung | Abraham | MPT |
| High-performance matrix computations | Bientinesi, Bücker | VPT (V3/ÜE1) |
| High-performance matrix computations - Final Exam | Bientinesi, Bücker | MP (V3/ÜE1) |
| Current Topics in Media Computing and HCI | Borchers, Wacharamanottham, Lichtschlag | VÜT (V2/Ü3) |</p>
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Computer Science Colloquium – Talks

13. September 2011  Prof. Michael E. Houle, National Institute for Informatics, Tokyo, Japan  
*Intrinsic Dimensionality and its Applications to Databases and Data Mining*

*Development of a Surgical Assistance System for Guiding Transcatheter Aortic Valve Implantation*

13. July 2011  Rafaela Hillerbrand, Humtec, RWTH Aachen  
*Simulierte Wissenschaft oder Erkenntniswerkzeug? Ein philosophischer Blick auf Computersimulationen*

30. June 2011  Mark Guzdial, Georgia Tech, Vice President ACM SIGCSE  
*Using Digital Media to Motivate Learning about Computer Science*

30. June 2011  Prof. Dr. Bernd Finkbeiner, Universität des Saarlandes  
*Logics and Algorithms for the Synthesis of Distributed Systems*

*CrowdDB: Answering Queries with Crowdsourcing*

28. June 2011  Prof. Dr. Martin Grohe, Humboldt-Universität zu Berlin  
*Logik, Struktur und Komplexität*

28. June 2011  Prof. Dr. Martin Lange, Universität Kassel  
*Logic and Algorithms for the Foundations of Computer Science*

27. June 2011  Prof. Dr. Thomas Schwentick, Technische Universität Dortmund  
*Strings und Bäume mit Daten: Betrachtung eines neuen Datenmodells aus verschiedenen Blickwinkeln*

27. June 2011  Prof. Dr. Javier Esparza, TU München  
*Solving fixed-point equations on semirings*

20. June 2011  Prof. Dr. Nicole Schweikardt, Goethe-Universität Frankfurt am Main  
*On the expressive power of invariant logics*

20. June 2011  Prof. Dr. Markus Lohrey, Universität Leipzig  
*Algorithmische Modelltheorie und Verifikation unendlicher Systeme*

15. June 2011  Dr. Byron Cook, Microsoft Research, Cambridge, UK  
*Proving that programs eventually do something good*
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<td>Stochastic Hybrid Systems: Reachability and Related Properties</td>
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<td>27. April 2011</td>
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<td>Characterizing the Influence of System Noise on Large-Scale Parallel Applications</td>
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<td>Frank Thuijsman</td>
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<td>Nash network formation in the one way flow model</td>
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<td>Modulare modellbasierte Spezifikationen und Entwicklung verteilter interaktiver Systeme</td>
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<td>Microsoft Research, Cambridge, UK</td>
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<td>TU München</td>
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<td>11. November 2010</td>
<td>Prof. Michael E. Houle</td>
<td>National Institute of Informatics, Tokyo</td>
<td>The Relevant-Set Correlation Model for Data Clustering</td>
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<td>9. November 2010</td>
<td>Prof. James P. Delgrande</td>
<td>Simon Fraser University, Canada</td>
<td>Parallel Belief Revision</td>
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4. November 2010  Prof. Dr. Volker Diekert, Universität Stuttgart  
*Aspekte der Theoretischen Informatik entlang der Goedel-Preise*

13. October 2010  Prof. Dr. Andreas Henrich, Universität Bamberg  
*LFRP-Search: Multi-Layer Ranked Visual Faceted Search – An Approach to Cope with Complex Search Situations*

7. October 2010  Prof. Dr. Jörg Flum, Albert-Ludwigs-Universität Freiburg  
*Optimale Beweissysteme und PTIME-Logiken*
## Diploma Theses

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<td>Entwicklung eines Merkmalsmodells zur Verwaltung von Systemen und Modulen in dem modellbasierten Entwurf von Elektrik-/Elektronic-Architekten (Development of a Feature Model for Management of Systems and Vehicle Modules within the Model-Based Design of Electric-/Electronic-Architectures)</td>
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<td>Hybride Parallelisierung der FEM Bibliothek iMOOSE zur Beschleunigung dreidimensionaler elektromagnetischer Feldberechnung (Hybrid Parallelization of the FEM Library iMOOSE to speed up Threedimensional Electromagnetic Field Computations)</td>
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<td>Integration der OCL in die Architekturmodellierungssprache MontiArc (Integration of the OCL into the Architecture Description Language MontiArc)</td>
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<td>A Machine-Learning Packet-Classification Tool for Processing Corrupted Packets on End Hosts</td>
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<td>Wei</td>
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<td>Timm</td>
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<td>Evaluierung von Stream Clustering Algorithmen (Evaluation of Stream Clustering Algorithms)</td>
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<td>Ramin Rezai Rad</td>
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<td>Djaber Said</td>
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<td>Entwicklung und Implementierung eines autark erweiterbaren Kommunikationssystems für kryptographische Protokolle (Design and Implementation of a Self-Sufficient Expandable Communication System for Kryptographic Protocols)</td>
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<td>Mark Schlößer</td>
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<td>Michael Schmitz</td>
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<td>Konsistenz zwischen Implementations- und Featuremodellen in der...</td>
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<td>Hossein</td>
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<td>Konzeption und Implementierung von Multimedia-Lastgeneratoren im open WNS (Conception and Implementation of Multi-Media Traffic Models in the openWNS)</td>
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<td>Ventsislava</td>
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<td>Workflow-Unterstützung für Managementprozesse in dynamischen Entwicklungsprojekten (Workflow Support for Management Processes in Dynamic Development Projects)</td>
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<td>Markus</td>
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<td>Automatische Erfassung von Körpersilhouetten mit Hilfe von 3D-Modellen (Automatic Tracking of Body Shapes Based on 3D-Models)</td>
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<td>Martin</td>
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<td>Entwicklung einer mikrokernelbasierten Sicherheitsarchitektur (Development of a Microkernel-based Security Architecture)</td>
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<td>Jan Chr.</td>
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<td>Typsichere Integration von Abfragesprachen in Scala (Type-safe Integration of Query Languages into Scala)</td>
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<td>Ontologie-basiertes Datenqualitätsframework für Datenstromanwendungen (Ontology-based Data Quality Framework for Data Stream Applications)</td>
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<td>Daniel Chr.</td>
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<td>Mehrpersonenspiele mit partieller und monoton wachsender</td>
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Information: Ein mengentheoretisches Rahmenwerk (Multiplayer Games with Partial and Monotonically Increasing Information: A Set-Based Framework)

Florian Weingarten Vollständig homomorphe Kryptosysteme in Secure Multi-party Computation (Evaluating the use of Fully Homomorphic Encryption in Secure Multi-Party Competition)

Sebastian Weise Outermost Termination von Termersetzungssystemen (Outermost Termination of Term Rewrite Systems)

Xunlei Weng Rekonstruktion von Gehirnaktivitäten mit dem OpenCL-Standard zur parallelen Programmierung von heterogenen Systemen (Reconstruction of Brain Activity with the OpenCL Standard for Parallel Programming of Heterogeneous Systems)

Martin J. Wermers Interaktionsmethoden für kleine Gruppen auf ortssensitiven mobilen Audioführern (Small Group Interaction Methods on Location-Aware Mobile Audio Guides)

Martin Weusten Kollaborative Rekonstruktion von 3D Stadtmodellen (Collaborative Reconstruction of 3D City Models)

Dirk Wilden Automated Transfer of Animations to 3D Characters

Christoph Wollgarten Energy Efficient Neighbor Discovery for Podcast Sharing on Mobile Devices under Linux

Hao Wu Semantics and Analysis of SADF Specifications

Wie Wu Three-dimensional Online Social Network Analysis

Bo Xiao Analyse von LTE-Access und Backhaul Link Performance (Analysis of LTE Access and Backhaul Link Performance)

Hongchao Xu Implementierung und Bewertung eines Demonstrators zur Wegewahl in heterogenen Netzen (Implementierung und Evaluation of a Prototype for Path Selection within Heterogeneous Networks)

Mohammad R. Yazdandoost Indoor/Outdoor Context-aware Queries in the Cloud

Yan Zhang Modellierung von Interferenz in heterogenen, drahtlosen Netzen (Interference Modelling for Heterogeneous Wireless Networks)

Xiaotong Zhang Analyse von Dienstgüteunterstützung in heterogenen Netzen (Analysis of Quality of Service Support for Heterogeneous Networks)

Jan H. Ziegeldorf Realisierung und Potential identitätsbasierter Signalisierung von Herkunfts- und Flussinformationen auf dem Kommunikationspfad (Enabling and Capitalizing Origin and Flow Information on the Communication Path using Identity-based Signaling)

Master Theses Software Systems Engineering

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<td>Solution Patterns for Variability in Model-based Product Lines</td>
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<td>Bratan</td>
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<td>Development of a Generic Report Engine with Domain-Specific Adaptations (hier liegt keine Arbeit vor, lediglich bei den Gutachtern)</td>
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<td>Stefan</td>
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<td>Conception of Collaborative Project Cockpits with Integrated Interpretation Aids</td>
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<td>Exploration of Different Stages of Feedback Details in Ubi Comp Environments -A Combinatory Approach Between Tactile and Visual Feedback</td>
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<td>Standards-Based Rules Centralization for Service-Oriented Enterprise</td>
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<td>Masterarbeit an der Universität Trento/Italien (es liegt keine Masterarbeit hier vor)</td>
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<td>Gomez Rozenkranz</td>
<td>Model Based Integration of Process Improvement Instruments</td>
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<td>SPRING: Speech &amp; Pronunciation Improvement through Games For Immigrant Hispanic Children</td>
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<td>Application of Graph Abstractions for Performance Evaluation of Wireless Ad-Hoc Networks</td>
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<td>Minimizing Energy Consumption Constrained by QoS Requirements in Multi-hop Wireless Networks</td>
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<td>Design Space Explorations of Ubiquitous Computing Applications Using Agent-Based Simulations</td>
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<td>Ricardo</td>
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<td>Systematic Tool Supported Tailoring of Metrics</td>
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<td>Guangwei</td>
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<td>A Toolchain for Adaptive Medium Access Control Protocol Design and Implementation - a Wiring Approach</td>
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**Master Theses Media Informatics**

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<td>Diana</td>
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<td>Design and Evaluation of Different Smoothness Constraints for Scene Flow Estimation</td>
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<td>Matrix Factorization for Graph Link Prediction</td>
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<td>Loredana</td>
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<td>Supporting Mobile Users of Shared Workspaces</td>
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<td>Abdalrahman</td>
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<td>Action Recognition in Still Images</td>
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<td>Concept and Evaluation of Mobile Application Server for IP Multimedia Subsystem</td>
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<td>Development of a Mobile Display and Analysis Unit for the IPANEMA Body Sensor Networks</td>
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<td>Discovery of Semantic Relationships in Schema Matching</td>
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<td>Brainstorming using Multi-Touch Tabletop</td>
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<td>Using Background Knowledge in Schema Matching and Ontology Alignment</td>
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<td>Practical Evaluation of Polygonization Algorithms</td>
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<td>Speech Technology for Computer Assisted Subtitling of TV Shows</td>
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<td>Anomaly Detection in Different Contexts on Mobile Phones</td>
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<td>Increasing Energy Awareness in Office Spaces: A Pervasive Game-Based Approach</td>
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<td>Twitter Author Analysis (Tweets - Stylistic Pattern Recognition)</td>
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<td>A Social Web Service Adaptation Portal Driven by user Context</td>
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<td>Mining Correlation Clusters in Subspaces of High Dimensional Databases</td>
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<td>Design and Implementation of a Content Rating and Recommender System for a Collaborative Work</td>
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<td>Comparison and Evaluation of Procedural and Stereo Modeling Techniques for Rapid Prototyping of Real Cities</td>
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Number of Diploma students in Computer Science
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## Number of Master students in Software Systems Engineering

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  Dipl.-Inform. Sascha Geulen
  Dipl.-Inform. Oliver Göbel (since May 2011)
  Dipl.-Inform. Thomas Kesselheim
  Dipl.-Inform. Marcel Ochel
  Dipl.-Math. Klaus Radke
  Dipl.-Inform. Benjamin Ries
  Dipl.-Inform. Melanie Winkler

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  Math.-Techn. Ass. Viktor Keil

• Student Researchers and Teaching Assistants
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  Sebastian Freitag
  Alexander Heinsius
  Russ Lucas Jukic
  Benjamin Kaminski
  Simon Keller
  Jonathan Meyer
  Jan Rappen
  Thomas Schleiden
  Michael Tegethoff
  Andreas Tönnis
  Lisa Wagner
  Martin Wohnout
• **Guests**
  
  Petra Berenbrink (Simon Fraser University)  
  Xavier Munoz (Universitat Politècnica de Catalunya)  
  Thomas Sauerwald (MPI für Informatik)  
  Alexander Skopalik (NTU Singapur)  
  Andreas Sprock (ETH Zürich)
Overview

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

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

During the last year, we successfully continued our work in algorithmic game theory and network algorithms. A focus of this year's work was lying on resource allocation for realistic network models with SINR constraints and for packing problems with gradually improving estimations on capacity bounds. In addition, we worked on the design of incentive compatible mechanisms for different variants of combinatorial auctions with valuations over multi-parameter domains.

A new junior professorship at the Lehrstuhl was established in April 2011. Prof. Martin Hoefer's focus lies in algorithmic game theory. This area is concerned with algorithmic challenges arising in distributed and networked systems, such as the Internet, wireless and mobile networks, or social networks. In this area, Prof. Hoefer's work addresses the impact of locality and strategic behaviour, and the design and analysis of local algorithms and protocols.

In recent years, he has worked on various aspects including game-theoretic analyses of resource sharing and network optimization problems, convergence aspects of dynamics in games, computational mechanism design, price setting, and cost sharing. This year the focus was on distributed algorithms for power control in wireless networks and matching and contribution problems with rational agents. The latter work was also awarded with a prestigious best paper award at ICALP 2011.
Game theory provides tools for the analysis of social interaction of self-motivated, rational agents. Rationality is usually captured in a way that agents are acting autonomously in order to maximize a utility function. This leads to much interest in the study of stable outcomes in games, making it the central topic in game theory. In strategic games the standard concept of stability is the Nash equilibrium - a state resilient to unilateral strategy changes of players. A drawback of Nash equilibrium is that it neglects coalitional deviations by groups of players; these are captured most prominently by the notion of strong equilibrium (SE) in which no coalition can strictly improve the utility of all participants, or even stronger concepts, such as super-strong equilibrium (SSE), where no coalition can deviate so that the utility of at least one participant strictly improves and for the others it does not get worse.

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

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

In this project, we significantly strengthen the partition equilibrium concept by considering coalitional deviations and equilibria based a rich combinatorial structure derived from a social network among the players rather than just partitions. In our case, (1) coalitions of players that execute a strategy change must be cliques in the graph, and (2) their decision must not strictly deteriorate any neighboring players. We introduce and study the solution concept naturally corresponding to considerate behavior: considerate equilibrium i.e., a state in which (1) no coalition formed by a clique in the social network can deviate so that the utility of at least one member of the coalition strictly improves and (2) none of the players neighboring the clique gets worse. Our study is focused on the existence of this solution concept for classes of games dealing with resource allocation problems.
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 the convergence time of power control dynamics in which selfish agents in a wireless network scenario can control their transmission powers. Besides giving a general bound for the convergence of best-response dynamics, we proposed a no-swap-regret learning algorithm and analyze its convergence. We also studied social networks where players strive to be matched to other players and the matching has a value specified by edge weights. We studied the convergence to matchings that allow no incentive to deviate.

For the following years we plan to address further questions related to wireless networks. Besides considering other stochastic channel models, we plan to analyze other issues in wireless networks like scheduling transmissions for broadcasting a message to all nodes. The main challenge here is the design of simple and reliable possibly distributed algorithms, which cope with local information, asymmetric interference relations and dynamically adjusting request structure.

In combinatorial auctions bundles of items are sold to agents which give bids for item sets according to their valuation of these sets. After collecting all bids, an allocation of items to agents as well as payments for the bidders are determined. The agents aim at maximizing their benefit. This might result in giving strategical bids instead of bidding according to their true valuation. In contrast to the agents, an auctioneer is interested in all participant's overall benefit (social welfare), so that he wants the agents to report their true valuation instead of any strategical value. For this purpose, we aim at finding mechanisms which ensure this desired behavior. Such mechanisms are called incentive compatible or truthful. Allocating items to the bidders often results in the need to solve the Independent Set problem, which is not only known to be NP-complete but cannot be approximated within a factor being smaller than $n^{(1-\epsilon)}$ in the general case.

In this project we want to take advantage of structural properties of the underlying objects to obtain better approximation guarantees for item allocation. In disk graphs, for example, where the graph's nodes are composed of circles in the plane, polynomial time approximation
schemes exist. Our current work focuses on a more general property called fatness. Here, geometric objects in which the fraction of the object's sizes in the different dimensions does not exceed a certain value, are considered.

Obtaining truthful mechanisms in general combinatorial auctions can be done by applying VCG payments to maximal-in-range allocation schemes. In those MIR mechanisms social welfare is maximized when performing item allocation on a fixed subset of possible allocations. The challenge in that case is to find an according subset, called range, that is suitable. This MIR property is important because the VCG payment scheme does not necessarily yield a truthful mechanism when the allocation is approximated only. In the special case of single-parameter auctions, the use of a monotone allocation algorithm is sufficient to getting a truthful mechanism. For this purpose, either non-monotone algorithms are modified or new approaches must be pursued. Especially in the first case there are many open question concerning the preservation of approximation guarantees. The adequate use of randomization can yield an algorithm which is truthful in expectation.

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**Online Packing with Gradually Improving Estimations on the Packing Constraints**

*M. Ochel, K. Radke, B. Vöcking*

We introduce and analyze a new online model for optimization problems that can be described in terms of a linear packing problem.

In previous online models, capacities of a packing instance are assumed to be totally known from the start, where the online information is given over time by gradually revealing new objects together with their respective capacity requirements and profits, that have to be rejected or added instantly (possibly multiple times) to the packing with respect to the capacity constraints.

Our model adresses the complementary case of an a priori fixed set of objects, defined by their requirements and profits, that may be packed while the exact capacities are initially unknown. Only by exploiting a resource, an improving estimation on the respective capacity can be derived in terms of lower and upper bounds (that differ at most by a factor alpha) on the remaining capacity. However, reallocation of already blocked capacities is not allowed.

A practical problem which fits naturally into this framework is the one of network lifetime maximization of sensor networks. There, sensor nodes have battery capacities which are not exactly known a priori, whereas the structures that may be packed are fixed from the beginning (e.g. broadcast trees). Only estimates of the sensor's battery capacities are known and these estimates become more and more accurate while using the capacities. In particular, the exact capacity of a sensor node is known only ex post, that is, when it is completely used up.

When designing competitive online algorithms for our online model, one can see that a trivial $1/\alpha$-competitive solution can be achieved by just optimizing the packing program with respect to the initial lower bounds. By recursively applying the same approach to exploit possible remaining capacities, one could hope to improve this competitive factor. However, it can be shown that this is not the case. This raises the question of whether it is possible at all to exploit the gradually improving capacity estimates?
In our study we could answer this question positively by developing an online algorithm with a competitive ratio of \( \ln(\alpha)/(\alpha - 1) \) on general linear packing problems. Also we have proven a complementary upper bound of \( O(1/\sqrt{\alpha}) \) on the best possible competitive ratio showing the limits of online algorithms using gradually improving capacity estimations.

**Competitive Buffer Management for QoS Networks**

*K. Al-Bawani*

In this project, we design and analyze online algorithms for the problem of buffer management in QoS networks. This problem is briefly stated as follows. A sequence of data packets, each with a non-negative value (priority), arrive one by one at a network switch, and are to be stored temporarily in a buffer (queue) inside the switch. While infinitely many packets may arrive in any time step \( t \), only one packet can be sent out of the switch at \( t \). Provided that the queue is limited in capacity, that gap between the arrival and transmission rates often results in buffer overflow. Upon the arrival of a packet, we want to decide whether to insert the packet into the queue or drop it, so that the total value of the sent packets (the weighted throughput) is maximized. We consider the preemptive variant of this problem, i.e., enqueued packets can be dropped before they are sent. The main handicaps to deal with when tackling this problem are uncertainty of future arrivals and that packets must be sent in the order of their arrival (FIFO).

Since it was introduced a decade ago, no online algorithm has solved this problem with a competitive ratio less than 1.73. We say that an online algorithm is \( c \)-competitive if, for any sequence of packets, the optimum throughput is at most \( c \) times the throughput of the online algorithm. It is also known that any algorithm cannot be better than 1.414-competitive. Exploiting the fact that all previous attempts to solve this problem were memoryless algorithms, we study online algorithms that store information from the past and use it to assess the process of preempting (dropping) enqueued packets. We focus on a special class of algorithms, the comparison-based algorithms, which do not address the actual values of packets, but rather the relative order between them. This restriction reduces general-valued sequences to sequences of values 0 and 1 only, a property that significantly simplifies the algorithm analysis.

**Design and Analysis of Algorithms in Wireless Networks**

*M. Hoefer, A. Fanghänel, T. Kesselheim, B. Ries, B. Vöcking*

Funded by DFG, UMIC Research Cluster in the Excellence Initiative.

For communication in a wireless network it is vital that concurrent transmissions do not interfere. To avoid collisions, one can assign multiple channels or different time intervals to the communication requests.
In research dealing with this problem of scheduling in wireless networks there is often a large gap between different approaches. On the one hand theoretical computer scientists analyze algorithms considering only simple interference models. This tends to oversimplify the physical aspect that for example result from different transmission powers used. On the other hand, there were engineers studying heuristics under complex, yet realistic models. However, they do not derive general performance guarantees.

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

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

With the insights obtained in the past years, we could proceed to more involved problems. This includes the design and analysis of secondary spectrum auctions. These are a novel approach to deal with the scarcity of spectrum for wireless services. We designed a general algorithmic framework, guaranteeing good approximation factors and incentive compatibility.

In the next year, we plan consider further realistic aspects in this setting. For example, we are going to evaluate algorithms we developed in simulations on realistic networks. Furthermore, we are going to consider more sophisticated models for signal propagation such as Rayleigh fading. The results indicate that our results are robust again changes in the model.

### Economical Caching: Online Learning for Buffering Problems

*S. Geulen, B. Vöcking, M. Winkler*

Funded by AlgoSyn.

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

Today, engineers use mainly heuristic algorithms for this kind of power management problems. These heuristics were developed using realistic test cases. Indeed, in these test cases these algorithms achieve a good performance, but in general they do not have any
guarantees on the quality of the solution. In the case of a hybrid car, a heuristic algorithm for a battery control unit can be optimized, e.g., for city scenarios (slow speed and stop-and-go traffic). If this condition is not fulfilled, the performance of this heuristic can be very bad.

This insight led us to a new research direction based on online learning: Consider a set of these heuristics and call each of them an expert. Based on this set, an online learning algorithm chooses in each time step an expert whose decision it wants to follow, under the objective of achieving an accumulated cost at most in the order of that of the best expert chosen from this set in hindsight. This cost difference is called the regret. There are algorithms whose regret per time step converges against zero if the set of experts is finite. But there are scenarios in which the set of experts is not finite. For example, a heuristic can depend on a parameter which is chosen from the real numbers. Another problem occurs if not all real numbers can be chosen in each time step, but only a subset of them, e.g., an interval. The gradient descent algorithm of Zinkevich cannot be applied in this setting directly. It is an open problem how this generalized problem can be handled.

Beside using heuristics given from engineers, there are several other ways of building experts. For example, experts can be based on complex models like Markov Decision Processes. For this reason, a cooperation with the Hybrid Systems Group and the Institute for Control Engineering is intended with the purpose of the construction of appropriate experts and the implementation of these experts together with an online learning algorithm in the control unit of a hybrid car.

Online-Algorithms With Advice

W. Unger

A new model of online-algorithms is investigated. In this model the online-algorithm may read a limited number of bits given by an adviser. The adviser has the same computing power and knowledge as the adversary. The focus of research lies in the comparison of the number of read bits with the competitive ratio of the online-algorithm.

For the colouring of outer-planar, SP and bounded tree-width graphs we did achieve good results. For outer-planar and SP graphs which are always 3 colourable we introduce two algorithms which use n bits for a valid 4 colouring. The first one read at most one bit for each given node, the second one may read more than one bit for some nodes and no bits for others. These algorithms are extended to bounded tree-width graphs.
Other Activities

Courses
Our group offered the following lectures and seminars:

**Winter semester 2010/11**
- Lecture on Computability and Complexity Theory
- Lecture on Algorithmic Graph Theory
- Seminar on Contention Resolution
- Seminar on Algorithmic Cryptography

**Summer semester 2011**
- Lecture on Efficient Algorithms
- Lecture on Algorithmic Cryptography
- Lecture on Algorithmic Game Theory
- Seminar on Advanced Algorithms
- Seminar on Recent Topics in Graph 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 editorial board of Distributed Computing
- Member of the program committee of 3rd International Symposium on Algorithmic Game Theory (SAGT), Athens, Greece, October 18-20, 2010
- Senior member of the program committee of 12th ACM Symposium on Electronic Commerce (EC), San Jose, USA, June 5-9, 2011

Martin Hoefers scientific activities
- Member of the program committee of 12th ACM Symposium on Electronic Commerce (EC), San Jose, USA, June 5-9, 2011
- Member of the program committee of 7th International Workshop on Internet & Network Economics (WINE), Singapore, December 11-14, 2011
Talks and Publications

Talks


Martin Hoefer: Contribution Games in Social Networks. Nanyang Technological University, Singapore, March 2011.


Martin Hoefer: Local Matching Dynamics in Social Networks. International Colloquium on Automata, Languages and Programming (ICALP), Zürich, Switzerland, July 2011.

Martin Hoefer: Considerate Equilibrium. Spain-Italy-Netherlands Meeting on Game Theory (SING7), Paris, France, July 2011.


Thomas Kesselheim: Convergence Time of Power-Control Dynamics. International Colloquium on Automata, Languages and Programming (ICALP), Zürich, Switzerland, July 2011.


Publications


Martin Hoefer. Local Matching Dynamics in Social Networks. In Proc. of the 38th International Colloquium on Automata, Languages and Programming (ICALP), Zürich, Switzerland, pp. 113-124, 2011. (Best Paper Award, Track C)


Staff

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

- **Secretary**
  Birgit Willms

- **Research Assistants**
  Dr. rer. nat. Joachim Kneis (until February 2011)
  Dipl.-Inform. Alexander Langer
  Dipl.-Inform. Felix Reidl (since March 2011)
  Somnath Sikdar, Ph.D.

- **Student Assistants**
  Fernando Sanchez Villaamil
Overview

Our teaching and research profile mainly consists of

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

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

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

Preprocessing of the input is an important step in computation. A preprocessing algorithm, also called a kernelization algorithm, is a computer program that takes as input an instance, applies a set of well-defined reduction and preprocessing rules and finally outputs a new instance whose size can be bounded by a certain parameter of the original input. For example, if one wants to decide whether a graph admits a vertex cover of size $k$, the application of a rather simple set of reduction rules reduces the original input instance to a graph with at most $2k$ vertices, called a linear kernel. For several problems we were able to show that there are linear kernels on large classes of graphs. Fix, for instance, an arbitrary graph $H$. Then for any graph $G$ that does not contain $H$ as a topological minor there exists preprocessing algorithm that outputs a linear kernel for the INTERVAL VERTEX DELETION and CHORDAL VERTEX DELETION problems, two well-known graph modification problems.
Research Projects

Algorithms for Graphs of Small Treewidth

Alexander Langer, Joachim Kneis, Peter Rossmanith

Funded by DFG under grant RO 927/8

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.
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.
Other Activities

Courses
Our group offered the following lectures and seminars:

Winter 2010/2011
• Lecture on ‘Exact Algorithms’

Summer 2011
• Lecture on "Datenstrukturen und Algorithmen"
• Proseminar on "Algorithm Engineering"
• Seminar on ‘Medizinische Bildverarbeitung’ (with Deserno, Kobbelt, Ney, Seidl, Spitzer)

Scientific Activities
Peter Rossmanith was program committee co-chair of IPEC 2011 in Saarbrücken.

Between February 2011 and March 2011, Peter Rossmanith visited the group of Prof. Juraj Hromkovic at the ETH Zürich, Schweiz, on a sabbatical to collaborate in the research area of online algorithms.
Talks and Publications

Talks


Peter Rossmanith: A Practical Approach to Solve Hard Optimization Problems of Graphs with Small Treewidth, CWI Amsterdam, Amsterdam, The Netherlands, April 2011.


Somnath Sikdar: Are there any Good Digraph Measures? Indian Statistical Institute, Kolkata, India, September 2011.

Publications


Technical Reports

Software Modelling and Verification

Staff

• **Faculty**
  Prof. Dr. Ir. Joost-Pieter Katoen
  Prof. em. Dr. Klaus Indermark
  AOR Priv.-Doz. Dr. Thomas Noll

  http://moves.rwth-aachen.de

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  Hongfei Fu, M.Sc.
  Dipl.-Inform. Friedrich Gretz (since Feb. 2011)
  Dr. Tingting Han (until Feb. 2011)
  Dipl.-Inform. Jonathan Heinen
  Dipl.-Inform. Christina Jansen
  Dr. Etienne Lozes (until Jul. 2011)
   (Alexander-von-Humboldt Stipendium)
  Dr. Alexandru Mereacre (until Jan. 2011)
  Viet Yen Nguyen, M.Sc.
  Dipl.-Inform. Maximilian R. Odenbrett
  Arpit Sharma, M.Sc.
  Falak Sher, M.Sc.
  Dipl.-Inform. Sabrina von Styp
  Dipl.-Inform. Haidi Yue
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  Markus Bals
  Henrik Barthels
  Lisa von Büttner
  Silvio de Carolis
  Jonas Dederichs
  Christian Dehnert
  Bernhard Ern
  Hussein Hamid Baagil
  Dirk Hauptmann
  Tobias Hoffmann
  Rafał Korzeniewski
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• **Visiting Scientists**
  Alessandro Abate (TU Delft, NL)
  Albert Benveniste (IRISA Rennes, F)
  Dragan Bosnacki (TU Eindhoven, NL)
  Marco Bozzano (FBK Trento, I)
  Souymodip Chakraborty (IIT Delhi, India)
  Taolue Chen (University of Oxford, UK)
  Andreas Classen (University of Namur, B)
  Pedro D’Argenio (University of Cordoba, Argentina)
  Hubert Garavel (INRIA Rhone-Alpes, F)
  Holger Hermanns (Saarland University, D)
  Daniel Kroening (University of Oxford, UK)
  John Lygeros (ETH Zurich, CH)
  Hua Mao (Aalborg University, DK)
  Alexandru Mereacre (University of Oxford, UK)
  Vivek Sarkar (Rice University, USA)
  Arnaud Sangnier (LIIFA, F)
  Mani Swaminathan (University of Oldenburg, D)
  Mark Timmer (University of Twente, NL)
  Yuri Yushtein (ESTEC, NL)
  Anton J. Wijs (TU Eindhoven, NL)
Overview

Enormous progress has been booked in our research during 2011 which is reflected in the list of publications at the end of this section. In particular, the results of the ESA COMPASS project have had a large impact in the last year. The availability of a tool-set together with the successful application of the developed techniques by companies, have led to invited talks, invited tutorials (e.g., on one the largest European aerospace exhibitions), and formal inquiries from several (large) companies. This year the GUI will be finished, and an in-house case study for a new satellite system at ESA has been completed. It is great to see – and enormously stimulating! – that verification and dependability analysis techniques that are based on a firm theoretical basis indeed can have practical impact.

In September the Aachen Concurrency and Dependability Week attracted 300 attendants from all around the globe to our university. This week, organised by our chair, consisted of:

- the 22nd International Conference on Concurrency Theory (CONCUR);
- the 8th International Conference on Quantitative Evaluation of Systems (QEST);
- the 6th International Symposium on Trustworthy Global Computing (TGC).

In addition 9 workshops and 6 tutorials were held by world experts in the field. The social program consisted of a reception in the historic Ballsaal in Aachen (see picture), and a guided tour, a boat trip and a banquet (on the boat) in Maastricht, The Netherlands. The ability to visit 3 countries in (less than) a single day excited many of the attendants. To conclude, ACDW 2011 was a great success both scientifically as well as socially.
Other highlights during 2011:

- Joost-Pieter Katoen received the Educational Price 2010 for the course on Data Structures and Algorithms;
- Alexandru Mereacre finished his doctoral studies with honours;
- Falak Sher received an award for the best Master Thesis in the Department of Computer Science in 2010.

On the personnel side, Tingting Han (postdoc) and Alexandru Mereacre (PhD student) both left to join the group of Marta Kwiatkowska at the University of Oxford (UK), whereas Henrik Bohnenkamp continued his career in industry. In addition, our Alexander-von-Humboldt visiting professor, Etienne Lozes (ENS Cachan, F) left to join the group of Martin Lange in Kassel. As new member to the chair, we welcome Friedrich Gretz, who started early this year as PhD student in the Research Training Group AlgoSyn.

To conclude: 2011 was a busy, successful and exciting year, and we are looking forward to what 2012 will bring us.

Joost-Pieter Katoen.
**Research Projects**

**QUPES: Verification of Quantitative Properties of Embedded Software**

*T. Han, J.-P. Katoen*

Funded by the Dutch Research Council (NWO)

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

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

Further, compositional reasoning is a key strategy in analysing complex systems as it allows the use of hierarchical and modular modelling formalisms like stochastic process algebras, stochastic activity networks or generalised 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.
The incorrect use of pointers is one of the most common sources of software errors. Proving the correctness of 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 programs with memory allocation that handle linked data structures which are potentially unbounded in their size.

After considering (possibly cyclic) singly-linked list data structures, the approach was extended to analyse 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 modelling 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 concretised again. This avoids the necessity for explicitly defining the effect of pointer-manipulating operations on abstracted parts of the heap.

The central issues in this context are correctness, usability, and efficiency. The first essentially boils down to the requirement that a nonterminal can always be concretised to the data structure from which it was abstracted. To ensure this property, we defined a novel normal form for hyperedge replacement grammars that is inspired by the well-known Greibach normal form for string grammars. Moreover we developed an algorithm for constructing a normalised grammar from a given hyperedge replacement grammar with bounded degree.

To improve the usability of the overall approach, the idea is to adopt learning techniques to automatically infer abstraction grammars for data structures. More concretely this means that the heap configurations arising during the execution of the given pointer-manipulating program have to be inspected at runtime, and that hypergraph production rules for generating these structures have to be found. This proceeds in an incremental fashion as more and more heap structures are created during runtime. The automatic generation of corresponding rules then circumvents the complex and error-prone procedure of developing grammars manually.

The incremental construction of grammars also raises new challenges with regard to the Greibach normal form that was mentioned in the previous paragraph. Efficiency will be improved by avoiding the re-computation of the normal form for the whole grammar, instead using an incremental approach where the normal form of the extended grammar is obtained by adding new Greibach rules to the normal form of the previous grammar. A first step towards this direction was taken by developing an incremental algorithm for deriving the Greibach normal form of a string grammar.

Another step for improving the efficiency of the approach was taken by developing an automata-theoretic concept for finding hypergraph embeddings, which is required for implementing grammar-based heap abstractions.
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 Modelling (SLIM) Language in which engineers are provided with convenient ways to specify a.o. nominal hardware, as well as software operations, timed and hybrid behaviour, (probabilistic) faults and their propagation, error recovery and degraded modes of operation. This language is based on the Architecture Analysis and Design Language (AADL) and its Error Model Annex which allows for the modelling of error behaviour. A kernel of the SLIM Language is equipped with a formal semantics that provides the interpretation of SLIM specifications in a precise and unambiguous manner. Systems are considered as a hierarchy of (hardware and software) components which are defined by their type (interface) and implementation. Components interact via ports allowing for both message-oriented and continuous communication. The internal structure of a component implementation is specified by its decomposition into subcomponents, together with their HW/SW bindings and their interaction via connections over ports. Component behaviour 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 parametrized “templates” to the engineers and thus offer a comprehensible and easy-to-use framework for requirement specification.

The properties are checked on the SLIM specification using rigorous analysis methods. The precise character of these techniques together with the formal semantics of SLIM yield a trustworthy modelling and analysis framework for system and software engineers. The formal analysis is based on state-of-the-art model checking techniques such as bounded SAT-based and symbolic model checking, and extensions of model checking with numerical and simulative means to reason about quantitative requirements such as performance and dependability. The analysis facilities support, among others: automated derivation of dynamic (i.e., randomly timed) fault trees, Failure Modes and Effects Analysis (FMEA) tables, assessment of Fault Detection, Isolation, and Recovery (FDIR) measures, and observability requirements for effective diagnosability by FDIR.

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

Present activities concentrate on improving both the applicability and efficiency of the toolset. Currently the SLIM models to be analysed have to be provided in a textual format that is based on the syntax of AADL. This requires users to perform text-based system modelling. The usability and adoption of the COMPASS toolset will greatly benefit from the possibility of graphical modelling, allowing engineers to specify systems in a graphical notation that eases the understanding of their architecture and behaviour. To this aim, a graphical editor for SLIM models is being under development.

Moreover we are addressing some shortcomings and limitations of the current dependability and performability analysis techniques of AADL models that been identified during evaluation. This particularly applies to systems that exhibit complex characteristics in terms of non-determinism, timed and hybrid behaviour, and discrete and continuous-time probabilistic errors. Our goal is to specify formal semantics for such models, and to develop novel and advanced techniques to support their analysis. In particular, compositional techniques exploiting the hierarchical structure of component-based models will be required to combat the state-space explosion problem. Corresponding approaches are currently investigated in the framework of a PhD on "Extending and Improving Formal Methods for System/Software Co-Engineering", sponsored by both ESA and Thales Alenia Space.
The MOVES group participates in the European research project "Quasimodo", funded by the European Commission under the IST framework programme 7 for Information and Communication Technology, ICT. The objective of this project is to develop theory, techniques and tool components for handling quantitative (e.g. real-time, hybrid and stochastic) constraints in model-driven development of real-time embedded systems. Ultimate aim is to increase the competitiveness of European industrial companies which develop, implement and deploy embedded systems.

More specifically, the project aims are:

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 code with predictable behaviour from quantitative models.
4. Improving the overall quality of testing by using suitable quantitative models as the basis for generating sound and complete 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 evaluation of the quality-of-service of Wireless Sensor Networks is mostly done by simulation. In the context of the Quasimodo and UMIC projects, and in cooperation with the company CHESS, Haarlem, NL, we evaluated the second generation of a gossiping MAC protocol (GMAC), a TDMA protocol for completely unconfigured wireless networks, which aims to maintain message propagation with energy as low as possible.

The new GMAC protocol is modelled with a specific radio model: SINR model of Gupta Kumar. And as network topology, we considered three different node arrangements: grid, uniformed distribution and Gaussian distribution.

Simulations, carried out with the MoDeST/Möbius tool set, show that comparing to the simple slotted Aloha protocol, the new GMAC has indeed a significant beneficial influence on
energy consumption for all the three networks. However, it also delayed message propagation. Furthermore, we discovered that GMAC with constant sending power may cause a lot of interference in dense area, and in sparse area, nodes may disconnect to each other. Hence we proposed a dynamic energy scheduling schema, so that a node can regulate its sending power with respect to its current number of neighbours. Simulation results show that for Gaussian networks, our dynamic power management not only improved energy consumption, but also accelerated message propagation.

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

<table>
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<tr>
<th>Formal Models of Microcontroller Systems</th>
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<tbody>
<tr>
<td>Th. Noll,</td>
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<tr>
<td>J. Brauer (Chair of Software for Embedded Systems)</td>
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Embedded systems usually operate in uncertain environments, giving rise to a high degree of nondeterminism in the corresponding formal models. Moreover they generally handle data spaces whose sizes grow with the memory and the word length of the respective microcontroller architectures. This, together with other effects, leads to the well-known state-space explosion problem, meaning that the models of those systems grow exponentially in size as the parameter values increase. Careful handling of both nondeterminism and large data spaces is therefore crucial for obtaining efficient methods and tools for analysis and verification.

The goal of this project, carried out in close cooperation with the Embedded Software Laboratory of our department, is to develop abstraction techniques to tackle this problem. With regard to control structures, a technique for refining loops in microcontroller programs has been developed. It is based on abstract interpretation using octagons and affine equalities in order to identify infeasible sequences of loop iterations. Our approach naturally integrates wraparound arithmetic during the generation of abstractions. Abstract interpreters operating on a refined control structure then typically derive strengthened program invariants without having to rely on complicated domain constructions.

With regard to data spaces, activities have been concentrating on static analysis methods for approximating the possible run-time values of data values. For this purpose, intervals have successfully been used for decades. Binary code on microcontroller platforms, however, is different from high-level code in that data is frequently altered using bit-wise operations and that the results of operations often depend on the hardware configuration. We therefore came up with a method that combines word- and bit-level interval analysis and that integrates a hardware model by means of abstract interpretation in order to handle these peculiarities. Both techniques have successfully been applied to a suite of benchmark examples.
Efficient model-checking algorithms exist for qualitative and quantitative properties for a range of probabilistic models. Their popularity is due to the presence of powerful software tools, and their wide applicability; security, distributed algorithms, systems biology, dependability and performance analysis, to mention a few. The main deficiencies of probabilistic model checking are the state explosion problem and the restricted treatment of data.

The state space grows exponentially in the size of system components and data domains. Whereas most abstraction techniques obtain smaller models by collapsing sets of concrete states at the model level, this project takes a radically different approach. We will develop and implement symbolic reduction techniques for probabilistic models. These techniques aim to reduce models by model transformations at the language level in order to minimise state spaces prior to their generation while preserving functional and quantitative properties. Our symbolic reductions will support data as first-class citizens, i.e., we will develop techniques to symbolically reduce formalisms for modelling probabilistic systems that are equipped with rich data types, allowing, e.g., probabilistic choices parameterised with data.

Our approach is based on successful symbolic transformation techniques in the traditional and timed setting, viz. linear process equations (LPEs). We will generalise and extend these techniques to probabilistic automata (PA), a model akin to Markov Decision Processes that is tailored to compositional modelling. The LPE technique is applicable to large or even infinite systems, and will be equipped with symbolic transformations such as confluence reduction, bisimulation minimisation and static analysis for PA.

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

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

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

### Invariant Generation for Probabilistic Programs

_F. Gretz, J.-P. Katoen, A. McIver (Macquarie Univ, Sydney)_

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

One way of finding annotations is to place them speculatively on the program, as parameterised formula containing only first-order unknowns, and then to use a constraint solver to search for parameter instantiations that would make the associated “verification conditions” true. In this project, we aim to generalise and extend constraint-solving techniques for invariant generation to probabilistic programs. This allows for the verification of probabilistic programs that cannot be treated with currently available automated techniques such as abstraction refinement together with model checking. This work includes theory development as well as prototypical tool development to illustrate the feasibility.
In Process Control Engineering controller for plants that are not correct with respect to their specification can cause fatal disasters, e.g. when tanks with acid run over, people get injured or too high pressure leads to explosions. Therefore an intensive testing of the controller is crucial but it consumes a lot of time and money.

Model based testing is one promising technique allowing the automatic generation of test-cases from a given formal model. In model based testing the specification is given by a transition system. A conformance relation formally defines under which circumstances an implementation is correct to the specification. Based on this relation test-cases are derived automatically and are used to for testing the real implementation. In this project, which is a cooperation with the institute for process control engineering, we apply the methods of model based testing on the plant controller in order to reduce costs, time and therefore to automate and systematise the testing process.

In order to apply model based testing first the specifications of controllers, given as sequential function charts, are translated to transition systems. Hence first rules for the systematic translation had to be developed. We started testing using a simple controller, i.e. a motor controller, which allowed us to use the already existing theories such as ioco and sioco including the testing tool JTorX. This test-cases are still in an early stage and therefore only allow testing for a restricted set of programs. Future research shall loosen this restriction.

Data-dependent control flow in combination with real-time behavior is an important feature of the plant controllers, e.g. the next action depends on the current filling level of a tank and it may be crucial that certain actions are executed within a certain time. Therefore this project looks at extending the existing test theory to allow real-time behaviour together with data-dependent control flow. We start by giving a formal definition in form of a transition system for representing systems that allow data-dependent control flow for inputs and outputs and real-time behaviour. Afterwards a symbolic trace semantic is defined. This semantic then is needed to define the conformance relation, which describes under which conditions an implementation is correct with respect to a given specification. Future steps will include to look at the applications such as on the fly testing. This then shall be implemented in the test tool JTorX and finally be used to test controllers in process control engineering.
Verification of infinite structures has been extensively studied in the past two decades. The motivation of this study is that (i) typical system components are often infinite-state (e.g., counters, buffers), which cannot be modelled by a finite-state system; and (ii) adding timed information to a finite-state system will also induce an infinite-state system.

The difference between finite-state and infinite-state verification lies in the fact that exhaustive traversal of the state space which is effective on finite-state systems cannot be applied to infinite-state systems. Thus new techniques should be developed. Currently, the study of infinite-state verifications is divided into two sub-areas: equivalence checking and model checking. In equivalence checking, the task is to check if two given system are equivalent under a pre-established equivalence relation. In model checking, the task is to check if a given system satisfies a certain property encoded by a logical formula.

In the non-probabilistic setting, namely on labeled transition systems, verification of infinite structures has been well studied. Various results have been obtained on infinite-state models such as Pushdown Automata, Petri Nets, etc. The aim of this project is to investigate infinite-state verification in a probabilistic setting. Probability is a mechanism to model uncertainty, which can be caused by randomised algorithms, unpredictable errors, or simply underspecification in system design.

Our main work is to study probabilistic model checking and probabilistic equivalence checking on probabilistic infinite-state systems. To do so, we may extend existing techniques on discrete infinite-state system to probabilistic setting, or instead discover new techniques if necessary.

Markov chains are widely used for the evaluation of performance and dependability of information processing systems. Extending Markov chains with rewards results in Markov reward models which are useful for analysing the average behaviour of executions in Markov chains. Equivalence relations are used to reduce the state space of Markov chains, by combining equivalent states into a single state. The reduced state space obtained under an equivalence relation called a quotient can then be used for analysis provided it preserves a rich class of properties of interest. Various branching-time relations on Markov chains have been defined such as weak and strong variants of bisimulation equivalence and simulation pre-orders. Their
compatibility to (fragments of) stochastic variants of CTL has been thoroughly investigated.

Stochastic model checking tools such as PRISM and MRMC have been used to model check interesting properties on Markov chains and Markov reward models, respectively.

The goal of this project is to explore and investigate the linear-time equivalence relations and interesting properties that are preserved under these equivalences for Markov chains. During the course of this project we also plan to study and explore if these linear-time equivalences are compatible with compositional modelling of systems. Next step would involve developing quotienting algorithms and implementing tools for computing these equivalences. Finally, we plan to extend the minimisation techniques developed for Markov chains to other more expressive models, for example Markov automata, Interactive Markov chains, Markov decision processes and non-probabilistic systems.

Efficient Multi-Core Model Checking

M. R. Odenbrett

joint work with dr. Dragan Bosnacki, dr.ing. Anton J. Wijs,
prof.dr. Mark G. J. van den Brand and prof.dr. Peter A. J. Hilbers
from Eindhoven University of Technology

Funded by the Dutch Research Council (NWO)

Our project aims at developing new algorithms for model checking, including probabilistic and stochastic model checking, that can exploit the parallelism of multi-core systems. We consider multi-core CPU as well as many-core GPGPU (CUDA) hardware architectures.

The main motivation for our work arises, as for so many other projects on model checking, from the well-known state space explosion problem. It limits the practicability of model checking by two important factors: memory and run-time. While long run-times can be seen as an annoying necessity to prove correctness, the memory requirements are strict hardware-based limiting factors. However, since the shift from 32 to 64 bit word sizes, modern computer architectures can address $2^{32}$ times more memory than before. Consequently, the memory bottleneck is relieved, at least for the time being. This led us to the conclusion, that now the run-time itself should be addressed. Given the fact that Moore's Law (doubling of transistor density roughly every two years) does not imply a corresponding increase of processor clock rates anymore but now leads to multi- and many-core processors, shared memory parallelisation of the model checking problems seems to us to be the way to go.

We plan to develop prototype implementations of the new algorithms in model checkers, like Spin and its extensions, as well as the probabilistic model checker MRMC. The prototype implementations will be validated on case studies including models of biological systems.
Today’s society relies increasingly on the correct and timely functioning of a large variety of information and communications technology systems. Can this reliance be justified? Dependability analysis answers this question. Rigorous and systematic dependability analysis must then play an important role in the design of such systems. Since many dependability properties are stochastic in nature, stochastic analysis techniques are crucial in developing reliable and safe computer systems.

The ROCKS project focuses on two system classes which are gaining prominence in the world of computing but which are not amenable to classic stochastic analysis techniques. Large scale homogeneous systems, such as wireless sensor networks and gossiping protocols, provide a challenge because of the sheer size of the systems involved. Safety-critical heterogeneous systems, such as production plants and automotive control systems, on the other hand consist of a number of very different components. The challenge here is to handle the diversity of system modalities.

Within ROCKS we further study how, given a system configuration or parameter set, the optimal design can be synthesised automatically. Attention will also be given to the study of architectural description languages which are increasingly being used to describe complex systems, but for which analysis techniques are often lacking. The members of the ROCKS project cooperate in four different research areas: Modelling, analysis, synthesis and case studies. In modelling we study how complex systems can be represented concisely, accurately and hierarchically. Analysis techniques to study the properties of such models are developed as well as synthesis techniques in order to automatically generate optimal models. Finally the applicability of the newly developed models and techniques is studied in a number of industrial case studies.
Other Activities

Joost-Pieter Katoen

- Member of the Steering Committee of ETAPS (European Joint Conferences on Theory and Practice of Software).
- Member of the Steering Committee of FORMATS (Formal Methods and Analysis of Timed Systems).
- Member of the Steering Committee of QEST (Quantitative Evaluation of Systems).
- Member of the Steering Committee of TACAS (Tools and Algorithms for the Construction and Analysis of Systems).
- Member of the Editorial Board of the Journal on Software Tools for Technology Transfer (STTT), Springer Verlag.
- 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:
  - Fundamental Approaches to Software Engineering (FASE 2011)
  - International Colloquium on Automata, Languages and Programming (ICALP 2011)
  - Perspectives of System Informatics (PSI 2011)
  - Concurrency Theory (CONCUR 2011) (co-chair)
  - Computer Aided Verification (CAV 2011).
- Invited speaker at
  - LIAFA Workshop on Automata and Logic for Data Manipulating Programs, Paris, France.
  - ETAPS Workshop on Hybrid Autonomous Systems (HAS), Saarbrücken
  - 18th Summer School on Computer Science (RIO), Rio Cuarto, Argentina.
  - 4th Summer School on Verification Technology, Systems & Applications (VTSA), Liege, Belgium.
  - 5th Int. Workshop on Reachability Problems (RP), Genova, Italy.
  - International Symposium on Interdisciplinary Modelling of Cyber-Physical Systems (IMCPS), Manchester, UK.
  - 4th Conference on Fundamentals of Software Engineering (FSEN), Tehran, Iran.
  - Member of the IFIP Working Group 1.8 on Concurrency Theory.
  - Member of the IFIP Working Group 2.2 on Programming Concepts
  - Member of the EPSRC Review College (Engineering and Physical Sciences Research Council), UK.
• General Chair of the Aachen Concurrency and Dependability Week:
  – 22nd Int. Conference on Concurrency Theory (CONCUR)
  – 8th Int. Conference on Quantitative Evaluation of Systems (QEST)
  – 6th Int. Symposium on Trustworthy Global Computing (TGC)
• Member of several external international PhD committees.
• Chairman of Selection Committee of Full Professorship on Logics and Automata Theory.
• Chairman of Evaluation Committee of Junior-Professorship on Theory of Hybrid Systems.
• Chairman of the Examination Board of Department of Computer Science.

Thomas Noll
• Student advisor for the following applied subjects within CS:
  Electrical Engineering, Civil Engineering, and Medicine
• Member of CS Commission for Teaching Service
• Member of the Program Committee of the following events:
  – Software Engineering Track at the 27th Annual ACM Symposium on Applied Computing (SAC 2012)
  – 2nd Analytic Virtual Integration of Cyber-Physical Systems Workshop (AVICPS 2011) at the 32nd IEEE Real-Time Systems Symposium (RTSS 2011)
  – 5th IEEE International Conference on Secure System Integration and Reliability Improvement (SSIRI 2011)
  – Software Engineering Track at the 26th Annual ACM Symposium on Applied Computing (SAC 2011)
Talks and Publications

Talks


Joost-Pieter Katoen. Can your CTMC keep up with your timed automaton? Talk, Quasimodo Meeting at Hydac, Saarbrücken, 2011. Project presentation.


Joost-Pieter Katoen. Can your CTMC keep up with your timed automaton?. Talk, Quasimodo Meeting at Hydac, Saarbrücken, 2011. Project presentation.


Joost-Pieter Katoen. Can your CTMC keep up with your timed automaton?. Talk, Technical University Delft, The Netherlands, 2011. Project meeting EU project MoVeS.


Publications


Joost-Pieter Katoen, and Barbara König, editors, 22nd Conference on Concurrency Theory (CONCUR), Volume 6901 of LNCS. Springer-Verlag, 2011.


Technical Reports


Programming Languages and Verification

Staff

- **Faculty:**
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  http://verify.rwth-aachen.de/

- **Secretary:**
  Elke Ohlenforst

- **Research Assistants:**
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  Dipl.-Inform. Fabian Emmes
  Dipl.-Inform. Carsten Fuhs (funded by GIF)
  Dipl.-Inform. Carsten Otto
  Dipl.-Inform. Martin Plücker
  Dipl.-Inform. Thomas Ströder (funded by DFG)

- **Student Assistants:**
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  Patrick Kabasci
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  Fabian Kürten
  Richard Musiol
  Janine Repke
  Tim Rohlfs
  Kristian Scholz

- **Technical Staff:**
  Arnd Gehrmann
Overview

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

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

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

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

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

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

In the winter term 2010/11, we held the lecture on \textit{Logic Programming}, a seminar on \textit{Verification Techniques}, and a seminar on \textit{Satisfiability Checking} (together with the group of Prof. Dr. E. Ábrahám). In the summer term 2011, we held the lecture on \textit{Term Rewriting Systems}, a seminar on \textit{Advanced Topics in Term Rewriting}, and a proseminar on \textit{Advanced Programming Concepts in Java, Haskell, and Prolog}.

From May to October 2011, Prof. Dr. Fausto Spoto spent a sabbatical in our group, supported by a research fellowship for experienced researchers by the Alexander von Humboldt foundation. Together with him, we worked on improving analysis techniques for Java Bytecode in order to apply them to large realistic programs.
We are developing a verification environment which allows a fast and easy implementation of new approaches and techniques for program verification. In this way, their practical applicability can be evaluated and experiments can be performed to develop heuristics which increase their degree of automation. The system is designed in a modular way such that the implemented techniques can be extended and modified easily.

Our verification framework is also applicable for teaching purposes in courses on formal methods, term rewriting, or program verification. The tool is written in Java and verification can be performed both in fully automated or interactive mode via a graphical user interface.
In particular, we design and implement a powerful automated termination prover within our system AProVE. Experiments on large benchmarks and AProVE's success at the annual International Competition of Termination Tools show that our system is currently among the most powerful termination provers available. The system can be obtained from

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

### Termination Analysis for Logic and Functional Programs

**J. Giesl, P. Schneider-Kamp, T. Ströder, R. Thiemann, D. De Schreye, F. Emmes, C. Fuhs**

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

### Termination Analysis for Imperative Programs

**J. Giesl, C. Otto, M. Brockschmidt, M. Plücker, T. Ströder, F. Spoto**

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

J. Giesl, C. Fuhs, M. Codish, P. Schneider-Kamp, R. Thiemann

This project is partially funded by the GIF and is a collaboration with the Ben-Gurion University (Israel), the University of Innsbruck, and the University of Southern Denmark. Here, we work on new efficient algorithms to tackle the search problems arising in automated termination proofs. In particular, our goal is to encode them as SAT problems in a suitable way and to investigate the use of SAT solvers in automated termination analysis. Moreover, we also explore the use of our approaches to SAT encoding in order to synthesize and minimize Boolean programs in the form of digital circuits.

Strategies and Combinations of Techniques for Termination Analysis

J. Giesl, C. Fuhs, M. Codish, A. Ben-Amram, F. Emmes, M. Plücker, Y. Fekete, P. Schneider-Kamp

Typically, a termination prover offers a large number of different termination techniques. In our project with the Ben-Gurion University (funded by the GIF), we explore approaches to combine several such techniques originating from different areas. In particular, we aim to couple size-change-based techniques (originating from logic and imperative programming) with rewrite-based techniques like dependency pairs. In order to increase the power and efficiency of termination proving, an important question is when to apply which of these techniques. While appropriate such strategies were developed manually up to now, in our project we examine the use of machine learning techniques in order to synthesize successful sophisticated strategies automatically.

Certified Termination Proofs

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

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

J. Giesl:

- Chair of the IFIP Working Group 1.6 on Term Rewriting and organizer of the WG 1.6 meeting, Novi Sad, Serbia, June 2011
- Editor of a special issue of the Journal of Automated Reasoning on the 5th International Joint Conference on Automated Reasoning (IJCAR ’10), 2011 (together with Reiner Hähnle)
- PC-Member of the 23rd International Conference on Automated Deduction (CADE ’11), Wroclaw, Poland, 2011
- PC-Member of the 22nd International Conference on Rewriting Techniques and Applications (RTA ’11), Novi Sad, Serbia, 2011
- PC-Member of the 10th International Workshop on Reduction Strategies in Rewriting and Programming (WRS ’11), Novi Sad, Serbia, 2011
- PC-Member of the 8th International Symposium on Frontiers of Combining Systems (FroCoS ’11), Saarbrücken, Germany, 2011
- Member of the Steering Committee of the Federated Logic Conference (FLoC)
- Member of the Steering Committee of the International School on Rewriting (ISR)
- Member of the Steering Committee of the Annual Termination Competition
- Research visit to the University of Paris-Sud, France, November 2010
- Research visit to the University of Nancy, France, June 2011
- Participant of the AlgoSyn Meeting, Rolduc, The Netherlands, November 2010
- Participant and laudatory at the Festkolloquium for Prof. A. Buchmann, Prof. S. Huss, and Prof. C. Walther, TU Darmstadt, Germany, November 2010
- Participant of the TeReSe Workshops in Amsterdam (November 2010) and Eindhoven (June 2011)
- Participant of the Seminar Deduction at Scale, Ringberg Castle, Germany, March 2011
- Participant of the 22nd International Conference on Rewriting Techniques and Applications (RTA ’11), Novi Sad, Serbia, May - June 2011
- Participant of the Workshop Two Faces of Complexity (2FC ’11), Novi Sad, Serbia, May 2011
- Reviewer for the Ph.D. thesis of Cody Roux (University of Nancy, France)
- Reviewer for the habilitation theses of Xavier Urbain (University of Paris-Sud, France) and of Temur Kutsia (University of Linz, Austria)
- Project reviewer for the DFG (several projects)
- Reviewer for many international journals and conferences
M. Brockschmidt:
• Participant of the TeReSe Workshops in Amsterdam (November 2010) and Eindhoven (June 2011)
• Participant of the 22nd International Conference on Rewriting Techniques and Applications (RTA ’11), Novi Sad, Serbia, May - June 2011
• Reviewer for several international conferences

F. Emmes:
• Research visit to the University of Southern Denmark, Odense, and the University of Aalborg, Denmark, March 2011
• Participant of the TeReSe Workshops in Amsterdam (November 2010) and Eindhoven (June 2011)
• Participant of the 23rd International Conference on Automated Deduction (CADE ’11), Wroclaw, Poland, August 2011
• Reviewer for several international journals and conferences

C. Fuhs:
• Editor of the Department Of Computer Science Technical Reports of RWTH Aachen
• PC-Member of the 21st Workshop on Logic-based Methods in Programming Environments (WLPE ’11), Lexington, Kentucky, USA, 2011
• Research visit to the KU Leuven, Belgium, October 2010
• Research visit to the Ben-Gurion University, Beer-Sheva, and the Tel-Aviv Yaffo Academic College, Israel, November 2010
• Research visit to the University of Oslo, Norway, December 2010
• Research visit to the University of Southern Denmark, Odense, and the University of Aalborg, Denmark, February 2011
• Research visit to the University of Sherbrooke, Canada, April 2011
• Research visit to the Queen Mary University, London, UK, September 2011
• Participant of the 17th International Conference on Logic for Programming, Artificial Intelligence, and Reasoning (LPAR ’10), Yogyakarta, Indonesia, October 2010
• Participant of the 8th International Workshop on the Implementation of Logics (IWIL ’10), Yogyakarta, Indonesia, October 2010
• Participant of the TeReSe Workshops in Amsterdam (November 2010) and Eindhoven (June 2011)
• Participant of the 17th International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS ’11), Saarbrücken, Germany, March - April 2011
• Reviewer for several international journals and conferences
C. Otto:
- Participant of the TeReSe Workshops in Amsterdam (November 2010) and Eindhoven (June 2011)
- Participant of the 22nd International Conference on Rewriting Techniques and Applications (RTA '11), Novi Sad, Serbia, May - June 2011
- Reviewer for several international journals and conferences

M. Plücker:
- Participant of the TeReSe Workshops in Amsterdam (November 2010) and Eindhoven (June 2011)

T. Ströder:
- Member of the Local Organization Team of the Odense Summer on Logic and Programming (Organization of the conferences LOPSTR, PPDP, WFLP, and AAIP in Odense, Denmark, July 2011)
- Springorum Award for excellent studies in Computer Science, June 2011
- Research visit to the University of Southern Denmark, Odense, Denmark, February 2011
- Participant of the AlgoSyn Meeting, Rolduc, The Netherlands, November 2010
- Participant of the TeReSe Workshop in Amsterdam, November 2010
- Participant of the AlgoSyn Workshop, Dagstuhl, Germany, March 2011
- Participant of the Joint Workshop of the German Research Training Groups in Computer Science, Dagstuhl, Germany, June 2011
- Participant of the 21st International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR '11), Odense, Denmark, July 2011
- Participant of the 13th International ACM SIGPLAN Symposium on Principles and Practice of Declarative Programming (PPDP '11), Odense, Denmark, July 2011
- Participant of the 20th International Workshop on Functional and (Constraint) Logic Programming (WFLP '11), Odense, Denmark, July 2011
- Participant of the 4th International Workshop on Approaches and Applications of Inductive Programming (AAIP '11), Odense, Denmark, July 2011
- Participant of the Summer School Marktoberdorf, Bayrischzell, Germany, August 2011
- Reviewer for several international conferences
Talks and Publications

Talks

J. Giesl: Laudatio for the 60th birthday of Prof. Dr. C. Walther, TU Darmstadt, Germany, November 2010

J. Giesl: Modular Termination Analysis for Java Bytecode by Term Rewriting, Seminar Deduction at Scale, Ringberg Castle, Germany, March 2011

J. Giesl: Modular Termination Analysis for Java Bytecode by Term Rewriting, Lehrstuhlseminar, RWTH Aachen, April 2011

J. Giesl: A Dependency Pair Framework for Innermost Complexity Analysis of Term Rewrite Systems, Lehrstuhlseminar, RWTH Aachen, May 2011

J. Giesl: A Dependency Pair Framework for Innermost Complexity Analysis of Term Rewrite Systems, Workshop Two Faces of Complexity (2FC '11), Novi Sad, Serbia, May 2011

J. Giesl: Programmiersprachen und Verifikation, Ringvorlesung für Oberstufenschülerinnen und –schüler, RWTH Aachen, June 2011

M. Brockschmidt: Modular Termination Proofs of Recursive Java Bytecode Programs by Term Rewriting, 22nd International Conference on Rewriting Techniques and Applications (RTA '11), Novi Sad, Serbia, May - June 2011

M. Brockschmidt: Automated Detection of Non-Termination and NullPointerExceptions for Java Bytecode, Lehrstuhlseminar, RWTH Aachen, September 2011

F. Emmes: A Framework for Automated Analysis of Runtime Complexity, University of Southern Denmark, Odense, Denmark, March 2011

C. Fuhs: Lazy Abstraction for Size-Change Termination, Lehrstuhlseminar, RWTH Aachen, October 2010

C. Fuhs: Lazy Abstraction for Size-Change Termination, 17th International Conference on Logic for Programming, Artificial Intelligence, and Reasoning (LPAR '10), Yogyakarta, Indonesia, October 2010

C. Fuhs: Optimizing the AES S-Box using SAT, 8th International Workshop on the Implementation of Logics (IWIL '10), Yogyakarta, Indonesia, October 2010

C. Fuhs: Generating Optimal Linear XOR-Programs, Ben-Gurion University, Beer-Sheva, Israel, November 2010

C. Fuhs: Optimizing the AES S-Box using SAT, University of Oslo, Norway, December 2010

C. Fuhs: Optimizing the AES S-Box using SAT, RWTH Aachen, January 2011

C. Fuhs: SAT-Based Synthesis of Shortest Linear Straight-Line Programs over GF(2), University of Southern Denmark, Odense, Denmark, February 2011

C. Fuhs: SAT Encodings: From Automated Termination Analysis to Program Synthesis, University of Aalborg, Denmark, February 2011

C. Fuhs: SAT Encodings: From Automated Termination Analysis to Program Synthesis and Beyond, University of Sherbrooke, Canada, April 2011

C. Fuhs: Automated Termination Analysis for Programming Languages via SAT Solving and Term Rewriting, Queen Mary University, London, UK, September 2011
C. Fuhs: Harnessing First Order Termination Provers Using Higher Order Dependency Pairs, Lehrstuhlseminar, RWTH Aachen, September 2011

T. Ströder: Termination Analysis of Real Programming Languages with Termination Graphs and Dependency Triples, TeReSe Workshop, Amsterdam, The Netherlands, November 2010

T. Ströder: Verification of Real Programming Languages, Tag der Informatik, RWTH Aachen, December 2010

T. Ströder: Term Rewrite System Synthesis for Termination Analysis of C Programs, University of Southern Denmark, Odense, Denmark, March 2011

T. Ströder: Term Rewrite System Synthesis for Termination Analysis of C Programs, Lehrstuhlseminar, RWTH Aachen, March 2011

T. Ströder: Term Rewrite System Synthesis for Termination Analysis of C Programs, AlgoSyn-Seminar, RWTH Aachen, March 2011

T. Ströder: Graph-Based Methods for Analysis and Synthesis of Programs, Joint Workshop of the German Research Training Groups in Computer Science, Dagstuhl, Germany, June 2011

T. Ströder: Benchmarking in Computer Science, Joint Workshop of the German Research Training Groups in Computer Science, Dagstuhl, Germany, June 2011

T. Ströder: A Linear Operational Semantics for Termination and Complexity Analysis of ISO Prolog, Lehrstuhlseminar, RWTH Aachen, July 2011

T. Ströder: A Linear Operational Semantics for Termination and Complexity Analysis of ISO Prolog, 21st International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR '11), Odense, Denmark, July 2011

T. Ströder: Graph-Based Methods for Analysis and Synthesis of Programs, Summer School Marktoberdorf, Bayrischzell, Germany, August 2011

R. Thiemann: IsaFoR - An Isabelle Formalization (not only) of Rewriting, Lehrstuhlseminar, RWTH Aachen, October 2010

F. Spoto: Julia: A Java Bytecode Static Analysis Tool, Lehrstuhlseminar, RWTH Aachen, April 2011

F. Spoto: Initialisation Analysis of Fields in Java, Lehrstuhlseminar, RWTH Aachen, May 2011


B. Cook: Proving That Programs Eventually Do Something Good, Informatik Kolloquium, RWTH Aachen, June 2011

S. Falke: Using a Compiler Intermediate Language for the Analysis of C Programs, Lehrstuhlseminar, RWTH Aachen, September 2011

C. Kuknat: SMT-Based Synthesis of Certified Termination Proofs, Lehrstuhlseminar, RWTH Aachen, March 2011

A. Dyck: Partial Argument Filtering for Termination Analysis of Logic Programs, Lehrstuhlseminar, RWTH Aachen, September 2011
Publications


Theory of Hybrid Systems

Staff

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  Daniela Lepri (University of Oslo, N)
• **Guests**
  
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  Moritz Hahn (Universität des Saarlandes, D)
  Prof. Dr.-Ing. Holger Hermanns (Universität des Saarlandes, D)
  Daniela Lepri (University of Oslo, N)
  Prof. Dr. Peter Csaba Ölveczky (University of Oslo, N)
  Dr. Anne Remke (University of Twente, NL)
  Dr. Tobias Schubert (Albert-Ludwigs-University Freiburg, D)
  Dr. Olga Tveretina (Karlsruhe University, D)
  Dr. Ralf Wimmer (Universität Freiburg, D)
Overview

Our junior research group "Theory of Hybrid Systems", led by Erika Ábrahám, was set up in 2008 in the context of the Excellence Initiative. After 3 years, the group was positively evaluated this year and got an extension for the second acting period of further 2 years.

We are happy to welcome Florian Corzilius as a new research assistant started April 2011.

Our main research interests cover (1) the modelling, synthesis and analysis of hybrid systems, (2) the analysis of probabilistic systems, and (3) decision procedures for real algebra, especially Sat-Modulo-Theories (SMT) solving, and their application in the above two areas.

Currently we are involved in four third-party-funded projects. The HySmart project (DAAD PPP), devoted to rewriting techniques for the modelling, simulation, and verification of hybrid systems in cooperation with the University of Oslo, is in its final stage. Two years of intensive collaboration lead to a number of joint publications, one of them distinguished by a Best Paper Award. The CEBug project (DFG), started last year in cooperation with the University of Freiburg, led to promising new approaches and we could successfully improve state-of-the-art techniques for the counterexample generation for probabilistic systems. We act as German site coordinator in the ROCKS project (bilateral DFG-NWO), aiming at the improvement of methods and tools for the analysis of stochastic systems. Finally, we actively participate in the AlgoSyn research training group. Ulrich Loup and Nils Jansen were the speaker respectively a member of the AlgoSyn steering committee till the mid of the year, and Johanna Nellen was elected as a member of the new board. We thank for their engagement, especially for the organization of the AlgoSyn Workshop 2011 and our excursion.

Besides research, we attach great importance to teaching. In 2011 we developed lecture notes for our lecture "Modelling and Analysis of Hybrid Systems". Currently we are developing new learning materials (lecture notes and video recordings) also for the lecture "Satisfiability Checking". The evaluation of our courses by the students (average mark 1.55) shows that they are very happy with the teaching quality, and appreciate the new materials.

In the tradition of the last years, we have again put much effort into different events to inform and motivate pupils and high-school students for the studies of computer science at the RWTH Aachen University (Schüleruniversität Informatik, Ringvorlesung “Was ist Informatik?”, Aachener Informatiktage, Girls' Day, Helle Köpfe). Ulrich Loup also contributes as mentor to the success of the RWTH TANDEM mentoring program for high-school students.

As the speaker of the Aachen Center for Young Researchers (AixCYR), Erika Ábrahám organized different seminars and took active part in the development of new structures for the support of young scientists.

Our group also contributed to the local organization of the Aachen Concurrency and Dependability Week 2011 (CONCUR/QEST/TGC).

Erika Ábrahám.
Research Projects

Counterexample Generation for Probabilistic Systems

E. Ábrahám, N. Jansen, J.-P. Katoen,
B. Becker, and R. Wimmer (Albert-Ludwigs-University Freiburg, D)

For the correction of erroneous systems it is crucial to provide detailed information about errors in the form of so-called counterexamples. Such counterexamples are system runs which lead to erroneous behavior and may - in the case of probabilistic systems - consist of large or even infinite sets of paths through the system. Although there already exist efficient algorithms and tools for the analysis of probabilistic systems, there is still no tool available for the generation of counterexamples. We develop new methods and tools that both apply model checking and compute counterexamples. To handle the state explosion problem, we provide abstract representations of counterexamples which are computed in a hierarchical manner.

Our work is embedded into the DFG project CEBug (Counterexample Generation for Stochastic Systems using Bounded Model Checking), the NWO-DFG bilateral cooperation program ROCKS (Rigorous Dependability Analysis using Model Checking Techniques for Stochastic Systems) and the DFG Research Training Group AlgoSyn (Algorithmic Synthesis of Reactive and Discrete-Continuous Systems).

HySmart: Hybrid Systems Modelling and Analysis with Rewriting Techniques

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

Advanced real-time computer systems pose a challenge to modelling formalisms, in that different aspects, such as, e.g., continuous and probabilistic behavior, advanced communication and interaction features, complex and unbounded data types, etc., must be captured. In this project we extend the rewriting-logic-based formalisms and algorithms of the Real-Time Maude tool to support the modelling and analysis of hybrid systems. Firstly, we develop basic classes as types that can be inherited for the convenient and intuitive modelling of complex hybrid systems. Secondly, we implement different numerical methods in Real-Time Maude and apply them to develop functionalities for simulation and verification.
Modular Synthesis and Analysis in Process Control Engineering
E. Ábrahám, J. Nellen, U. Epple (ACPLT), and D. Kampert (ACPLT)

Sequential function charts (SFCs) are a popular formalism to specify programmable logic controllers. Though there are verification methods for SFCs, without a model of the controlled system we cannot prove important properties of the continuous dynamic behaviour of plants. In this research project we extend the expressiveness of SFCs to additionally support the modelling of the continuous dynamics of the controlled physical system. Based on this extended modelling language of hybrid SFCs, we develop an algorithm for the verification of safety properties of plants, and provide tool support.

The verification algorithm uses counterexample-guided abstraction refinement (CEGAR) as follows: We first transform the discrete SFC into a hybrid automaton and use existing tools for its reachability analysis. If the analysis fails to prove correctness then we get a counterexample. We use this counterexample to add some information about the continuous dynamics of the plant to certain elements of the SFC. We continue with transforming the refined hybrid SFC into hybrid automata and re-run the analysis.

In a later step, we will also extend our methods to the synthesis and modular verification of hybrid SFCs.

SMT Solving for Real Algebra
E. Ábrahám, F. Corzilius, and U. Loup

Hybrid automata are powerful models to describe discrete controllers in continuous, real-world applications. Such models are often used in projects in the context of AlgoSyn, where control and process engineering are involved. In both the synthesis and the analysis of hybrid automata, highly tuned solvers for Boolean combinations of polynomial (in)equations over the real numbers play an important role.

On the one hand, most existing algebraic decision procedures focus on conjunctions of such polynomial constraints, but do not work well for arbitrary Boolean combinations. On the other hand, efficient SAT solvers can be used to handle the Boolean skeleton. Combining these approaches could lead to more efficient SAT-module-theories (SMT) solvers.

Unfortunately, currently available decision procedures for real-algebraic constraint systems are not directly suited for SMT embedding. In this ambitious project we develop adaptations of real-algebraic decision procedures to make them suited for being used in SMT solvers. Currently, we work on the SMT-adaption of three decision procedures (the virtual substitution method, the cylindrical algebraic decomposition method, and a method for computing realizable sign conditions).
State-of-the-art reachability analysis methods for hybrid automata use conservative over-approximations for state sets. The state sets can be represented using different geometric objects such as polytopes, zonotopes, ellipsoids, etc. Though several analysis methods were proposed in the literature, tools implementing those methods are still rare.

In this project we develop a C++ library supporting the fast prototype implementations of existing methods. We use our library to compare and evaluate the analysis methods and the representations. Additionally, we also work on novel algorithms and implement them using our library. E.g., we use a combination of Taylor models and geometric representations for the reachable sets such that we can also handle continuous dynamics specified by non-linear differential equations.
Other Activities

Erika Ábrahám

- PC member of the Int. Symposium on Formal Aspects of Component Software (FACS'11)
- PC member of the Int. Symposium on Fundamentals of Computation Theory (FCT'11)
- PC member of the Int. Conference on Simulation and Modelling Methodologies, Technologies and Applications (SIMULTECH'11)
- Member of the CS Commission for School and Pupils
- Speaker of the Aachen Center for Young Researchers (AixCYR)
- Member of the Commission Gender Activities in the RWTH Research Training Groups

Courses

Winter semester 2010/11
- Satisfiability Checking
- Seminar: Satisfiability Checking
- Practical course: Lego Mindstorms

Summer semester 2011
- Modelling and Analysis of Hybrid Systems
- Proseminar: Real Time Systems

RWTH Events Organized for Highschool Pupils
- Organization of Aachener Informatiktage 2011 (Workshop zum BwInf)
- Organization of Schüleruniversität Informatik 2011
- Organization of Ringvorlesung Informatik 2011
- Co-organization of Girls Day 2011 an der RWTH Aachen
- Contribution to Helle Köpfe 2011
Talks and Publications

Talks

Erika Ábrahám: Hierarchical Counterexamples for Discrete-Time Markov Chains, Talk presented at the 9th Int. Symp. on Automated Technology for Verification and Analysis (ATVA’11), Taipei, Taiwan, 2011.

Erika Ábrahám: Informatik ≠ Computer, Talk presented at the Schüleruniversität Informatik, RWTH Aachen University, Germany, 2011.

Erika Ábrahám: Informatik ≠ Computer, Talk presented at the Ringvorlesung "Was ist Informatik?", RWTH Aachen University, Germany, 2011.

Erika Ábrahám: The CEBug Project, Talk presented at the ROCKS project workshop, München, Germany, 2011.

Xin Chen: Choice of Directions for the Approximation of Reachable Sets for Hybrid Systems, Talk presented at the 13th Int. Conf. on Computer Aided Systems Theory (EUROCAST’11), Las Palmas, Spain, 2011.


Nils Jansen and Jens Katelaan: Hierarchical Counterexamples for DTMCs, Talk presented at the ETAPS Workshop on Rigorous Dependability Analysis using Model Checking Techniques for Stochastic Systems (ROCKS’11), Saarbrücken, Germany, 2011.

Ulrich Loup: GiNaCRA: A C++ Library for Real Algebraic Computations, Talk presented at the AlgoSyn Seminar, RWTH Aachen University, Germany, 2011.

Johanna Nellen: Confluence Analysis and Completion of Graph Grammars, Talk presented at the AlgoSyn Seminar, RWTH Aachen University, Germany, 2011.

Johanna Nellen: Ulrich Loup, Jan Oliver Ringert, and Wolfgang Thomas, Tutorial on Citation Metrics, Talk presented at the AlgoSyn Workshop, Dagstuhl, Germany, 2011.

Publications


Technical Reports


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  Dipl.-Inform. A. Lindt (since April 2011)
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  Dipl.-Inform. C. Mengi
  Dipl.-Inform. A. Navarro Pérez
  Dipl.-Inform. C. Pinkernell (BMBF funded)
  Dipl.-Wirt.-Inform. H. Rendel
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  Dipl.-Inform. M. Schindler (EU funded)
  Dr.-Ing. S. Völkel (EU funded)
  Dipl.-Inform. I. Weisemöller (EU funded)
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- K. Chatterjee, MA of Science

• Technical Staff
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- F. Leppers, Trainee MATSE
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- E. Lücke, Trainee MATSE (since September 2011)
- P. Schütze, Trainee MATSE (since September 2011)

• Student Researchers
Overview

In our third year with Bernhard Rumpe as Chair of the Software Engineering Group, we had been able to strongly extend our cooperations and research activities in all four fields: automotive, cloud computing, energy optimization and model based software development.

Our core research domains are the application of UML as well as domain specific languages (DSLs) 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. 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-homes, business processes, web systems, energy optimization, autonomous driving of cars, trucks and trains, requirements management, product line engineering and management of complex function nets.

On the one hand we were focussing on a good quality of our lessons, exercises and practicals. Besides the already existing lectures that are well received, we extended our range of lectures with Applied Software Engineering within the life cycle of Automotive Electronics (Dr. Ansgar Schleicher, DSA) and Generative Software Engineering for the Automotive Domain (Dr. Christian Berger, Audi). We reissued the second version of the first book concerning the topics of the lecture Model Based Software Development “Modellierung mit UML”. It was continuously revised and is now based on UML 2.3 and Java 6.

On the organisational side, we are involved in the Commission for Teaching (“KfL”) that deals with strategic issues for the computer science curricula and the Commission for Service Teaching (“KfSL”) that deals with lessons exported to other curricula. Both have the duty to ensure a good quality of the relatively new Bachelor/Masters programs, we are dealing with.
We took over the speaker’s position for the Forum Informatik and organized some very interesting talks. On the industrial side, our working group on Cloud Computing within REGINA is ongoing.

In this year we got several successful project proposals for funding from the BMWI, BMBF and EU that will further expand our group substantially. Furthermore, our Software Engineering Laboratory (SE Lab) has started some projects, partly in combination with industry, partly on our own projects, to deliver industrial strength software.

We also had the completion of two doctoral dissertations. Namely Thomas Heer and Steven Völkel finished their work and started their career at IVU Traffic Technologies respectively Volkswagen Financial Services. We thank them, assuming they have learned and explored the proper techniques, concepts and gained appropriate management skills for their future work. We wish them good luck in their new positions. Both Ph.D. theses are available at the book series “Aachener Informatik-Berichte, Software Engineering” by Shaker publishing, Aachen.

Quite a number of new papers have been published. We are especially proud having received the Springer Best Paper Award and the ACM Distinguished Paper Award of the MODELS 2011 International Conference for the paper: S. Maoz, J. O. Ringert, B. Rumpe:


Funding comes from various sources, including DFG, EU, BMBF and e.g. the following industrial partners Daimler, Bucyrus, Volkswagen, and Siemens.

We await an interesting and challenging forthcoming next academic year.

Link to research activities of the group: http://www.se-rwth.de/
Forum Informatik: http://www.fi.rwth-aachen.de/
Regina Working Group „CC“: http://www.se-rwth.de/ak-cloudcomputing/
Research Projects

Algorithmic Synthesis of Reactive and Discrete-Continuous Systems

J.O. Ringert and B. Rumpe

DFG Graduiertenkolleg AlgoSyn

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

We support these efforts with our modeling and software systems engineering experience in taming the complexity of the specification and development of distributed reactive systems. Part of our contribution to this goal is the development of languages and tools for specification, verification and synthesis. We currently focus on modeling languages for distributed components with asynchronous communication via message passing. Modeling the behavior of these systems as a specific type of automata allows high level specification and verifications as well as the synthesis to concrete implementations in certain cases.

During the last two semesters J.O. Ringert has served in AlgoSyn’s steering committee as one of four student members assisting in setting up the diverse and stimulating scientific and social program of AlgoSyn. B. Rumpe has given a special group tutorial on generative software engineering and organized and invited the AlgoSyn participants to interesting talks given by international guests.

COMPASS – Safety Management in Complex ATM System of Systems using ICT approaches

A. Horst, B. Rump and S. Völkel

In cooperation with University of York, THALES Information Systems, INNAXIS Research Institute

Air Traffic Management (ATM) systems are complex and heterogeneous; they comprise a large number of communicating and interdependent components and sub-systems. They are also predominantly safety-related systems; failures can result in major accidents, loss of property, or loss of life. During the operation of an ATM system, its constituent parts produce a high volume of system-level events (such as the health status of individual devices). Of interest in terms of safety management are those combinations of events that predictably and with a high degree of probability lead to a situation where safe operation is compromised. The challenge that we address in this project is how to identify combinations of events as they
The objective of this project is to provide powerful and more automated safety management support to human operators of complex ATM systems. This will be done by taking a pattern-based approach and by combining state-of-the-art technology from data mining, intelligent modeling and complex event processing. The combination will allow engineers to mine safety patterns from past data, filter and enrich these patterns using their expertise and domain knowledge, and then use these patterns to monitor running ATM systems in an automated manner. Monitoring will help to identify, and report to human operators, situations which could compromise the safe operation of the ATM system.

The project will deliver new and novel scientific techniques for identifying, encoding and exploiting safety information, along with new technical applications of these techniques. The delivered techniques and applications go beyond the nominal SESAR timescales, i.e., for exploitation by 2020. Specifically:

- It will deliver novel automated safety warning technology and techniques that offer substantial promise in reducing the amount of human intervention in identifying potentially hazardous situations and generating warnings to ATM experts.
- It will exploit and bring within the scope of SESAR research and development several novel technologies and theories from the ICT community specifically targeted at management of complex systems.
- It will deliver novel intelligent modeling techniques for safety management in ATM systems.

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

Since not only software-requirements are being included, a brief search throughout the whole product-development process is necessary to bring together the whole picture. Marketing, product management as well as vehicle and prototype testing and many other departments and teams are being analyzed during this project. While trying to find similarities between documents and processes, abstract data models are constructed to prepare the introduction of a continuous requirements management tool. The knowledge gathered from interviews is analyzed and structured to build a foundation with which four scenarios are being constructed, describing possible worlds of Volkswagen’s requirements management in 2020.
This allows for the detailed capturing of requirements for a continuous requirements management tool from tomorrow’s needs as well as from today’s.

**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 plants or concrete core activation. These facilities are monitored by a multitude of sensors, which produce measured data. The measured data is typically used to control the facility itself (control circuit), but not for integrated monitoring and controlling.

![Figure 1: The Energie Navigator framework](image)

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

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

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

An energy community platform is implemented as an innovative web system based on Google Web Toolkit. Users can register their buildings and report and comment optimization tasks. The platform provides a wide-spread energy expert knowledge network.

The interdisciplinary workgroup of the project consists of members of Department of Software Engineering (CS3), RWTH Aachen University, Institute of Building Services and Energy Design TU Braunschweig, Ingenieurgesellschaft für energieeffiziente Gebäude mbH (energydesign- braunschweig), synavision GmbH 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).
Global software engineering has become a common practice in many companies, as few can afford to produce software on their own and at a single location. But this leads to number of new challenges in software development projects. Quality management for example is much more difficult and schedule and budget overruns can be observed more frequently. Additionally global software engineering projects have to cope with different cultures, different languages, and different time zones – across companies, and across countries. The diversity of development locations on several levels seriously endangers an effective and goal-oriented progress of these projects.

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

Cost Reduction Through Mainframe Performance Tuning

R. Hildebrandt and B. Rumpe

In cooperation with itestra GmbH and several industrial partners

In the insurance and finance sector, most of the daily business transactions are processed on mainframe systems. For these systems, the computing power is paid based on a per-consumption-model. In context of the huge size of the systems and enormous amount of transactions processed on a daily basis, operation costs of mainframe systems often constitute significant portions of the overall IT budget of an organization.

Most of the applications running on mainframe systems have continuously increased their complexity throughout several years of maintenance and often consist of million lines of procedural code, written in legacy programming languages like COBOL.

Therefore inefficient algorithms and unnecessary processing often remain unknown, but waste vast amounts of the IT budget, up to a point where it might limit the overall business capabilities.
In cooperation with our industrial partners we analyze and optimize operative mainframe systems based on economical considerations. Our work includes the identification of economically relevant performance-problems, the design and implementation of efficient solutions, and the quality assurance of the optimized system-components. Common performance-problems, solutions, and quality assurance methods are disseminated in terms of anti- and solution-patterns, as well as an overall methodology.

**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 3. It supports an integrated definition of the concrete and the abstract syntax of languages and language modules, and the automatic generation of language processing infrastructure such as lexers and parsers. It also allows for efficient development model analysis and for development of code generators.

![Figure 3: Compositional Development of Languages with MontiCore](image-url)
A new major version, MontiCore 2, has been released in March 2011. Major improvements include coherent compositionality in language development, including concrete and abstract syntax, symbol table computation and context conditions, as well as compliance to the wide spread Eclipse Modeling Framework (EMF).

As future work after this release we plan to extend MontiCore by a model transformation engine and to deliver a library of languages and languages components.

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

O(SC)$^2$ar

A. Navarro Pérez and B. Rumpe

The O(SC)$^2$ar project (Open Service Cloud for the Smart Car), incorporating partners from industry and academia, is a member of the project cluster IT for E-mobility: Smart Car, Smart Grid, Smart Traffic which is funded by the Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie). The goal of O(SC)$^2$ar is to reinvent the combined EE and IT architecture of modern, inexpensive mobility via cloud-connected electric vehicles. Taking a fresh approach, two existing e-car prototypes will be extended with a cloud-based IT infrastructure that has components both in and outside the actual car. This IT infrastructure will enable car manufacturers, car fleet operators and the cars themselves to provide innovative new values in the areas of car customization, infotainment, car maintenance, fleet management and car-to-car communication.

The architecture of O(SC)$^2$ar is decomposed into (1) an open extensible cloud-based platform and (2) an open extensible in-car software platform. This architecture allows the car to provide services based on up-to-date information from the cloud as well as to itself provide information about itself to the cloud. In addition, the car can dynamically download software extensions from the cloud to extend and upgrade its own software. This architecture allows the car to be customized towards hardware variations, individual fleet operator demands, individual regional electric vehicle infrastructure demands and driver preferences. Customization affects the cars infotainment capabilities as well as his technological capabilities, like battery management and hardware monitoring. Due to its openness, the O(SC)$^2$ar infrastructure will enable third-party service providers to develop own service and car software additions and provide them for O(SC)$^2$ar-based cars.

The Department of Software Engineering will develop the in-car software platform that connects the car to the cloud and enables it to dynamically extend itself with software additions downloaded from the cloud. This platform will consist of an integrated, high-performance electronic control unit that integrates with the car’s EE architecture and its communication infrastructure. In addition, the platform will provide a touch-based, extensible user interface. The department will tackle the challenges of dynamically extensible, cloud-
based car software and its security and quality assurance. Thereby, $O(SC)^2ar$ serves as a testbed for generic Internet of Things concepts.

MontiWeb

D. Reiss and B. Rumpe

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

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

In 2010 and 2011, 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).
Task of this project is the development of a prototype tool that simulates distributed process chains of manufacturing industries. The tool simulates and compares different scenarios of concrete process chains to evaluate, if e.g. outsourcing of certain production steps in the modeled chain is worthwhile.

In a first step it is evaluated, if modeling of process chains using the existing ADL MontiArc is intuitive and catchy. As it is not the case for engineers, a DSL has been developed capturing the domain of process chains that also translates process net models into MontiArc models. MontiArc serves a simulation runtime and code generation for distributed information flow architectures based on timed streams. In order to reuse this simulation, runtime and code generator have to be extended to match the process net semantics. In a final step parameterization of the simulation is developed to handle certain scenarios with the generated simulator.

The SensorCloud project, incorporating partners from industry and academia, is a member of the project cluster Trusted Cloud which is funded by the Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie). Trusted Cloud aims to develop and evaluate innovative, robust, secure and law conform cloud computing solutions. Pilot projects will apply those solutions to industrial demands and thus demonstrate the benefits and trustworthiness of cloud computing. These pilots will especially address the current skepticism towards cloud computing observable in small and medium enterprises and their consumers.

The goal of SensorCloud is to develop a cloud-based platform that integrates basically every kind of distributed internet-connected sensor and actuator devices. Such devices may be located at a variety of places like personal homes, offices, cars, industrial plants, outdoor areas and so forth. SensorCloud serves as a central hub to which such devices can be connected via internet connection. It aggregates their data and controls their functions. Thereby, it manages devices and data from different domains, places and owners at the same time.
On top of its base of devices and data, *SensorCloud* provides an extensible and flexible service platform that is populated by “apps” from third-party developers. Those apps leverage the potential of the centrally aggregated devices and data, providing a rich, diverse and innovative supply of end user functionality. Bringing together owners and suppliers of internet-connected sensors and actuators, developers of services working on these devices, and the provider of the integrating cloud platform, the *SensorCloud* project enables a marketplace for innovative customer solutions that minimizes costs and hurdles for all involved players.

Data transparency is a major aspect of *SensorCloud*. The platform inherently secures and monitors the usage of devices and data based on customer-preferences. It allows the customer to track the usage of his devices and data, get notified or asked about single usages and define usage constrains.

The Department of Software Engineering uses *SensorCloud* as a pilot project to develop and evaluate new software engineering methodologies and tools specific to cloud software. Our approach integrates agile development principles with model-based development techniques. At its core is a set of cloud-specific architecture-oriented modeling languages. Those languages allow for the formal specification of the software architecture of cloud software as well as properties of that architecture like distribution, elasticity, robustness and monitoring. Based on these languages, we develop a set of tools that allow for analysis/simulation, code generation and testing.

**An Integrated Concept for Modeling Logical Software Architectures Using UML**

*A. Navarro Perez, J.O. Ringert and B. Rumpe*

*In cooperation with the BMW Group*

The development and maintenance of automotive software for embedded distributed systems requires knowledge and data provided by many different heterogeneous sources. These sources are for example databases, human readable documents or artifacts created in other
development tasks. Often these sources serve a specific purpose and thus have domain specific schema. When developing the architecture of a software component this knowledge can influence design decisions and for the model based generation of artifacts like code and documentation the data from different sources has to be made available and integrated.

In the current project we are developing an integrated view on the data that needs to be available during the development of the software component’s software architecture. We are developing prototypes that demonstrate how artifacts previously generated or manually created can now be derived and generated from this integrated source of data. The goals of this project are to facilitate the checking of consistency between the various sources and the generated artifacts as well as automating additional development tasks previously done manual.

Based on the integrated model of available knowledge we investigate ways to model (partial) views on the system targeted to assist comprehension of the software architecture for different use cases during system development. The resulting models are based on a UML profile and can be used for documentation, discussion and comprehension as well as maintenance and construction of existing and new software architectures throughout the software component development process.

Software Product Lines
T. Gülke, 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 (see picture) and VW Passat. More systems for other vehicles are in development and need their own hardware and especially software.

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

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

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

Functional variability is realized in MATLAB® Simulink through so called variability mechanisms. At DAIMLER AG there are both proprietary and commercial variability mechanisms in use. With Releases R2009b and R2010b, MATLAB has introduced two new
library blocks as variability mechanisms: (1) Model Variants and (2) Variant Subsystem. While the first one captures variability on model level, the second one extends the mechanism on subsystem level.

In this project, we have analyzed and evaluated Model Variants and Variant Subsystem blocks. The underlying mechanism has been considered, the operating mode has been discussed and their advantages as well disadvantages have been highlighted on the basis of various criteria. In particular, a comparison between corresponding proprietary solutions and the new mechanisms has been made in order to clarify, whether the new mechanisms can substitute or extend proprietary solutions.
Other Activities

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

There are three innovative long-term in house development projects at the SE Lab which gain more and more attention in industry. The MontiCore framework as well as the framework MontiArc for Software Architectures and the SSE Lab provide basic software solutions for efficient and fast development of high-quality software. These tools are already used by software developing organizations at different universities and demanded by several software houses. The Energie Navigator is a tool to monitor and optimize energy consumption of large buildings and plants and is elaborated in various industrial projects. The cooperation project Compass targets providing more automated safety management support to human operators of complex Air Traffic Management systems. We analyze the development and usability of software interface on mobile devices within different of our projects. To learn more about the projects at SE Lab, please see the dedicated project reports below.
In 2010, the SE Lab initiated the *Technology Forum*. Here, members of the SE Lab network, industry partners, students, and members of the chair, talk about innovative technologies and trends and exchange knowledge. We welcomed talks from industry partners, such as Thales, SAP, DSA, Ericsson, EMIC, Audi, Daimler, and BMW. Research assistants and their students presented new technologies in developing android and iPhone applications as well as web applications with Google Web Toolkit. Also Cloud Computing technologies were introduced here.

The connection to industry could be tightened by gaining lecturers from BMW AG, Daimler AG, Volkswagen AG, local and supra-regional IT companies as well as nameable universities. Last winter Prof. Dr.-Ing. B. Wolff from University Paris-Sud (Orsay) and Laboratoire de Recherche Informatique (CNRS) gave a lecture on the Isabelle Platform: A Perspective for Collaborative and Fine-grained Parallel Test Case Generation. In summer Prof. Robert B. France from Computer Science Department of, Colorado State University gave a lecture about Why Modeling is Essential to Software Engineering. This winter Carsten Busse, department manager Development Steering Electronics at Volkswagen AG will give a lecture about Innovations in Electronic Engineering. This concept of interaction is very promising and will be followed up. In reverse, we plan offer advanced and special trainings to software developers in enterprises.

Besides lectures, we enabled students in the *SE Research Camp* and also in practical courses to learn how to build smart phone applications and web services first and to apply them in the following by realizing software in a team. Here, several nice software products were generated such as the building information system GISELA with an Android and iPhone interface or the autonomous driving system within the CarOLO project for DARPA Challenge.

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

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

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

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

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

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

In March 2010, Prof. Dr. Bernhard Rumpe took over the chairmanship of the QFAM. As the highlight of the 2010/11 academic year, Prof. Rumpe and staff hosted the 2011 edition of the workshop Modellierung from March 2\textsuperscript{nd} to 4\textsuperscript{th}. It was our pleasure to welcome 30 of the most renowned experts on modeling at Rolduc abbey, Kerkrade.

In 2012, the Modellierung will take place as a conference in Bamberg from March 14\textsuperscript{th} to 16\textsuperscript{th}.
Since with Cloud Computing emerging and promising technologies come up and REGINA industry members are potentially affected as users and suppliers of such technologies, the new Arbeitskreis “Cloud Computing” was initiated in 2010 by Prof. Rumpe. The aim of the Arbeitskreis is to enable the industry members from REGINA to make decisions, if, how, and where they could switch to Cloud Computing technologies and find new business models. That is why concrete applications, challenges, and limitations of Cloud Computing are focussed in the panel.

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

Since 2010, the Arbeitskreis met for four times where the subject in general was presented by Prof. Rumpe and the scope and aims of the Arbeitskreis were defined. We had referees from EMIC and Ericsson as well as Vcodyne who presented a platform solution for e-Science and an infrastructure solution, Telecom Clouds, for providing networks as a service and Cloud Computing for business critical applications.

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

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

Conference Activities and Academic Administration

M. Nagl

• Vice Chair of the Accreditation Committee of EQANIE (European Quality Assurance Network for Informatics Education)
• Vice Chairman of German Informatics Faculties Conference (Fakultätentag Informatik)
• Member of the Board of 4ING (Union of the German Faculties Conferences of Mechanical Engineering, Electrical Engineering, Civil Engineering and Informatics)
• Accreditation Expert, Member of the Accreditation Committee of EQANIE (European Quality Assurance Network for Informatics Education)
• Chairman of the “Informatics Europe Committee on Faculty and Department Evaluation”
• Reviewer’s Board of the Innovation Alliance SPES of the German Minister for Research
• Member of the Finding Commissions for the Professorships “Institut für Kunststoffverarbeitung” and “Baustatik und Baudynamik”
• David-Kopf-Preis 2010, Member of the Evaluation Committee
• Colloquium of Graph and Model Transformation Berlin 2010, Member of the Program Committee
• AGTIVE 2011 (Application of Graph Transformation with Industrial Relevance), Budapest, Hungary, Member of the Program Committee
• Co-Organizer of the acatech/TU9/4ING-Symposium on “Ingenieurpromotion - Stärken und Qualitätssicherung”

B. Rumpe
• Organizer of REGINA-Arbeitskreis Cloud Computing
• Organizer of QFAM-Meeting, Kerkrade, March 2011
• Organizer of the Workshop Modelling 2011, Kerkrade, March 2011
• Member of Program Committee: International Conference on Model Driven Engineering Languages and Systems, Oslo, Norway, October 3-8, 2010
• Member of Program Committee: 25. Model-Based Testing for Embedded Systems, MBTES 2010
• Member of Program Committee and Author: Modellierung 2010, Klagenfurt
• Member of the Program Committee of Modellbasierte Entwicklung eingebetteter Systeme, MBEES 2011), Dagstuhl, 16.-18.2.2011

A. Haber
• Co-Organizer of the Workshop Modellierung 2011, Kerkrade, March 2011
Talks and Publications

Talks


Maoz S., Ringert J.O., and Rumpe B.: *Summarizing Semantic Model Differences*, Models and Evolution (ME'11), co-located with MoDELS'11, October 2011, Wellington, New Zealand

Maoz S., Ringert J.O., and Rumpe B.: *Semantically Configurable Consistency Analysis for Class and Object Diagrams*, 14th Int. Conf. on Model Driven Engineering, Languages and Systems (MoDELS'11), October 2011, Wellington, New Zealand

Maoz S., Ringert J.O., and Rumpe B.: *CD2Alloy: Class Diagrams Analysis Using Alloy Revisited*, 14th Int. Conf. on Model Driven Engineering, Languages and Systems (MoDELS'11), October 2011, Wellington, New Zealand


Maoz S. and Sa’ar Y.: *AspectLTL: An Aspect Language for LTL Specifications*, 10th International Conference on Aspect-Oriented Software Development (AOSD 2011), March 2011, Porto de Galinhas, Brazil


Nagl, M.: *Software-Architectures: An Integrative and Non-Mainstream Approach*, Universiti Teknologi Malaysia (UTM), Johor, Malaysia, 7. 2. 2011


Nagl, M.: *DFG-Projekte sind anders*, Workshop „Fit für die Forschung“, RWTH Aachen, 4.7.2011


Nagl, M.: *Managing Development Processes which Mostly are Dynamic*, Invited Talk, University of Victoria, British Colombia, Canada, Sept. 7, 2011


Nagl, M.: *Trying to Keep the Artefacts of Different Developers Consistent – The Role of Integrator Tools*, Invited Talk, Queen’s University, Kingston, Ontario, Canada, Sept. 12, 2011

Nagl, M.: *Integrators for Consistency Management, or How to Keep the Results of Different Developers Consistent?*, Invited Talk, McGill University, Quebec, Canada, Sept. 16, 2011


Ringert J.O.: *Semantics Supported Development of Distributed Interactive Systems*, Gemeinsamer Workshop der Graduiertenkollegs, June 2011, Dagstuhl, Germany


**Publications**


**Books**

![Image of books](image-url)
Software Construction

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  Ana-Maria-Cristina Dragomir
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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. Currently we are actively working in the following areas:

- **Metric-based Project and Process Management.** Like in other engineering disciplines, measuring is a prerequisite to determine the performance of processes and products. We are aiming to develop an integrated highly customizable measurement infrastructure.

- **Goal-based Process Improvement.** Different reference models (e.g. CMMI, SPICE, COBIT) are used by organizations to improve their software processes. A systematic and objective approach is developed to decide which reference models, parts of reference models, or combinations of them are best suited for the intended improvement.

- **Interactive Use Case based Prototyping.** Prototyping is an accepted technique to evaluate complex system behavior. Since prototypes are typically created manually prototyping may be time consuming. We develop a generative approach to automatically create interactive prototypes from use case based requirements specifications.

- **Reusing Domain Engineered Artifacts for Code Generation.** Model driven engineering uses certain diagrams to foster code generation. But these diagrams are rarely reused; overcoming this is one goals of this project.

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)
- OpenUMF (Use Case based Requirements Modeling Framework)
- MeDIC (Measure Documentation - Integration and Calculation)
- MoCCa (Model Composition and Combination Vault)

Teaching

We offer on the graduate level the following courses:

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

Furthermore we are responsible for the Software Engineering course of the master program Software Systems Engineering at TGGS, Bangkok, Thailand.

In 2011 Matthias Vianden (Software Quality Assurance) and Andreas Ganser (Beginners Course in Computer Science) were nominated in the category for best “teaching support” at the CS’s Open Day in December. Furthermore Simona Jeners (Pricope) successfully presented her research project and won a prize in the “One Minute Madness” session.
Software development has undergone several changes over decades and evolved from manual typing up source code to (partially) generating source code from diagrams. However, some of the motivating motives remained constant over time. One of which is the urge to reduce time necessary for developing a system. This is because development will remain a partially manual executed task as long as no way for completely generating software is found. Another motivation is the need for a certain quality which can be guaranteed upfront, if some parts of the system are generated from diagrams.

These and more motivating aspects have been extensively developed in the industries and largely discussed in science until model driven architecture (MDA), and model driven engineering (MDE) emerged. Both address the above mentioned aspects and comprise of several methods which include a domain specific modeling (DSM). This methodology brings about figures which maps the objects under consideration to models. Among these models are class diagrams as know from UML which are called domain models in these contexts.

While both approaches take these domain models as inputs for code generation, only MDE includes reuse in DSM. But this reuse remains rather rudimentary. Taking a closer look at model repositories one might suppose that these repositories are meant to store models so they can be reused rather easily in different projects. But the goals for these tools are totally different! All the available repositories (by and large) only consider versioning, migration, transformation, conflict detection, merging and search. This means, models are not related to each other, there is barely a description of models, no examples are present how the models could be used or no interfaces are defined which point to the most important aspects that could help reusing a particular model.

The goal of this research project is to bolster model reuse by providing interfaces attaching descriptions and providing examples. Furthermore, models should not be treated as in an isolated world, but related to each other, knowing not only that these models worked out together but even how they did. These relationships cross borders and overcome the usual reuse obstacles and unleash the full power of previously modeled knowledge.
Nowadays, the software market is expanding and clients are requesting better, faster, and cheaper software products. One important impact factor to project success is the quality of the applied IT-processes. Hence, more and more organizations are obligated to identify, structure, and improve their processes systematically. There is a variety of reference models known as maturity-, process- and quality-models as well as standards, norms, etc. that can be used. Organizations have to decide which of these models they want to use. The adoption of multiple RMs allows an organization to exploit synergy effects between them. On the one hand organizations can address co-coordinately different and common areas. On the other hand the weaknesses of a single RM can be overcome by the strengths of others.

The aim of this project is to develop a model based approach that provides an objective and semiautomatic selection of improvement practices of multiple RMs that best fit to an organization. To select the best suited practices the organizations’ internal processes, wishes, problems, environment etc. have to be considered. The selected practices have to address the improvement potentials of the internal processes and the organizations’ wishes. These are reflected by the goals of the organization. The selected practices should also be evaluated and filtered according to their return on investment. According to goals and on this analysis improvement practices can be selected that are extracted from similar or standalone practices from a build-in repository of all considered RMs. For an efficient implementation of the RMs, the traces between the improvement practices and their corresponding RM’ practices and the dependencies between the improvement practices are also given. For efficient adoption and further selection of improvement practices, the implementation of the improvement practices should be continuously monitored considering the given goals.

Interactive Use Case based Prototyping

V. Hoffmann, H. Lichter

Prototyping is a widely accepted technique to evaluate complex system behavior. Prototypes are especially helpful to analyze use cases that many stakeholders find complicated due to their abstractness and fragmentation. Nowadays prototypes are typically created manually and they are not directly connected to other requirements specification documents. Thus their development is expensive and often of sync with corresponding requirements specifications. Therefore we have devised a generative approach to derive interactive prototypes automatically from a use case based requirements specification.

Our approach is based on an integrated requirements model that combines functional use case models with user interface prototypes and domain concept models. Additionally we have defined a formal token-flow based execution semantic for this model.
Based on this requirements model we have created a fully automated transformation approach that is able to generate interactive behavior prototypes. The simulation runs are performed on UI mockups derived from user interface prototypes. This enables non-technical stakeholders to experience the behavior in a simple intuitive fashion and can additionally be used as basis for feasibility studies. Because of a specific structure of our generation approach we are moreover able to use the simulation proactively during requirements modeling.

During the last year we developed an integrated tool support called OpenUMF for the specification of all perspectives of the requirements model based on ViPER technology. Additionally we developed an integrated simulation environment that is able to generate and execute interactive prototypes from our requirements model. The generation approach is implemented in a flexible way such that it can be used to generate prototypes for only partially complete models. Thus the prototypes can be used for requirements inspections as well as proactively during requirements modeling.
Model-based Testing of Web Applications
T. Sattaya-aphitan, H. Lichter

External cooperation: TOT Public Company Limited, Bangkok

Nowadays many organizations are using web applications for e-business/e-commerce purpose. Hence, it is important to ensure the required quality of web applications before distributing them. In contrasts to traditional software, there are many aspects of web applications that are different. First, web applications typically implement a 3-tier-architecture comprising web browser, web server and database tier which are communicating by stateless protocols such as HTTP request and HTTP response. Second, each tier is implemented using a diversity of programming languages (e.g. HTML, JavaScript, JSP, PHP, ASP). Third, web pages are often generated from prior dynamic web pages which depend on their previous inputs and server's states.

There are many published approaches to test Web application. However, none of these approaches reflects the complete behavior of web applications. This project aims to develop a new model-based testing approach using structural analysis methods, called white–box testing. The basic idea is to transform the source code into an intermediate model which is used to generate test cases, test setup information and test oracle information. In addition, our proposed approach introduces a novel coverage metric called “Content Coverage”. The generation procedure ensures that there are no duplicated and no un-executable test cases as well as 100% content coverage. The approach should guide testers to setup the test environment before running the test cases (e.g. selecting input data and parameters needed to run the tests) and aims to produce expected results which can be automatically compared to the actual program execution.

Metric-Based Project and Process Management
M. Vianden, H. Lichter

External cooperation: Generali Informatik Services, Aachen

It is commonly known, that projects management greatly benefit by the application of metrics. However, research shows that it is demanding to find the right metrics; 58% of all project managers and 50% of all senior managers find it difficult to collect, analyze, and use the right metrics. On the one hand, metric frameworks like GQM help to derive metrics from abstract goals for the project. On the other hand, defining measures just for one project (in a multi project organization with a lot of similar projects) is costly and ineffective. Hence, it is wise to reuse metric experience (metric definitions, evaluations, and models) as all experience can and should be reused.

Although considerable research has been devoted to the modeling of metrics and metric frameworks, rather less attention has been paid to investigating how the results of this
research (metric meta models, metric frameworks, and metric experience bases) can lead to a sound concept for metric reuse. Therefore, the aim of this project is to develop such a concept for metric reuse. The concept should be enriched by metric processes which include metric reuse as well as dedicated tool support for metric documentation, metric reuse and metric calculation.
Other Activities

- Member of the international program committee, 3rd International Workshop on Formal Methods and Agile Methods, Limerick, Ireland, June 20-24, 2011, H. Lichter
- Member of the international program committee, 26th Annual ACM Symposium on Applied Computing, Software Engineering Track, Tai Chung, Taiwan, March 21-25, 2011, H. Lichter
- Member of the international program committee, 5th IEEE International Conference on Secure Software Integration and Reliability Engineering, Jeju Island, June 27-29, 2011 H. Lichter
- Member of the program committee, Software Engineering 2011, Karlsruhe, February 27 – March 2, 2011, H. Lichter
- Member of the international program committee, IEEE ICCCSIT, 4th International Conference on Computer Science and Information Technology, Chengda, China, June 10-12, 2011, H. Lichter
- Reviewer for dpunkt-Verlag Heidelberg and computing reviews, H. Lichter
- Organization of the Computer Science Department’s mentors program, H. Lichter
- Member of the Computer Science Department’s committee for Lehre and Service-Lehre, H. Lichter
- Member of the examination board of Computer Science, H. Lichter
- Member of workgroup “Zusammenarbeit Hochschule und Industrie”, GFFT, Gesellschaft zur Förderung des Forschungstransfers, H. Lichter
- Member of the PhD defense committee M. Funk, TU Eindhoven, H. Lichter
- Member of the board of management AFST, Association for Social Technologies e.V., Aachen, H. Lichter
- Organization and member of workgroup “Messen und Bewerten”, REGINA e.V., H. Lichter, M. Vianden, S. Jeners (Pricope), A. Ganser
- Organization of the Beginner’s Course in Computer Science 2011, H. Lichter, A. Ganser, S. Jeners (Pricope)
- Member of Beginner’s Course Task Force, 2011, A. Ganser
- Member of Computer Science Faculty Committee, 2011, A. Ganser
- Member of RWTH Aachen University Scientific Staff Committee, 2011, A. Ganser
- Member of Steering Committee Computational Science Center RWTH, 2011, A. Ganser
- Member of Steering Committee ZLW/IMA, 2011, A. Ganser
- Member of workgroup “Qualität von textuellen Anforderungen”, GI, Gesellschaft für Informatik – Fachgruppe Requirements Engineering, V. Hoffmann
Talks and Publications

Talks


Publications


Staff

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  Prof. Dr. rer.nat. Dr. h.c. Otto Spaniol (Emeritus)

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  Dipl.-Inform. Georg Kunz
  Mónica Alejandra Lora, MSc
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  Dipl.-Inform. Raimondas Sasnauskas
  Dipl.-Inform. Benjamin Schleinzer
  Dipl.-Inform. Florian Schmidt
  Dipl.-Inform. Tim Seipold (until July 2011)
  Dr. Dirk Thißen
  Dipl.-Inform. Tobias Vaegs (since November 2010)
  Dipl.-Inform. Nicolai Viol
  Dipl.-Inform. Hendrik vom Lehn
  Dipl.-Inform. Elias Weingärtner
  Dipl.-Inform. Hanno Wirtz
  Dipl.-Inform. Alexander Zimmermann (until January 2011)

• Technical Staff
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  Rainer Krogull
Overview

Research at ComSys focuses on the development of flexible, scalable & resilient communication systems and the required models, methods, and tools to design, analyse, realise, and evaluate these systems.

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

With flexibility, scalability, mobility and resilience as key challenges in mind, the three important research areas:

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

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

In addition, the Chair is active in the field of ICT Standardisation Research.

Taught courses include
• Advanced Internet Technology,
• Mobile Internet Technology,
• Multimedia Internet Technology,
• Operating Systems and System Software,
• Data Communication and Security.

For further information please see: http://comsys.informatik.rwth-aachen.de.
Research Projects

Uncovering the Privacy Implications of Web Usage

Hendrik vom Lehn, Klaus Wehrle

Internet users visit a considerable number of websites every day. This makes keeping track of which information is disclosed to which site increasingly difficult. To aggravate this situation, the inclusion of third-party services into websites is often hidden or easy to overlook. Information leakage can therefore become invisible and opaque.

Having incomplete knowledge about disclosed information is not a problem in itself, but can have implications for the users' privacy. Knowing about potential information leaks, on the other hand, allows users to assess and utilize websites in an appropriate manner.

This project introduces a novel approach that tries to fill this information gap: By locally monitoring and analyzing web traffic for disclosed information such as visited websites or geotags in pictures, it becomes possible to confront users with their digital personality. In combination with details how the information has been disclosed and advice how to avoid this kind of information disclosure, users get a tool at hand that helps them to keep an eye on their privacy while surfing the web.

UMIC Simulation Framework

Georg Kunz, James Gross, Klaus Wehrle

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

Model Complexity: Simulation models of wireless networks typically require a considerably more detailed modeling of the lower network layers than models of wired networks. In particular, the wireless channel and the physical layer demand precise models to capture the subtle effects and interactions of advanced wireless communication technologies such as MIMO transmissions or successive interference cancelation. Consequently, simulation runtimes increase drastically which in turn hampers the development process and in-depth evaluations.
Parallel Discrete Event Simulation: Being an active field of research for more than two decades, parallel discrete event simulation is supported by a wide range of network simulation frameworks. Despite this tool support, creating a parallel simulation model is still challenging and running simulations on a distributed simulation cluster is complex. At the same time, the increasing number and speed of processing cores in today’s commodity hardware makes a higher degree of parallelization very attractive and cost-effective for speeding up network simulation. Nevertheless, a key challenge in parallel simulations, in particular of wireless networks, is the efficient utilization of the available processing power.

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

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

*Jó Ágila Bitsch Link, Klaus Wehrle*

Natural behaviour of animals takes place in complex environments, allowing for a wealth of social and ecological interactions. While laboratory studies have been extremely useful to identify individual mechanisms of behaviour, the functioning of such behaviour in natural environments is still only poorly understood. Efficient means of animal monitoring in the wild as well as tools for modelling complex systems are required for a deeper understanding of phenomena such as spatial cognition, optimal foraging, social behaviour and learning, or multi-species interactions. Current telemetric approaches to animal monitoring are often limited by the range and bandwidth of radio-transmission, especially in large, subterranean, or under-water environments.

In this interdisciplinary project (in cooperation with the Department of Zoology at Tübingen University), we aimed at developing a novel system for animal surveillance in the wild, using tiny sensor node technology. Programmable sensor nodes with a multitude of sensing capabilities attached to the animals recorded data such as motion and vocalizations of the carrier. Upon encounter of another animal, sensor nodes interact, exchange and aggregate data on the time and participants of the meeting. Stationary base nodes at occasionally visited, but easily accessible locations collect the animal data for further analysis, like trajectory reconstruction.

As this project was coming to an end, we focused on the more general challenges in terms of communication, like the sporadic general connectivity and the lack of continuous end-to-end connections, in this case due to the subterranean environment and limited size and carrying capacities of the animals under research. We counter this challenges by neighbor discovery schemes, that do not require any synchronization while at the same time limiting the maximum discovery latency. Furthermore, we investigated geography based forwarding schemes for delay-tolerant forwarding.
In cooperation with the department of Engineering Geology and Hydrogeology, we are working on a sensor-based landslide early warning system. While, the system prototype was originally developed at the Geology department in cooperation with ScatterWeb, we joined those efforts bringing in our expertise in sensor node and network development (RatPack).

We contributed to a month-long running test-bed in an area being renaturalized after open pit mining. Furthermore, we help in the further development of the base stations and information processing, as well as updating the system to a more modern operating system that allows easier access for novice and casual programmers.

In the area of geological monitoring, wireless sensor systems are still very novel. We aim to lessen the gap between the current state of the art in computer science and other fields. Companies like Vattenfall are very interested in these developments for streamlining and simplifying their measurement processes.

Bringing smart navigation systems to indoor environments has long been a challenge, especially on resource constrained devices. In this project, we address this demanding task using only sensors readily available in modern smartphones. Building on our experience in previous projects (RatPack), we are detecting steps and directions and map them unto the route of the users using a variety of alignment algorithms from the field of bioinformatics, thereby being able to provide her with accurate turn-by-turn instructions.

Furthermore, we address the challenge of attaining indoor maps using a collaborative and incrementally deployable approach: We integrate our solution with OpenStreetMap (OSM). OSM, similar to Wikipedia, is freely editable, and very extensible with millions of contributors around the world, making it an ideal candidate for us. We firmly believe, that once a sufficient mass of tools and applications as well as public buildings support the jump-start of indoor navigation systems for consumer devices, we can crowd-source the further mapping of indoor environments.

While still in an early phase, the multi-faceted interdisciplinary nature of this project as well as the early results were very well received at the international conference on indoor positioning and indoor navigation (IPIN) and resulted in invitations as guest lecturer, possible cooperations with companies in this field and a journal invitation.
EcoCom – Efficient Power Management Using Out-of-Band Signalling

Tobias Vaegs, Klaus Wehrle

A tremendous amount of energy is wasted today, because computing devices are left running all the time even though they are needed only sporadically. Especially in office environments many devices (e.g., printers) are very rarely turned off, because they need to be available from time to time and because it is inconvenient having to switch them on and off manually. Existing solutions, such as Wake-on-LAN (WoL), provide support for managing the power consumption of the network devices remotely using an always-on data channel. However, these solutions are inefficient, because power to the network interface has to be maintained even when the host system is asleep just to ensure remote accessibility.

We propose a Wireless Sensor Network (WSN) based out-of-band signalling architecture for network interfaces, which minimizes the systems' power consumption during the large idle periods when nobody is using them. This is done by separating the data and control channels on the Internet-enabled devices using a low-power out-of-band signalling channel based on battery driven, energy scavenging devices. Unlike existing solutions, which only allow parts of the system to go in sleep modes, our architecture allows the whole system, including the main power supply, to be shut down.

QoE in Collaborative Wireless Local Area Networks

Mónica Alejandra Lora Girón, Klaus Wehrle

funded by B-IT Research School

One of the major’s contributions of Collaborative Wi-Fi Networks is to provide a widely distributed Wi-Fi access network in a low cost and ubiquitous way. In order to promote the participation of more actors (both Wi-Fi providers and users) and the success of this kind of emerging solutions is important to satisfy the expectations that the user has regarding the network and the services, increasing the Quality of User Experience (QoE)

As one might expect the wireless nature of the Collaborative Wi-Fi Networks imposes a set of challenges those have to be addresses in order to guarantee the QoE that the users are expecting.

In this project, we outline research challenges encountered to improve the overall experience of the user of Collaborative Wi-Fi Networks. Our approach is to study the effect of the user’s perception firstly modifying the way that the user picks the Access Point during the Wireless Association and then through efficient mechanisms that improve the experience of the user into a BSS.
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.
Multihop wireless networks, such as sensor-, ad hoc- and mesh-networks, although different share some common characteristics. All these networks exhibit link dynamics. Protocols designed for these wireless networks must overcome the challenge of link dynamics and the resulting churn in network topology. Due to structural and topological similarities, protocols developed for one class of wireless network should also be applicable in the other classes. However, network-layer protocols are usually developed for and tested in only one class of wireless network due to the lack of a platform that allows testing of protocols across different classes of networks. As a result, we unnecessarily constrain the range of settings and scenarios in which we test network protocols.

In this project, we develop TinyWifi, a platform for executing native sensornet protocols on Linux-driven wireless devices builds on nesC code base that abstracts from TinyOS and enables the execution of nesC-based protocols in Linux. Using this abstraction, we expand the applicability and means of protocol execution from one class of wireless network to another without re-implementation. We demonstrate the generality of TinyWifi by evaluating four well-established protocols on IEEE 802.11 and 802.15.4 based testbeds using a single implementation.

Enhancing the Quality of VoIP with Cross-Layer-Iterated Soft Information

Florian Schmidt, Klaus Wehrle

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

In current systems for wireless IP transmission of audio-visual signal, bit errors on a wireless link are detected by CRC on the physical layer and erroneous packets are discarded. However, many voice and video coding schemes make use of error concealment, and therefore prefer the reception of partially corrupted data to no data at all. Being able to receive partially corrupted data therefore is a vital point in enhancing the quality of VoIP communication, especially over wireless links, where bit errors are much more common.

However, if errors occur, the application needs to be made aware of these. Depending on whether it accepts partially corrupted data, it will receive the packet, or the packet will be dropped. An important problem here is the occurrence of errors in packet headers, because
these contain management information vital for identifying the correct receiver. These errors therefore have to be corrected while the packet is processed in the network stack.

One important building block is the use of soft information, that is, the confidence that the physical layer placed in its decision whether a bit decoded from the received analog signal is a 0 or 1. This approach has been used for some time already in turbo coding schemes, and is also used for specialized voice codecs. In a packet-switched network, however, the two decoders would reside in the APP and PHY layer, respectively, and therefore be separated. Cross-layer 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 in the same way as pilot bits, boosting the perceived speech quality of a VoIP stream after decoding with an iterative decoder.

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**Mobile ACcess: Mobile and City-wide Communication Environment for Secure Internet Services**

*Tobias Heer, René Hummen, Nicolai Viol, Hanno Wirtz, Klaus Wehrle*

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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 COMSYS, Informatik 8, and seven 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, which introduces secure tunneling, cryptographic identities, and certificates as primary security concepts to mitigate the lingering threats in Wi-Fi sharing communities.

The project progresses towards its end and we are now able to demonstrate and evaluate our prototype implementation in different scenarios. To this end, we created a “mobile” demonstration unit to present the network-related aspects of Mobile ACcess at conferences. In addition we created a stationary test-bed that integrates the component of all project partners. The stationary test-bed connects the test-networks of all partners and also includes selected access points in the city center of Aachen.
Device mobility plays an important role in the Mobile Access scenario. A user’s mobile device should be able to connect to the community network once and stay connected while moving as long as network coverage permits. Furthermore, the community-driven aspects of Mobile Access are based on the provisioning of authenticated access to the Internet through trusted entities within the community network in a decentralized fashion. In order to enable both node mobility and node authentication, we maintain an implementation of the Host Identity Protocol (HIP) called HIP for Linux (HIPL). Our research focuses on achieving fast handovers and on developing protocol extensions that allow for efficient in-network establishment of authenticity of the communicating peers and their generated data streams.

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

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

In today’s ubiquitous environment mobile users typically interact with a number of communication devices and services (e.g., PDA, smart phone, notebooks, PCs, media center, and remote services). Depending on their location and preferences they regularly switch between different devices (working contexts). A user who uses her mobile phone to take notes and make calls while roaming but prefers to take notes and do video calls with her PC while she is at home is such an example. It would be useful having the ability to migrate the call or any application in use from the mobile phone to the PC by only pressing one button, to save battery power of the mobile device, to give access to additional features like the above-mentioned video calls, or to provide more computing-intensive codecs which offer better...
voice quality. This example shows that supporting mobile users in their tasks is not only limited to maintaining uninterrupted network connectivity because typical users don’t only change their location but also their devices.

This project analyzes possibilities of describing applications and user preferences by a context model to allow for the migration of applications between heterogeneous devices in a device independent way. This enables application mobility by only migrating context information to another device during runtime. Migration of a context instead of a whole application is not only more efficient, but also opens the possibility to integrate even more use cases when combining it with composition aspects: as within a service-oriented architecture, an application could be composed of several functional building blocks, all characterized by parts of the context information. Thus, parts of an application always can follow the user on her mobile device, while more computing-intensive application parts are executed somewhere in the cloud. If the user changes to a PC, a fast reconfiguration of the application’s distribution can be done to adapt to the new user context, by only exchanging a few context control information. Prototypes for migrating applications are implemented for heterogeneous platforms to show the feasibility of this approach, with the goal to derive a flexible generic framework architecture to support migrating application developers.

SliceTime: Hybrid Evaluation of Distributed Systems

Elias Weingärtner, Klaus Wehrle

The goal of SliceTime aims at making the concept of network emulation accessible for the analysis of large-scale distributed systems. SliceTime relies on the integration of real-world prototypes, which are typically constituted by a software program, and a simulation, which models the context of the prototype. For example, the prototype may be the implementation of a network protocol, and the network simulation would model any arbitrary computer network in this case, for example, a corporate network or potentially a internet backbone which consists of a set of routers and network links. But why to combine network simulations with software prototypes? Network simulations allow one to conduct experiments in a simulated network in a flexible way. Simulation parameters can be easily changed, and a global picture of the entire network is available at any point in time. However, while network simulation mostly abstract from the detailed system behavior, such observations are possible with a real prototype in place. Here, it is possible to study performance metrics, such as memory and energy consumption as well as timing needs. Hence network emulation spans the gap between these worlds, compensating the weaknesses of each other.

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

• A first experiment has shown that SliceTime is applicable to large-scale scenarios with more than 10,000 hosts in the simulation. In the experiment, we investigated a emulation scenario with 15,000 nodes exchanging data in a P2P fashion.
• By porting the simulation engine to the ns-3 simulator, we are now able to leverage any ns-3 simulation set-up for investigations using our hybrid emulation framework.
• SliceTime has been extended for the analysis of 802.11 networks
Besides these contributions, we have also demonstrated the applicability of this methodology to the domain of embedded systems. We are also currently preparing the framework for benchmarking different BitTorrent implementations.

**High-coverage Testing of Communication Protocols Before Deployment**

*Raimondas Sasnauskas, Klaus Wehrle*

High-coverage testing of communication protocols is vital for pre-deployment bug cleansing, but has previously been difficult due to the limited set of available tools. The main challenge is to detect bugs that occur due to low-probability events or unforeseen interaction with the execution environment (e.g. OS). These events, due to their non-deterministic nature, have the potential to drive the distributed execution into corner-case situations hard to detect using existing testing and debugging techniques.

In our project, we designed and implemented KleeNet, a debugging environment that aims to effectively discover such situations before deployment. By running unmodified communication protocols on symbolic input and automatically injecting non-deterministic failures, KleeNet automatically generates distributed execution paths at high-coverage. Moreover, we generalized the problem space of SDE (Symbolic Distributed Execution) and developed an algorithm for significant elimination of redundant states during testing. In the next project phase, we will apply the ideas of KleeNet and SDE to selective symbolic execution – a novel method of transparent testing of unmodified (and even closed-source) software.

**Bright Brains in Computer Science**

*Helen Bolke-Hermanns, Kai Jakobs*

‘Bright Brains’ aim to convey to 4th-8th form students that computer science is much more than just programming, and that computer scientists are not necessarily nerds living in front of a computer screen feeding on Coke and fast food. That is, it will demonstrate how exciting and varied Computer Science can be.

The overall goal of the ‘Bright Brains’ project was “to develop course material to playfully introduce 4th – 8th form students to Computer Science”. This material is being made publicly available through the project web site. It has been designed to help teachers in the development of their own future courses.

More specifically, the objectives of the project included

- To demonstrate how interesting, exciting, and indeed fun Computer Science can be.
- To train the trainers (i.e., the teachers).
• To didactically improve the currently available (draft) course contents (especially through feedback from the students and the school teachers), and to design new contents. This will also include the development of a dedicated ‘hardware tool box’ (special deck of cards, specially prepared stationary, etc).

Material has been be developed for a number of course. Each such unit (and the associated material) were dedicated to a specific Computer Science topic. The underlying idea was that each of these topic is associated with, and can be explained through, a real-world ‘analogy’ that is comprehensible for the students. Sample topics include
• The ‘intestines’ of a computer (identification of individual components).
• ‘How can it be possible to scratch a CD?’ (error detecting codes).
• ‘Supercalifragilisticexpialidocious’ (how to deal with google translator)
• ‘“Rithmetics with 0s and 1s’ (Mystery of Binary Code).

The use of real-world analogies helps mitigate any potential fears of contact with universities and professors.

For more information please visit http://www.bright-brains.informatik.rwth-aachen.de/.

Netgrind – Ein Leistungsbewertungswerkzeug für Applikationen in Wireless Mesh Netzwerken

Benjamin Schleinzer

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

Peer-to-Peer techniques can be used in different ways which results in certain advantages, e.g. shared workload, redundant data storage, but also present new challenges, e.g. confidentiality and availability of data. Also the increased network load created by the communicating peers has to be considered. This means, during every step of the development the produced data volume needs to be kept low while data availability must be guaranteed. To streamline the development process we defined two data types: so called containers store metadata about the file system, directories or files and each container uses a unique celltree (a data structure organized as a tree consisting of single cells) as a data backend.
While communication protocols are researched in another group, my work focuses on the security of the file system. A critical aspect of our file system is that the content of the celltrees must be secured against unauthorized access or manipulation while sharing the content with multiple trusted users must still be possible. To satisfy this assumption and maintain the ability to store containers and celltrees on untrusted nodes strong encryption is needed. At the same time some data like the containers holding file system descriptors must be readable by everyone while still be resilient against manipulation.

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

Klaus Wehrle

PC member of the

- 3rd International Conference on Communication Systems and Networks (COMSNETS'11)
- 11th International Conference on Communication and Distributed Systems (KiVS'11)
- 8th International Conference on Wireless On-demand Network Systems and Services (WONS'11)
- 4th International Workshop on the Network of the Future (FutureNet IV)
- 4th International Workshop on OMNeT++ (OMNeT++'11)
- 11th IEEE International Conference on Peer-to-Peer Computing (P2P'11)
- 36th IEEE Conference on Local Computer Networks (LCN'11)
- 6th IEEE International Workshop on Practical Issues in Building Sensor Network Applications (SenseApp2011)
- ITU Kaleidoscope 2011, Track Technology and architecture evolution (K-2011)
- 9th European Conference on Wireless Sensor Networks (EWSN'12)
- IEEE International Conference on Communications, Next-Generation Networking Symposium (ICC'12 NGN)

Klaus has also been appointed member of the board of trustees of the Fraunhofer Institute for Communication, Information Processing, and Ergonomics (FKIE).

Dirk Thißen

PC member of the

- 7th Int. Conf. on International Conference on Web Information Systems 2010,
- 10th Int. Conf. on WWW/Internet 2010,

Kai Jakobs

Editor-in-Chief of the

- International Journal of IT Standards & Standardization Research,
- ‘Advances in IT Standards & Standardization Research’ book series,

Editorial Board member of the

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

PC member of the

- 4th ITU Kaleidoscope conference (Chair),
- 8th International Joint Conference on Computer Science and Software Engineering
- 7th Int. Conf. on International Conference on Web Information Systems 2010,
- 10th Int. Conf. on WWW/Internet,
• 7th Int. Conf. on Standardisation and Innovation in IT,
• 16th Int. Conf. of the European Academy for Standardisation

Reviewer for
• Technology Analysis & Strategic Management,
• Technovation,
• IEEE Communication Magazine,
• IEEE Transactions on Engineering Management,
• Technological Forecasting & Social Change,
• Organization Studies.
Publications


Hanno Wirtz, Robert Backhaus, René Hummen and Klaus Wehrle: Demo: Establishing Mobile Ad-Hoc Networks in 802.11 Infrastructure Mode. Proceedings of the Sixth ACM
Hanno Wirtz, Tobias Heer and Klaus Wehrle: A Generic Service Overlay for Wireless Mesh Networks. 3rd GI/ITG KuVS Fachgespräch on NG SDPs. Berlin, Germany.

Hanno Wirtz, Tobias Heer, Robert Backhaus and Klaus Wehrle: Establishing Mobile Ad-Hoc Networks in 802.11 Infrastructure Mode. Proceedings of the ACM MobiCom Workshop on Challenged Networks (Chants 2011), Las Vegas, NV, USA.

Hendrik vom Lehn, Jó Agila Bitsch Link and Klaus Wehrle: Work in Progress: Uncovering the Privacy Implications of Web Usage [Poster].

Jó Agila Bitsch Link, Christoph Wollgarten, Stefan Schupp and Klaus Wehrle: Perfect Difference Sets for Neighbor Discovery. Proceedings of the 3rd Extreme Conference of Communication (ExtremeCom 2011), Manaus, Brazil.


Mónica Alejandra Lora Girón: QoE in Collaborative Wireless Local Area Networks. Third International Workshop on Quality of Multimedia Experience - QoMEX 2011 (Abstract)


Information Systems

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  Luftschifftechnik GmbH & Co KG, ZLW/IMA 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 including logistics applications, metadata model management, and technology enhanced learning.

In the academic year 2010-2011, the group enjoyed once again a significant growth of third-party funding and reached close to 3 m€ in 2010. Large newly acquired projects include the European Network of Excellence GALA, the Gaming and Learning Alliance; and recently the eConnect project by the German Ministry of Economy (BMWi) in which from Jan. 2012 the ICT infrastructure for smart grids in eMobility will be explored with a consortium of regional energy providers.

Members of the group took leading roles in the organization and program chairing of international conferences, including the ICWL '11 conference in Hong Kong, and several summer schools and workshops in ontology matching, technology-enhanced learning, multimedia metadata, and cloud computing. An i5 team led by Dr. Krempels also organized the 2011 Informatics Summer party, and the i5 Soccer Team led by Dr. Quix won the Computer Science-internal championship InfoCup for the second time in a row.

The total personnel at Informatik 5 grew to over 40 researchers and administrative personnel, plus over 35 student assistants. The team represents almost 20 different nationalities. Doctoral theses were defended by David Kensche and Dominik Schmitz. David Kensche received the 2011 Friedrich-Wilhelm Prize for Best PhD Thesis in the Faculty of Mathematics, Informatics, and Natural Sciences, which comprises about 130 professorships; he joined the Aachen-based data warehouse enterprise Thinking Networks AG as Senior Systems Architect while Dominik Schmitz now serves as IT Director of the Central Library of RWTH Aachen University.

The cooperation with the Fraunhofer Institute for Applied Information Technology FIT continued in 2010, in research through many joint projects and personnel exchanges, in teaching through the Bonn-Aachen International Center for Information Technology (B-IT) and the B-IT Research School for Doctoral Training. Both the International Master Programs of B-IT and the B-IT Research School successfully passed extensive evaluations in 2011, which had to be prepared and coordinated by Informatik 5. For the first time, the new European accreditation agency EQANIE was active in Germany as part of this process, so that our master programs were the first computer science programs in Europe accredited both nationally and with the EuroInf label. The B-IT Research School now supports 32 scholarships, and a former RWTH library has been remodeled under our direction to improve the research training facilities. Another exciting highlight of the cooperation i5-FIT: Our 2010 Master Graduate in Software Systems Engineering, Georg Hackenberg (first ever to achieve a distinction (“Auszeichnung” in this degree) won the first prize of the Hugo-Geiger Award with which the Fraunhofer Society annually honors the best master thesis among its roughly 4,000 research students. Hackenberg, a former student researcher at UMIC, wrote his award-winning master thesis on marker-free gesture recognition at Fraunhofer FIT under the direction of Prof. Prinz and Prof. Broll (now TU Ilmenau). Last not least, Prof. Jarke, executive director of FIT, was appointed as Chairman of the Fraunhofer ICT Group, with 4,500 employees the largest ICT research organization in Europe, for the period 2010-2012; in this role, he is also member of the Fraunhofer Presidency.
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. Much of our work is linked to the Excellence Cluster “Ultra High-Speed Mobile Information and Communication (UMIC)” under the German Excellence Initiative. UMIC is the only Excellence Cluster fully dedicated to the field of information and communication technology approved in the first excellence competition in 2006. More than 20 institutions at RWTH Aachen participate in UMIC, aiming at interdisciplinary design of ultra high-speed mobile information and communication systems. Concepts and demonstrators for smart, mobile, broadband, low-cost systems will be developed to support the demanding applications of the next-decade mobile Internet. Informatik 5 works closely together with many institutes of electrical engineering, mechanical engineering, architecture, and computer science in two subprojects in the research area of “Mobile Applications and Services”.

Model Management and Data Integration Research

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Research in model management, funded in part by Excellence Cluster UMIC, 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 our 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 2011, the group worked on schema merging and schema matching. The schema matching framework has been extended to include background knowledge from structured and unstructured sources in the matching process. The methods for schema merging focus on a logical level, i.e., schemas have instance level semantics whereas the interrelationship among schemas are expressed in a fragment of first order logic. The goal is to investigate various fundamental aspects of schema merging including semantics, functional/operational properties, algorithmic, and expressiveness and efficiency, including the important aspect of minimizing the resulting integrated schema. The team developed a prototype capable of integrating relational schemas using a rather expressive language of relational data dependencies. A demo was shown at ICDE 2011 in Hannover to illustrate the feasibility in a data integration scenario, including query rewriting and query answering capabilities.
Furthermore, a novel Dataspaces framework aims at integrating heterogeneous disparate sources that do not necessarily confirm to a specific schema. In order to tackle the complexity that arises when managing heterogeneous sources, the group has developed a novel search method by extracting semantic associations among entities contained in a dataspace. This enables a domain-independent semantic search over heterogeneous sources, utilizing an open-source knowledge base for extracting semantic classes for the entities. The goal is to provide relaxed search services, enabling users to fulfill their information need even in scenarios when they have little or no knowledge about the underlying sources.

Mobile and Wearable P2P Information Management in Health Net Applications


In this subproject of the UMIC Excellence Cluster, 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 prototype was successfully demonstrated at the Lousberglauf 2011, an annual running event in Aachen with more than 2000 participants. Participants from the UMIC team were
equipped with a body sensor shirt for measuring vital parameters and a mobile device for data integration and analysis. The data collected on the mobile device was sent to other peers in the network. A trainer can thereby monitor the state of a running team on a mobile device. More complex data analysis can be performed on a server and other peers in the network can be notified if a critical situation is detected.

Informatik 5 develops the software on the mobile device for data integration, data exchange and data visualization, on the Android platform. The work on data integration and data exchange applies the basic research results of the model management project.

Furthermore, Informatik 5 organized the International Workshop on Managing Health Information in Mobile Applications (HIMoA) at the International Conference on Mobile Data Management (MDM) in Luleå, Sweden. Eight researchers from five countries presented their research results in the workshop. A highlight was the keynote talk by Prof. Upkar Varshney from Georgia State University, Atlanta, which gave a detailed insight into mobile and pervasive healthcare with its challenges and upcoming directions.

Cooperative Cars – CoCarX

M. Jarke, C. Quix, S. Geisler, S. Schiffer (Knowledge-based Systems Group), R. Rembarz (Ericsson GmbH Eurolab), Gordian Jodlauk (Ericsson GmbH Eurolab), M. Grintal, P. Roy, S. Weber

The Cooperative Cars (CoCar) project tested the suitability of UMTS technologies and their foreseeable extensions (such as LTE) for direct, targeted transmission of traffic data arising from both stationary and vehicle-based sensors. The CoCar project was a part of the research initiative Adaptive and Cooperative Technologies for the Intelligent Traffic (aktiv) led by the German automotive industry.
Informatik 5 cooperated with Ericsson in Aachen and Fraunhofer FIT and developed data models, algorithms and systems for data stream management systems as the core component for data processing in traffic information systems to realize multiple traffic applications. Furthermore, the project studied data (stream) mining algorithms for traffic applications. Based on a quality- and priority-based traffic information fusion architecture, Informatik 5 developed a simulation testbed to identify the properties of roadway networks and system design parameters which have a significant impact on the quality of the traffic applications. The simulation framework has been applied to the queue-end detection problem: Based on messages sent by CoCars (e.g., emergency braking or warning flashers) the system has to identify the location of the queue end. This is an important application as many accidents are caused by drivers not realizing a queue-end in front of them. In a second case study, the framework was used for traffic state estimation and the effect of multiple mining algorithms was investigated. A map visualization was implemented, and the data stream-based evaluation framework has been extended by a data quality component which provides a reliability measure to the information provided by the system.
ConceptBase - A deductive object manager for meta databases
M. Jarke, C. Quix, D. Kensche, S. Geisler, X. Li, M.A. Jeusfeld (Uni Tilburg, NL)

ConceptBase is a multi-user deductive object manager mainly intended for conceptual modelling, metadata management and model management. The system implements the knowledge representation language Telos which amalgamates properties of deductive and object-oriented languages. Since summer 2009, ConceptBase is available as an open-source system under FreeBSD license on SourceForge. In the academic year 2010/11, the group focused on continuous improvement of the system and removed several bugs.

Mobile Community Information Systems Research

Future Mobile Internet Services: Virtual Campfire
M. Jarke, R. Klamma, Y. Cao, D. Kovachev, M. Jansen (Sbg), G. Toubekis (Sbg), G. Aksakalli, A. Belur, M. Hackstein, S. Javaid, M. Lottko, G.M. Mbogos, P. Nicolaescu

Within Excellence Cluster UMIC, Virtual Campfire aims to provide professional communities an advanced framework to create, search, and share multimedia artifacts with context awareness easily and fast. Advanced multimedia storytelling approaches are based on metadata standards and Community of Practice concept. Requirements from professional communities are analyzed based on real research scenarios in cultural heritage management in Afghanistan together with the Aachen Center for Documentation and Conservation.

In 2011, we investigated three major themes: 1) a framework and infrastructure for mobile cloud computing (see below), 2) social network analysis methods for mobile communities, and 3) embedded research for professional communities in cultural heritage management in Afghanistan and Oman. Enhanced mobile user multimedia experience were studied on heterogeneous platforms (iPhone, Android), cloud-based media storage and intelligent processing. Social network analysis methods are applied to discover and support the development of mobile communities. The UMIC funding was complemented by doctoral student scholarships from several different sources.

Virtual Campfire prototypes were demonstrated at the annual UMIC Day 2010 and other academic events. Moreover, several academic events were organized to discuss emerging research questions in mobile multimedia management: The First IEEE PerCom Workshop on Pervasive Communities and Service Clouds (PerCoSC’11) -- organized by Informatik 5 (Yiwei Cao, Ralf Klamma, Dejan Kovachev) and Aarhus University (Christian Jensen) -- was successfully held in conjunction with IEEE International Conference on Pervasive Computing and Communications, March 21-25, 2011, Seattle, USA, and the Third International Workshop on Story-Telling and Educational Games in conjunction with ICWL 2010 (STEG 2010) continued the success of the first two workshops. The workshop proceedings are published in Springer’s LNCS series.
Cloud computing envisions the notion of delivering software services and customizable hardware configurations to public access, similar how public utilities (electricity, water, etc.) are available to the common man. The cloud abstracts infrastructure complexities of servers, applications, data, and heterogeneous platforms, enabling users to plug-in at anytime from anywhere and utilizes storage and computing services as needed at the moment. The goal of our mobile multimedia cloud (i5Cloud) is to provide infrastructure as a service (IaaS) and platform as a service (PaaS) for diverse services and applications in the domain of (mobile) multimedia and large-scale social network analysis.

A dissertation project by D. Kovachev investigates possibilities to augment the capabilities of weak mobile devices and develop middleware that can seamlessly offload the computing and storage of mobile applications into the cloud. Cloud computing technologies have been emerging recently as a solution to scalable on-demand computing storage resources that can be accessed via the Internet. The never ending strive for increasing mobile processing power and more data, clouds can be the best possible solution to augment the mobile execution platform. Furthermore, due to changing conditions in the mobile environments, context-awareness can play crucial role in delivering mobile services with best performance. This work is supported in part by the B-IT Research School.
B-IT Research School: Mobile to Mobile (M2M) multimedia service provisioning in future mobile networks

M. Jarke, A. C. Muzzamil

With the increasing number of mobile devices, mobile software has become a huge business industry providing vast technology and use case-driven consumer applications. Requirements for integrating diverse vendor-specific and legacy mobile applications have pushed the adoption of service-oriented computing principles in the mobile domain. Thus, mobile devices are now able to provide and consume Mobile Web Services (MobWS) simultaneously. Following several earlier Ph.D. theses in this area, a new PhD project in the context of the B-IT Research School tries to convert these server architectures into a fundamental platform for IP-based high-quality multimedia service delivery. The mobile applications are planned to be developed for the future IP networks, such as the IP Multimedia Subsystem (IMS), which is now seen as an application/service layer in the Long Term Evolution (LTE) and 4G cellular networks. The goal of the research is to efficiently combine existing and new communication standards to guarantee QoS delivery of multimedia services over mobile networks. Additionally, traffic performance of different ISO/OSI layers has to be analyzed in order to understand the overhead of enhanced server architecture and better use of future networks.

DAAD Project: Community-centered Semantics for the Detection of Faked Multimedia

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

This DAAD-funded dissertation project investigates the possibility of combining the capabilities of content-based similarity search and retrieval with the power of Web 2.0
techniques and community approaches to facilitate fake multimedia detection by means of providing semantics for faked multimedia search and retrieval. To realize these objectives, a study of the social aspect by means of trust built-up over time is coupled to concepts such as incentives engineering and collective intelligence to facilitate fake detection. Gaming with a purpose is used to overcome the cold-start problem. A trust-aware media quality profile is proposed to provide helpful metadata for classifying the media. The combination of content based multimedia and social interaction (trust, rates, and multimedia reputation) can be used as service to provide metadata able to infer semantics of multimedia in term of forgery. Social network analysis is used to rank experts, attacks are modeled to construct countermeasures to prevent attacks and developed robust expert ranking algorithm.

BIT Research School: Knowledge Discovery in Digital Libraries

M. Jarke, R. Klamma, M.C. Pham

Another ongoing Ph.D. project linked to UMIC within the B-IT Research School investigates aspects of Social Network Community Analysis. It aims to represent and analyze scientific knowledge in the field of Computer Science and develop recommendation techniques that support researchers to find conferences, journals and publications, to search for interesting research communities and potential collaborators. Social Network Analysis (SNA) is applied to discover the pattern of interaction between researchers, 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 2010-2011, we investigated the dynamics of computer science knowledge and research communities. A new model characterizes the development pattern of research communities of conferences and journals, and thus allows comparison of the development pattern of different communities in the same sub-discipline or in different research areas. Based on the data from two large digital libraries - DBLP and CiteSeerX, we performed time series analysis on social network analysis measures to qualify the development stages of a particular community in term of collaboration (co-authorship) and topical (citation) development. The result is useful for conference/journal organizers and stakeholders as well as community members to have an overview of their community, to identify potential problems and the solutions. The result was presented in ICALT 2011 and ECTEL 2011, and received great interest from conference organizers and participants.

DFG CONTici: Context Adaptive Interaction in Cooperative Knowledge Processes

M. Jarke, R. Klamma, A. Hannemann, C. Terwelp, M. Hackstein

The aim of this DFG-funded cluster project of four NRW universities is context adaptive systems for knowledge processes. The Informatik 5 subproject “Traceable Cooperative Requirements Engineering for Communities-of-practice” extends earlier context, process or
cooperation models by comprehensible evolution histories, thus leading towards a cycle of comprehensible information collection, processing and employment for learning and re-engineering. In 2010, a model for requirements engineering for communities of practice was formalized and published ("Bazaar der Anforderungen", Informatik Spektrum). In order to apply the proposed model previously developed services were extended and some other were additionally designed. The Bubble Annotation Tool service was integrated in our UMIC storytelling requirement engineering environment YouTell for story viewing and collaborative annotation. The service was extended to allow end-users to negotiate about the use case story elements remotely in form of a virtual RE workshop. A new Community Aware Interactive Narration Environment (CAINE) service realizes the community tagging of all the community generated elements and all executed actions by the community members within YouTell. Additionally, a service for monitoring user actions was integrated. Hence the requirements engineering process combines the analysis of social state of a community, the community generated content and the activities of the community members and thus implements the proposed model for requirements engineering for communities of practice.

DAAD IKYDA: Non-linear Digital Storytelling for the Battleship “G. Averof”

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

This project complements the empirical UMIC work by another case study in cultural heritage. Non-linear digital storytelling is an interdisciplinary research project with Harokopio University, Athens, starting in 2009 within the Greek-German IKYDA program of the DAAD. 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. The project was finished successfully in December 2010. Thirteen research assistants and students from both partners paid seven research visits to each other. Two Workshops on Storytelling and Educational Games (STEG’09 and STEG’10) were coorganized with the project partner. Two master theses on storytelling have been finalized, and five joint papers were published at conferences on information systems and GIS.
ROLE is an EU-funded large-scale integrating project within the 7th Framework Program in the domain of technology enhanced learning (TEL). The project aims at delivering and testing prototypes of highly responsive TEL environments, offering breakthrough levels of effectiveness, flexibility, user-control and mass-individualization, thereby advancing the state-of-the-art in human resource management, self-regulated and social learning, 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 (or mashup) new components and functionalities, which can be adapted by collaborating learners to meet their needs and to enhance the effectiveness of their learning. Informatik 5 is the vice-coordinator of the project, acting as technical leader and community facilitator.

Building on earlier results and ongoing efforts we further elaborated the idea of Social Requirements Engineering and the ROLE Requirements Bazaar, resulting in an initial journal publication for Informatik-Spektrum. Another focus was on real-time communication and collaboration in widget-based web applications using the XMPP protocol. As technical coordinator, we hosted and maintained crucial parts of the development infrastructure and released two versions of the ROLE Software Development Kit. To disseminate and exploit the ROLE vision and outcomes we coordinate the internal Enchantment project, aiming at demonstrations of ROLE results for different stakeholder groups, namely business, academics, and developers. These initiatives included co-organization of two workshops at the ICALT and UMAP conferences, focusing on self-regulated learning and personalization approaches in responsive open learning environments. We also initiated the 2nd ROLE Widget Enchantment Competition and co-organized the 3rd ROLE Developer Camp. To facilitate knowledge transfer to industry we were active in organizing ROLE events at the I-KNOW 2011 in Graz, Austria, the Professional Training Facts 2011 in Stuttgart, Germany and the Online Educa Berlin 2011, Germany.
GaLA gathers the cutting-the-edge European Research & Development organizations on Serious Games, involving 31 partners from 14 countries. Partnership involves universities, research centers, and developer and education industries. The GaLA motivation stems from the acknowledgment of the potentiality of Serious Games (SGs) for education and training and the need to address the challenges of the main stakeholders of the SGs European landscape (users, researchers, developers/industry, educators). GALA aims to shape the scientific community and build a European Virtual Research Centre aimed at gathering, integrating, harmonizing and coordinating research on SGs and disseminating knowledge, best practices and tools as a reference point at an international level. The other key focuses of the project are: the support to deployment in the actual educational and training settings; the fostering of innovation and knowledge transfer through research-business dialogue; the development high-quality didactics on SG by promoting and supporting courses at Master and PhD level.

In the first year, i5 has contributed expertise in several GaLA special interest groups (SIG) and technical committees (TC). These include the SIGs on Humanities and Heritage as well as on Personal and Social Learning & Ethics; additionally i5 has contributed to research field reports for the TC on Personalization & Artificial Intelligence, the TC on Interoperability, as well as the TCs on Psychology and Neuroscience. In June 2011, i5 had a successful week at the 1st GaLA Alignment School which was held in Edinburgh, UK. We presented results of several previous i5 projects of relevance to GaLA, giving lectures on Interactive Storytelling for Web 2.0 and Serious Games, and on Social Network Analysis and Serious Games. Additionally we demonstrated the YouTell interactive Web 2.0 storytelling platform that was developed at i5.
Learning Design Grid (LD-Grid) is a team of individual researchers from all over Europe, whose work is funded by the EU network of excellence STELLAR. LD-Grid aims to produce a concise, comprehensive and accessible set of resources which will empower educators and learners to participate in design discourse and practices in technology enhanced learning (TEL). These resources will enable learners and educators to collaboratively reflect on their goals and constraints, characterise contexts of learning, and devise viable means of achieving their goals within these contexts and in light of the constraints.

The outputs of this effort will include (1) an annotated mapping of representations of design knowledge in TEL (such as narratives, patterns and principles, scripts, scenarios, and sequences); (2) a review of existing banks of design resources and tools; and (3) an articulation of effective and accessible practices and methodologies for use of the above representations, resources and tools in collaborative reflection on learning design.

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

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

In the first year of the project, i5 has produced several key contributions to the project. We hosted and developed services for the project’s service portal for the European Commission at www.learningfrontiers.eu. We extended the Mediabase, which was established by i5 in the FP6 project PROLEARN, with new information on collaboration networks in EU funded projects, as well as with publications related to TEL, thus supporting TEL-MAP in achieving its mapping and roadmapping objectives. We were able to achieve synergies within i5 by (1) adopting and adapting cutting-edge widget developments from the ROLE project and by (2) adopting the established academic event recommender system (AERCS) developed at i5. In 2011, i5 has represented and disseminated TEL-MAP results in several project deliverables, at IEEE ICALT in Georgia, US, as well as at ADVTEL and EC-TEL in Palermo, Italy.

EU Life Long Learning Program TeLLNet: Teachers’ Lifelong Learning Networks
M. Jarke, R. Klamma, Y. Cao, Z. Kensche, M. C. Pham, R. Vuorikari (European Schoolnet), A. Sahib, T. Duong

The new EU Life Long Learning Project TeLLNet supports the development of European Schoolnet (www.etwinning.net) in cooperation with the European Schoolnet, Open University the Netherlands, and Institute for Prospective Technological Studies (IPTS) as one of European Commission Joint Research Centers. 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.

In 2011, we have finished the first project deliverable with the following two foci. One is modeling and establishment of a data warehouse for the large scale eTwinning data set. The other is application of SNA as a meta-competence to describe, represent and evaluate social and professional competence for teachers’ lifelong learning. The prototype Cafe has been presented and evaluated at several European Schoolnet workshops in Karlsruhe and Bonn, and has received positive feedback from the attendant teachers.

Since then, we have been continuing with time-series network data analysis. Dynamic social network analysis methods are applied to observe the development of the European teachers’ network over years. Papers of the research results have been / will be presented to the technology-enhanced learning communities at EC-TEL’11 and ICWL’11.
Life Science Informatics

ExPrimage
T. Berlage, D. Zühlke, M. Häusler, Y. Wang, E. Khabvirova

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

In the remaining period, the project mainly focussed on the unsupervised regional and structural analysis of breast cancer tissue samples using a number of different functional and structural labels scanned under an automated microscope. We analyzed the distribution patterns of hormone receptors by quantitative statistics of islands of hormone receptor activity. These could be related to patient outcome at least for a reasonable prediction of healthy patients, but due to the low number of available samples, no valid prognosis of severance could be made.

The set of tools that has been developed in the project will be very useful for the future analysis of pathology images. These tools include image registration, supervised and unsupervised classification, and a database and user interface for metadata annotation and visualization of results. The resulting data are stored on a 150 TeraByte database server.

Toponomics in Cholestatic Liver Diseases
T. Berlage, O. Domanova

Transporter protein topology influences numerous cellular processes. Internalisation of transporter proteins into the cells or their directed placement into the cellular membrane regulates flow of substances and, if altered, causes diseases. As a part of the Clinical Research Group 217 "Hepatobiliary Transport and Liver Diseases (Speaker: Prof. Dr. D. Häussinger, University Düsseldorf) a workflow for an automatic data analysis was developed.

In the reporting period, we could finish the evaluation of canalicular transport and also complete the workflow for basolateral transport. A fully automated imaging method was established for nuclear translocation. We also analysed the properties of confocal vs. non-confocal imaging and the resulting information in the z-axis. The results are now going to be integrated into routine high-throughput workflows for clinical research.
Other Research Projects

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

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

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

In the reporting period, the group conducted several successful experiments within its new gesture lab (co-funded by HumTec and Informatik 5). Dr. Grandhi published a number of papers in prestigious outlets such as the International Journal of Human-Computer Studies, the ACM-CHI 2011 and ICIS 2010 conferences. It also presented its work to the German Wissenschaftsrat as part of its visit to the RWTH Aachen Future Concept in early 2011.

**Overcoming barriers in the innovation process**

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

The IMP Boost project “Overcoming Barriers in the Innovation Process” investigates “effectuation”, a new approach to explain the success or failure of entrepreneurs. In contrast to traditional “causation” approaches the entrepreneur is not considered to be driven by a concrete goal and to choose between different alternatives in regard to how well they help to achieve this goal. Instead the entrepreneur evaluates the alternatives, in particular the choice of strategic partners, in regard to their potential for future success. The goals are adapted to the choices and in particular the needs of the strategic partners. The aim of the IMP Boost project is to compare the two approaches, “effectuation” and “causation” by running simulations. Based on theoretical research neither of these two approaches is to be favoured in general. Accordingly, we need to identify the settings, conditions, and constraints that put either of these approaches in front. From first modelling experiences and basic considerations, agent-based approaches towards simulation seem well suited as a means for investigation. Due to the high importance of networking, approaches from social network analysis as well as actor-network theory are expected to become relevant as well. The work is carried out in tight
collaboration with our partners from the economics. The project was successfully finished in 2011 and will be continued and extended as a center for multi-agent simulation together with colleagues from the institute of sociology.

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. Recently, the section of open access publishing has been extended extensively by a cooperation with the Schloss Dagstuhl – Leibniz Center for Informatics.

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. In 2011, the wiki has been moved to the SunSITE serve for better services to the scientific community. After the leave of Dr. Schmitz, D. Renzel took over responsibilities.

BMBF Project SurgeryTube: Web 2.0 technologies in the training of surgeons
W. Prinz, N. Jeners, S. Franken

SurgeryNet offers an innovative Web 2.0 training platform surgeons, with a key focus on minimally invasive surgery. The central idea is the combination of daily work processes and the collection of learning content, through a time- and location-independent provision of the latest know-how. SurgeryNet simplifies the creation of case-related online content into the daily work processes and enables the users to share current knowledge.
The online content in terms of videos, 3D-models, pictures, and slideshows can be stored by all users to document their own work, or to serve education and training of surgeons. Thus, the problem of increasing time pressure in the operating room can be mitigated by the training of surgeons with the content of SurgeryNet. Users can comment and discuss the existing content to ask questions and bring in their knowledge.

The popular BSCW platform is utilized to build the basis of the SurgeryNet platform. BSCW provides general purpose document management functions with an HTML interface. During the project, a new interface and new functions will be developed and integrated in the BSCW to create the SurgeryNet platform. SurgeryNet will provide functions of a social community, like a profile and communication features and also picture and video sharing functions.

CAIRO - context aware intermodal routing
K.-H. Krempels, C. Terwelp

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

Service

Matthias Jarke’s major service activities in 2010-2011 include:

• Deputy coordinator, UMIC Excellence Cluster on Mobile Information and Communication, RWTH Aachen University
• Executive Director, Fraunhofer FIT, Birlinghoven
• Chairman, Fraunhofer Information and Communication Technology group, and Member of Presidential Board, Fraunhofer Society
• 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
• Vice President, European Research Consortium for Informatics and Mathematics (ERCIM), (until December 2010)
• Scientific advisory board, Faculty of Informatics, University of Vienna, Austria
• Scientific advisory board, Learning Lab Lower Saxony (L3S), Hannover
• Chair, Scientific advisory board, OFFIS e.V., Oldenburg
• Advisory board, Large Scale Complex IT Systems Initiative (LSCITS), UK
• Hochschulrat, FH Köln
• Member of Program Board, LOEWE Excellence Initiative Hessia
• Curatory board and scientific advisory board, IBFI, Schloss Dagstuhl (until June 2011)
• Jury, Wissenschaftspris Stifterverband der Deutschen Wirtschaft
• Chairman, ASIIN review group for University of Potsdam and Hasso-Plattner-Institute
• Co-advisor or second reader on Ph.D. dissertations at RWTH Aachen, Tel Aviv University, and University of Potsdam;
• reviewer for tenure committees and search committees at TU Munich, University of Stuttgart, University of Washington and others
• 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. 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.
Thomas Berlage served as a reviewer for the French Agence Nationale de Recherche for their excellence initiative "investissements d'avenir" in the 2010 Bioinformatics call.

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

Ralf Klamma is technical leader & community facilitator of the EU IP ROLE, senior researcher in the EU projects TELLNET, TELMAP, and the Network of Excellence in Serious Gaming GALA as well in the DFG project CONTICI. He is standing expert of the W3C in the Media Annotations Working Group and founding member of the European Association on Technology Enhanced Learning (EATEL).

D. Kovachev is member of the BITKOM Working Group “Cloud Computing and Outsourcing” and member of the RWTH Industry Working Group “Cloud Computing”.

Milos Kravcik is executive peer-reviewer of the Journal of Educational Technology & Society and reviewer of the Serious Games for Healthcare book, the Journal of Computer Assisted Learning, the IEEE Transactions on Learning Technologies journal, the Educational Technology Research and Development journal, the 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), and the 1st European Workshop on Awareness and Reflection in Learning and Networks (ARNets11) at EC-TEL 2011.

Christoph Quix maintains the interactive map and database for erlebe-it.de, a project by BITKOM (Federal Association for Information Technology, Telecommunications and New Media).

Dominik Renzel is a manager of the i* Wiki.

Thomas Rose served the European Commission as evaluation expert for EU Project Proposals on "ICT for Energy and Water Efficiency in Public Housing" (27. – 30.6.2011). He also acted as reviewer for running EU projects on “ICT for Energy and Water Efficiency”.

**Editorial Boards**


David Kensche served as a reviewer for the International Journal on Information Sciences.

Ralf Klamma serves as associate editor for IEEE Transactions on Learning Technologies (TLT), Springer Journal on Social Network Analysis and Mining (SNAM), IJASS, IJTEL, and IJHSC. He is section editor for the forthcoming Springer Encyclopaedia of Social Network Analysis and Mining (ESNAM) and editor for the IEEE Special Technical
Committee on Social Networks (STCSN). In the moment he is editing a special issue “Multimedia on the Web” for Springer Multimedia Tools and Applications (MTAP). He is editor-in-chief for the SunSITE CEUR and several community information systems like the PROLEARN Academy (www.prolearn-academy.org), the Multimedia Metadata Community (www.multimedia-metadata.info) and the Bamiyan Development Community (www.bamiyan-development.org). He also served as reviewer for Communications on the ACM, ACM Computing Surveys (CSUR), ACM Transactions on Intelligent Systems and Technologies (TIST), World Wide Web Journal (WWWJ), IEEE Transactions on Learning Technologies (TLT), IEEE Multimedia, International Journal for Artificial Intelligence in Education (IJAIIE), International Journal of Family Medicine (IFM), Computers & Security (COSE), International Journal on Knowledge and Learning (IJKL), it – Information & Technology, Multimedia Tools and Applications (MTAP), and Journal of Networks and Applications (JNCA).


Christoph Quix served as a reviewer for ACM Transactions on Management Information Systems, Data & Knowledge Engineering, Information Systems, and the Journal of Web Semantics.

Dominik Renzel was reviewer for the International Journal on Multimedia Tools and Applications.

Thomas Rose has been Programme Committee member of the workshop for "IT-support of rescue forces", GI conference 2011, Berlin

Conference Organization

Matthias Jarke served as Theme Track Chair “Gateway to the Future” at the International Conference on Information Systems (ICIS 2010) in St. Louis, Missouri, Dec. 13-14, and as program committee member of the following conferences: Software Engineering 2011 (SE 2011), 23rd CAiSE 2011 (London), 17th REFSQ ’11 (Essen), SSDBM 2011 (Portland, Or), 30th Intl. Conf. Conceptual Modelling (ER-2011, Brussels), 21. Intl. Workshop on Information Technologies and Systems in connection with ICIS 2011 (WITS 2011, Shanghai). He also serves on the Advisory Board of the CIO Colloquium, a network and conferences series of the Chief Information Officers in German industry. In spring 2011, he was elected as one of the two representatives of science in the CeBIT-Messeausschuss, an advisory board consisting mostly of the CEO’s of large international enterprises exhibiting at the world’s largest IT Fair.

Yiwei Cao co-organized and was chair of Third International Workshop on Story-Telling and Educational Games (STEG’10) at ICWL’11 and First IEEE PerCom Workshop on Pervasive Communities and Service Clouds (PerCoSC’11). She is program co-chair of Tenth International Conference on Web-based Learning (ICWL’11). She was program committee member of 7th International Workshop on MOBILE and NEtworking Technologies for social applications (MONET’11), CONTENT’11, 13th Workshop of the Multimedia Metadata Community (MMWeb’11), International Symposium on Models and Modeling Methodologies in Science and Engineering (MMMse’11), First International Workshop on Technology-Enhanced Social Learning (TESL’11), CTUW’11, Dexa’11, IMCIC’11, 10th International Workshop on Web Semantics (WebS’11), Mobile Learning’11 (ML’11), the


Sandra Geisler, Andreas Lorenz, and Christoph Quix organized the International Workshop on Managing Health Information in Mobile Applications (HIMoA) at the International Conference on Mobile Data Management (MDM) in Luleå, Sweden.

Christoph Quix was member of the organizing committee of the 6th International Workshop on Ontology Matching. He was member of the program committee of the 30th International Conference on Conceptual Modeling (ER 2011) and of the 28th International Conference on Data Engineering (ICDE).

Dejan Kovachev co-organized the 1st IEEE PerCom Workshop on Pervasive Communities and Service Clouds, held in conjunction with 9th Annual IEEE International Conference on Pervasive Computing and Communications 2011 (PerCom 2011).


Ralf Klamma is tutorial chair for the 2012 International Conference on Advances in Social Network Analysis and Mining (ASONAM 2012). He was also co-chair of the following events: 7th JTEL Summer School in Technology Enhanced Learning, Chania, Crete, Greece, June 2011, 1st International Workshop on Enhancing Learning with Ambient Displays and Visualization Techniques (ADVTEL’11), Palermo, Italy, September 2011, the 13th Workshop of the MPEG-7 Community on Multimedia Metadata (MMWeb’11), Graz, Austria, September, 2011, and PerCOSC’11 at the IEEE PerCom, Seattle, USA, March 2011. He was special track chair on competence management in personal learning environments at the Professional Training Facts 2011, Stuttgart, Germany, October 2011, and senior reviewer for the PLE’11, Barcelona, Spain, July 2011. He served as program committee member / reviewer for the following conferences: ACM CSCW’11, ACM Symposium on Applied Computing (SAC’11), 11th IEEE International Conference on Advanced Learning Technologies (ICAL’11), IEEE - Engineering Education (EDUCON’11), IEEE American Control Conference (ACC’11), 5th IEEE/FTRA International Conference on Multimedia and Ubiquitous Engineering (MUE’11), FTRA International Workshop on Multimedia and Semantic Technologies (MUST’11), Wirtschaftsinformatik’11, International Symposium on Collaborative Technologies and Systems (CTS’11), Communities & Technologies’11, ICWL’11, European Conference on Technology Enhanced Learning (EC-TEL’11), International Conference on Ambient Systems, Networks and Technologies (ANTS’11), 50th IEEE Conference on Decision and Control and European Control Conference (IEEE CDC-ECC’11), IEEE international conference on Technology for Education (T4E’11), 6th International Conference on Embedded and Multimedia Computing (EMC’11) 7th International Conference on Signal Image Technology & Internet Based Systems (ACM/IEEE
SITIS’11), GI-Workshop Digital Social Networks (GI-DSN’11), International Conference on Social Computing and its Applications (SCA’11), Conference on Learning Analytics & Knowledge (LAK’11), Computer Science Education Research Conference (CSERC’11), 3rd International Workshop on Search and Mining User-generated Contents (SMUC’11), Workshop Business Process Management and Social Software (BPMS2’11), Interactive Computer Aided Learning (ICL’11), I-KNOW’11, Workshop Computer-based Knowledge & Skill Assessment and Feedback in Learning Settings (CAF’11), Workshop on Text Information Retrieval (TIR’11), Workshop on Personalization Approaches in Learning Environments (PALE’11), Workshop on Business Applications of Social Network Analysis (BASNA’11).

Dejan Kovachev co-organized the 1st IEEE PerCom Workshop on Pervasive Communities and Service Clouds, held in conjunction with 9th Annual IEEE International Conference on Pervasive Computing and Communications 2011 (PerCom 2011).


Dominik Renzel co-organized the workshop "Usage and Development of Responsive Open Personal Learning Environments" at the Joint European Summer School on Technology Enhanced Learning. He was member of the programme committee for the 12th and 13th Workshop of the Multimedia Metadata Community (SMDT 2011, MMWeb 2011).

Thomas Rose organized an expert workshop on critical infra-structures in cooperation with the Frankfurt School of Finance & Management in the context of the “Public Management Conference” in September 2011 in Frankfurt.

Software Demonstrations

Automatic Mediated Schema Generation Through Reasoning Over Data Dependencies. 27th International Conference on Data Engineering (ICDE 2011), Hannover, Germany, April 11-16, 2011

CAFe, meeting of ambassadors in Germany, European SchoolNet, March 11, 2011, Bonn, Germany

Cafe, eTwinning Teacher Workshop, March 11, 2010, Bonn, Germany

Cafe, eTwinning Teacher Workshop, November 17, 2010 Karlsruhe, Germany


Rating Game for fake multimedia detection system, at the Workshop on Multimedia on the Web (MMWeb 2011) in conjunction with i-Know and i-Semantics 2011, 7–9 September 2011, Messe Congress Graz, Austria.

Virtual Campfire (SeViAnno in the Cloud), UMIC Day 2010, October 19, 2010, Aachen, Germany

Virtual Campfire, STEG Workshop at ICWL’10, December 10, 2010, Shanghai, China

Virtual Campfire, UMIC Day 2010, Aachen, Germany, October 19, 2010

YouTell, 1st GaLA Alignment School, Edinburgh, UK, June 21, 2011
Talks and Publications

Talks


T. Berlage, Advanced Toponomics. Screening Europe, 01.07.2011, Hamburg


M. Derntl: Collaborative Storytelling for Web 2.0 and Serious Games. 1st GaLA Alignment School, Edinburgh, UK, June 21, 2011

M. Derntl: Mapping the European TEL Project Landscape Using Social Network Analysis and Advanced Query Visualization. International Workshop on Enhancing Learning with Ambient Displays and Visualization Techniques, Palermo, Italy, September 20, 2011


M. Derntl: The ICALT Author Community. Invited talk, 11th IEEE International Conference on Advanced Learning Technologies, Athens, Georgia, USA, July 8, 2011


S. Geisler: A data stream-based evaluation framework for traffic information systems. ACM SIGSPATIAL Intl. Workshop on GeoStreaming (IWGS), San José, USA, November 2010.

S. Geisler: Accuracy Assessment for Traffic Information Derived from Floating Phone Data. 17th World Congress on Intelligent Transportation Systems and Services (ITS), Busan, Korea, October 2010.

S. Geisler: Data Stream Management Systems and Query Languages. Advanced School on Data Exchange, Integration and Streams (DEIS'10), Schloss Dagstuhl, Wadern, November 9, 2010.

M. Jarke (Chair) et al.: Design Requirements – Challenges and Approaches. Panel at RE 2011, Trento, Italy, 2.9.2011


M. Jarke: Opening Address on Occasion of Starting New Fraunhofer FIT Project Group at University of Augsburg. Augsburg 21.10.2011

R. Klamma Collaborative Storytelling on the Web 2.0, TERENCE Workshop, L3S, Hannover, Germany, March 2011

R. Klamma: ATLAS - Ein neuer Informationssystemansatz für Internet-Communities, Siegen, Germany, July 2011

R. Klamma: ATLAS Overview, Doctoral Seminar, Braunshausen, Germany, September 2011


R. Klamma: Learning Analytics for the Lifelong Long Tail Learner, Open University of the Netherlands, Heerlen, The Netherlands, February 2011


R. Klamma: SocialMedia Analytics – Aktuelle Herausforderungen, Gesellschaft für Informatik Regionalgruppe Köln, July 2011

D. Kovachev: Augmenting Pervasive Environments with an XMPP-based Mobile Cloud Middleware, the International Workshop on Mobile Computing and Clouds (MobiCloud 2010) in conjunction with MobiCASE 2010, Santa Clara, CA, USA, October 28, 2010

D. Kovachev: Mobile Multimedia Cloud Computing and the Web, the IEEE Workshop on Multimedia on the Web (MMWeb2011) in conjunction with i-Know and i-Semantics 2011, Graz, Austria, September 8, 2011


M. Kravcik: Learning Analytics for Communities of Lifelong Learners: a Forum Case. ICALT Conference, Athens, Georgia, USA, July 7, 2011.


Z. Petrushyna: Pattern-Based Competence Management: On the Gap between Intentions and Reality. 11th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2010, St. Etienne, France, October 11-13, 2010

Z. Petrushyna: "Die Kompetenzen von eTwinners messen und analysieren". The meeting of ambassadors in Germany, European SchoolNet, March 11, 2011, Bonn, Germany


M. C. Pham: Network Clustering for Recommender Systems: A Case Study with Academic Event Recommendation. Presentation at Meeting with Mendeley.com, Aachen, November 2010

M. C. Pham: Social Network Analysis and Its Application to Digital Libraries, IKYDA project meeting, Athen, Greece, December 7, 2010


K. Rashed: Trust-aware Media Quality Profiles in Fake Multimedia Detection. At the Workshop on Multimedia on the Web (MMWeb 2011) in conjunction with i-Know and i-Semantics 2011, 7–9 September 2011, Messe Congress Graz, Austria.


T. Rose has been a panelist in the expert meeting on power break-downs and their impacts on businesses and civil society in the context of “Public Management 2011”, Frankfurt, September 2011.


Publications

Books and Edited Volumes


Xiangfeng Luo, Yiwei Cao, Bo Yang, Jianxun Liu, Feiyue Ye: New Horizons in Web-Based Learning - ICWL 2010 Workshops: STEG, CICW, WGLBWS, and IWKDEWL, Revised Selected Papers, Shanghai, China, December 7-11, 2010, Lecture Notes in Computer Science (LNCS), Springer, Vol. 6537, 2011

Diana Perez-Marin, Milos Kravcik, Olga C. Santos (Eds.): Proceedings of the International Workshop on Personalization Approaches in Learning Environments, held in conjunction with the 19th User Modeling, Adaptation and Personalization conference (UMAP 2011), Girona, Spain, July 15, 2011. CEUR Workshop Proceedings, ISSN 1613-0073, online CEUR-WS.org/Vol-732/

Journal Articles

Y. Cao, Ralf Klamma, Matthias Jake: The Hero’s Journey - Template-Based Storytelling for Ubiquitous Multimedia Management, Special Issue on Journal of Multimedia (JMM): Advances in Interactive Media Technologies, Vol. 6, No. 2, 2011, pp. 156-169, Academy Publisher


Matthias Jarke, Pericles Loucopoulos, K. Lyytinen, J. Mylopoulos, W. Robinson: The brave new world of design requirements. Information Systems 36, 7 (2011): 992-1008 (Special Issue from Expanded Best Papers of CAiSE ’10)


Conference, Book Contributions, Patents


Sandra Geisler, Yuan Chen, Christoph Quix, G. G. Gehlen: Accuracy Assessment for Traffic Information Derived from Floating Phone Data. 17th Intelligent Transportation Systems and Services World Congress, Busan, South Korea, 2010.


Karl-Heinz Krempels, Christoph Terwelp: A Generic API for the Integration of RBS in an ESB. International Conference on Software and Data Technologies 2011 (ICSOFT ’11), Sevilla, Spain, 2011.


Christoph Quix, Marko Pascan, Pratanu Roy, David Kensche: Semantic Matching of Ontologies. Published in Fifth International Workshop on Ontology Matching (OM-2010), Shanghai, China, 2010.

Christoph Quix, Pratanu Roy, David Kensche: Automatic Selection of Background Knowledge for Ontology Matching. 3rd International Workshop on Semantic Web Information Management (SWIM 2011, in conjunction with ACM SIGMOD 2011), June 12, 2011, Athens, Greece.

Khaled Rashed, Dominik Renzel, Ralf Klamma, Trust-aware Media Quality Profiles in Fake Multimedia Detection. Published in IEEE Proceedings of Workshop on Multimedia on the Web (MMWeb 2011) in conjunction with i-Know and i-Semantics 2011, 7–9 September 2011, Messe Congress Graz, Austria.


**Position Papers and Interviews (Selection)**


Staff

- **Faculty**
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- **Postdoctoral Researchers:**
  Dr. rer. nat. Alexander Ferrein
  (until October 2011, funded by the Humboldt Foundation)

- **Research Assistants**
  Dipl.-Inform. Daniel Beck
  M.Sc. Vaishak Belle
  (funded by BIT)
  Dipl.-Inform. Jens Claßen
  (until July 2011, funded by DFG)
  Dipl.-Inform. Tom Goeckel
  (funded by AFR)
  Dipl.-Inform. Tim Niemueller
  (funded by DFG)
  Dipl.-Inform. Stefan Schiffer

- **Student Researchers**
  Tobias Baumgartner, Bahram Maleki-Fard,
  Christoph Schwering

- **Visiting Researchers**
  Prof. Hector Levesque, Ph. D., University of Toronto, Canada
  (September – December 2010)
  Prof. Yves Le’sperance, Ph. D., York University, Canada
  (May 2011)
  Radhakrishnan Delhibabu, Anna University
  (September 2010 – October 2011)
Overview

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

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

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

Alexander Ferrein, Gerhard Lakemeyer

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

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

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

Cognitive Service Robotic Systems and Applications

Stefan Schiffer, Tim Niemueller, Gerhard Lakemeyer

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

Figure 1: The pictures above illustrate the adaptation of the former soccer robot (left) to the requirements of the @Home league (center, 2006, and right, 2009 and 2011).

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

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

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

Important tasks in the @Home domain are to localize oneself in the home environment, not to collide with anything in the apartment, and to interact with humans living in it (human-machine interaction). The annual tournament is structured in several specific tasks called tests, that each check for one or more important abilities of the robot. In a so-called Open Challenge
and in the Final teams can freely demonstrate whatever they think is their robot’s most noteworthy functionality.

In the last years we continuously enhanced our robot’s abilities both in software 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. Finally, we completely redesigned the upper part of the robot and replaced the stereo camera with a Kinect RGB-D sensor. (cf. Fig. 1) The control software now features a generic object detection and recognition module, robust and flexible speech recognition used to command the robot, and further a new approach to face detection, recognition, and learning which is indispensable for any human-robot interactive application. After winning the world championship in 2006 and 2007 we became vice world champion in the 2008 competition in Suzhou, China. Furthermore, we won the RoboCup German Open in 2007 and in 2008.

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

To improve on the interactive capabilities we recently added means for modular gesture recognition for static and deictic gestures as well as dynamic gestures in 2D and 3D. Also, we developed a component for interpreting spoken language commands. It uses decision theoretic planning to infer the most likely request to the robot while taking into account the robot’s set of skills and abilities. To allow for more natural interaction we further improved the integration of reasoning with qualitative positional information. This is especially helpful since it enables a human to refer to objects and places in an indoor environment as usual when the human is interacting with a robot instead of another human.

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.
To advance the robot’s abilities to manipulate objects in the environment, new perception modules using point cloud processing have been developed. Point clouds are generated from the Kinect RGB-D sensor which produces registered color and depth images at the same time, providing a rich set of (colored) 3D points. These points are then segmented, e.g. to detect a table plane, and objects determined by clustering. With newly integrated OpenRAVE manipulation planning system, either the centroid of the cluster, or fitted models, can be used to grasp arbitrary objects with the robot’s arm.

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

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

Thanks to a grant of the Bonn-Aachen Institute of Technology and the support from the Chair of Computer Science 5 we were able to develop a new, specialized robot platform for the RoboCup soccer competitions. In the design of the new robots we followed the de-facto standard in the league by integrating an omni-directional drive system and an omni-vision camera system. Such an omni-directional drive system allows the robot to move into arbitrary directions without any constraints. The omni-vision camera system consists of a hyperbolic mirror that is mounted atop of a camera at the top of the robot (cf. Fig. 2). The images obtained from the camera depict the complete surroundings of the robot. Additionally, the robots are equipped with a stereo-camera which delivers a three-dimensional 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, named Fawkes. Major design goals were low latencies, support for multi-core CPUs, clearly structured flow of data, good scaling properties and a high degree of portability. The success of the last two goals is made clear by the fact that the control software for our soccer robots as well as for the humanoid Nao robots is developed on basis of the same framework.

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

### 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 interaural time difference as an azimuthal sound-localization cue. As an improvement over previous work, we used the complete three-dimensional coincidence map for determining the azimuth of a sound source. A first implementation of the algorithm on the mobile robot Carl has been completed with promising results. 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.

### Towards a sound localization unit for service robots.

*Tom Goeckel, Gerhard Lakemeyer, Hermann Wagner (Biologie II)*

The follow-up project of HeRBiE will be concerned with the extension of the concepts of HeRBiE in a way to give more robust localization estimates in acoustically cluttered environments and to isolate speech from other signals.

During the first year of the project, our main focus was on extending our understanding of the fundamental problems of localizing sound sources with interaural time differences (ITD) in order to increase the performance of our algorithms. Our findings - mainly on side peak suppression, or the cause of virtual sources due to phase ambiguities – were compared to
physiological data of barn owls. At the same time, we started two projects to extend the existing sound localization system.

On one hand, we are currently working on an adaptable gammatone filterbank to simulate the cochlea. This is going to allow us to implement features, as for example the detection of interaural level differences. The filtering of a single input signal to several narrowband signals, that have to be processed at the same time, leads to a significant increase of computational complexity. To tackle this problem, we will port our implementation to the CUDA API that supports highly parallel processing on graphic processing units (GPUs) and should guarantee real-time processing.

On the other hand, we started to develop a speech detection algorithm. This will allow us to facilitate attention guidance as the localization algorithm should emphasize the location of speech sources. Detection is implemented as a preprocessing stage. It delivers the information necessary to control the filter bandwidths of the filterbank and tells the system whether a potentially interesting speech signal was detected in the current section of the recorded signal. If a speech signal is detected, the spectral resolution of the filterbank gets increased to highlight the spectral components of the signal and reduce the influence of background noise. Detection is done by computing the base frequency of a speech signal and determining the cepstrum. Speech detection is also a first step towards a speech segregation or beam-forming algorithm.

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 years, the two separate fields began to converge again. Exemplary for this trend is the development of the planning domain definition language PDDL, which extends simple STRIPS-based planning by features such as conditional effects, time, concurrency, axioms, and plan constraints and preferences, and which virtually constitutes a standard in the field of planning.

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

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

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

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

An overview of the project and a summary of its result will appear in a special issue (volume 26, number 1) of the German AI journal ‘Künstliche Intelligenz’ in 2012.

Self-Aware Humanoid Robots in the RoboCup Standard Platform League

Alexander Ferrein, Tim Niemuller, 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. Recently, the modules to interact with the robot have been updated and made publicly available as part of the Fawkes software. With most of the low-
level components running, we started addressing the high-level control. During the report period, a Behavior Engine based on extended hybrid automata was developed (Niemueller, Ferrein, & Lakemeyer, 2009). The implementation was done in the scripting language Lua which is an interpreted language with a small memory footprint. The Behavior 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 with respect to 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.

At the NRAC-11 workshop we presented an extension that allows the computation of the optimal plan in the case that a complete model is given using the same abstraction techniques we used for reinforcement learning. The benefit of using these abstraction techniques for decision-theoretic planning are that optimal policies can be generated without knowing what objects and how many of them actually do exist. That is, it is possible to compute a policy that is optimal in all possible domain instances. In addition to that the abstraction techniques also led to a speed-up in planning time.
In the area of Knowledge Representation and Reasoning, a fundamental step towards specifying intelligent behavior is that of capturing the beliefs of a knowledge base, and providing an appropriate computational mechanism to reason about these beliefs. As an example, we may model a (fair) game-playing agent by insisting that all he knows are the rules of the game. In (say) Poker, these rules suggest that there are n players and k unique cards. Intuitively, this allows players to reason that if they have the king of hearts, then an opponent does not, but would not allow the agent to know which precise set of cards an opponent has (at least, not initially). A general methodology that has proven useful to specify rules and beliefs, both in artificial intelligence and other areas such as distributed systems, is with the use of formal logic.

While beliefs are typically modeled in epistemic logic, it was Levesque, in the early nineties, who proposed the logic of only-knowing where it is possible to say that a set of sentences in a first-order language is precisely all that an agent believes. In this way, he was able to capture both beliefs and also what is not believed. The logic is unique in the sense that in addition to the classical modal operator for belief, he introduces a companion modal operator to capture only-knowing. The semantics was shown to also capture a variety of default mechanisms. For instance, if all I know is that Tweety is a bird, and that birds typically fly, then I come to believe that Tweety flies (unless, I am told otherwise).

Clearly, such a framework is also desirable in a many agent setting, where one agent may capitalize on what she believes another agent to know with the goal of coordinating on tasks, planning strategies, and so on. While there are a number of approaches to extend only-knowing, none are without problems.

In a paper published last year (in Proc. of KR), we introduce a new semantics, which is shown to have two notable properties. The semantics is natural and correctly captures the intuitions of only-knowing for the many agent case. The second property is that we have an axiomatization that succinctly captures the properties of the new logic. So it appears, that for the first time, we have a natural generalization of Levesque’s logic, allowing us, besides other things, to capture knowledge bases and beliefs about an opponent’s knowledge base in a precise manner. This work is recently summarized as a chapter in Knowing, Acting, and Reasoning. Essays in the Honor of Hector J. Levesque, edited by Gerhard Lakemeyer and Sheila McIlraith (from the University of Toronto).

One of the main goals of Knowledge Representation, besides capturing the (static) beliefs of an agent, is to allow agents to reason about the dynamics inherent in the world. A first-order dialect called the situation calculus is one such formalism to reason about action and change. However, capturing knowledge in the situation calculus and proving properties pertaining to the beliefs of an agent is not straightforward. To this effect, Lakemeyer and Levesque (Proc. of KR, 2004) propose a first-order modal logic, called E S , which is an amalgamation of Levesque’s only-knowing logic with a dynamic logic-like syntax. E S , among other things, has all the main features of the situation calculus, and a conceptually attractive semantical apparatus.
In a multi-agent setting, one utility of such action formalisms is in reasoning about beliefs and strategies in games. For instance, resorting again to the Poker example: when a player observes that his opponent read a card, he comes to believe that the latter now has new information. It is also clear to the player that his own knowledge is unchanged. We remark that the standard epistemic models used in game theory has received some criticism on not being expressive enough to capture beliefs in an appropriate manner. Further, beliefs are typically analyzed manually and hence often prone to error. In another paper published last year (in Proc. of AAAI), we build on the new semantics for multi-agent only-knowing to include actions, as in E S. We show that, by specifying the rules of games as sentences in the logic, properties regarding beliefs and outcomes can be analyzed simply as entailments. Moreover, the situation calculus is equipped with a regression property, which allows one to reduce entailments about future situations, i.e. sentences that hold after some sequence of actions, to formulas about the initial situation. In a nutshell, goal-directed planning and reasoning can be analyzed from the initial situation. In games, this is a useful feature for agents to narrow down their choices regarding possible moves. We show that such a property also exist in our new setting.

Much of this work, in principle, should resort to first-order modal theorem proving. There are techniques, such as the representation theorem introduced by Levesque, that allow us to reduce reasoning to pure first-order theorem proving. Nonetheless, reasoning about validity in first-order logic is undecidable. Our current work is towards extending above results in two important ways. The first is an attempt to obtain fragments of the logic where reasoning is decidable, and perhaps, even tractable. Indeed, a well-known trade-off in Knowledge Representation is between the expressiveness of the representation language and the computational behavior of associated reasoning tasks. A noteworthy step towards this goal is taken, for instance, by Liu, Lakemeyer and Levesque (in Proc. of KR, 2004). However, the applications we focus on make use of function symbols while approaches such as the former are typically restricted to function-free languages. The second goal is based on the observation that while regression is a feasible tactic with a small sequence of actions, it may not be so with long-lived agents. Lin and Reiter introduced the notion of progression, which is intuitively the operation of updating the knowledge base with respect to the actions executed so far. Unfortunately, this definition comes at the cost of second-order sentences in the knowledge base.

Thus, it is necessary to arrive at finite and efficiently computable techniques for progression, even if under some restrictions. In IJCAI 2009, Liu and Lakemeyer have made important advancements in this area. It is also worth noting that (restricted forms of) progression is at the heart of STRIPS-based planning systems.

In IJCAI-11, we address the goals of query evaluation and progression with function symbols. In particular, this consists of extending the work by Liu and Lakemeyer to a language with functions, for three major syntactically restricted classes of basic action theories. We also proposed a new sound and complete decidable query evaluation mechanism, which was inspired by work on Boolean satisfiability and some special properties exhibited by the objective fragment of E S.

Finally, most approaches in reasoning about action do not consider probabilistic notions, sometimes for simplicity. In the real world, however, we expect robots equipped with faulty hardware and unreliable sensors. In this case, when the robot wants to move by a meter, due to the faulty hardware it may end up moving only .9 meters. If a representation formalism does not provide an effective way to deal with this noise, then the robot cannot operate in its environment in any purposeful manner.
In the situation calculus, there are two methods to handle noisy behavior, but both have some issues. In the first approach by Bacchus, Halpern and Levesque (Proc. of IJCAI, 1995), no precise characterization of the agent’s knowledge base is given and computing entailments after actions may involve second-order logic. In the second approach by Gabaldon and Lakemeyer (Proc. of AAAI, 2007), the practical utility is in question since a definition of regression and progression is unclear for the framework.

In AAAI 2011, we extend the notion of progression for a formalism that handles probabilistic notions. This involves a fresh amalgamation of the logic ES and uncertainty, and extending the ideas of progression by Lin and Reiter for the logic. Our main contribution here is to see in which sense the model-theoretic definitions of Lin and Reiter apply to the new language, and study if we are able to obtain definability theorems for the progressed knowledge base. This establishes, perhaps for the first time, how the Lin and Reiter notion of progression should work in the case of probabilistic uncertainty.

Robust Reliable Robotic Systems
Tim Niemue1er, Gerhard Lakemeyer

An intrinsic property all robot systems seem to share is that they fail sooner or later to accomplish their task. The reasons are manifold. For example, software components could fail due to programming errors, hardware can wear out and needs maintenance or replacement, and assumptions made by the developer might differ from the actual environment, e.g. it contains more clutter, has a less than optimal lighting, or has more human inhabitants than anticipated.

In this project we want to develop methods and systems to detect and recognize such failures and find strategies for the robots to cope with these errors. In the past year, we have started working on a system which can detect and explain known failures. Knowledge about the symptoms and causes of such errors is encoded and then verified at run-time by the robot. For example, the system can learn a known-good state of software components and their connections. Later when the robot is performing its job, the system is monitored if any of the constraints is violated. In this case, it can warn the user with precise information of what is missing or has failed.

Ready-ROS: Integrating the High-level Control Language Readylog into the Robot Operating System
Alexander Ferrein, Tim Niemue1er, Gerhard Lakemeyer

Previously, we were investigating (1) how to integrate reactive control into the logic-based robot programming and plan language Readylog and (2) how Readylog could be used on resource-restricted platforms such as the humanoid robot Nao. To this end, the robot control framework Fawkes has been ported to the Nao robot platform. An alternative approach is the
Robot Operating System (ROS) and it seems to develop as a standard robot control framework. ROS is used by over 50 research institutions world-wide, and packages for the Nao platform exist as well.

The aim of this project is to analyse ROS and compare it with the Fawkes framework. As both, Fawkes and ROS, are available for the Nao platform we aim at comparing both frameworks in a real-time scenario on the Nao platform. A thorough analysis of ROS in terms of run-time overhead and efficiency has, to the best of our knowledge, not been done so far. The target domain for the comparison should be the robotic soccer domain. This includes to have the same robot control instances running in both frameworks, and the same high-level control, too. Therefore, we furthermore aim to provide a package Ready-ROS containing the achieved re-implementation of Readylog for ROS. A Ready-ROS software package would yield one possible “off-the-shelf” solution to the high-level control problem of autonomous robots. While the previous work is situated in the field of Cognitive Robotics, which concentrates on knowledge representation and reasoning for autonomous systems, the proposed research programme is of interest for an even larger group of roboticists.
Other Activities

Program Committees
Gerhard Lakemeyer was PC member of numerous international conferences. He is on the Editorial Board of Artificial Intelligence, Computational Intelligence, and the Journal of Applied Logic, and a member of the Advisory Board of the Journal of Artificial Intelligence Research.

Stefan Schiffer was a PC member of the RoboCup Symposium, of the ERLARS Workshop, and of the HIMoA Workshop in 2011.

Vaishak Belle, Jens Claßen, and Alexander Ferrein were PC members of the Twenty-Second International Joint Conference on Artificial Intelligence (IJCAI-11) held at Barcelona, Spain.

Alexander Ferrein was co-chair of the Special Track on Robotics and Artificial Intelligence in Africa at the 10th IEEE Region 8 Africon 2011.

Technical Committees
Stefan Schiffer is an honorary member of the Technical Committee in the RoboCup-@Home league after serving as a regular member for three years.

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.

The Fawkes robot software framework along with components for perception, behavior execution and monitoring, and robot hardware and platform support, is made publicly available as Open Source Software (http://www.fawkesrobotics.org).

Research Visits
• Prof. Gerhard Lakemeyer and Stefan Schiffer visited the University of Cape Town, South Africa, in December 2010, to work with Dr. Alexander Ferrein.
• Between February 2010 and July 2010, Prof. Gerhard Lakemeyer visited the University of New South Wales, Australia and the University of Toronto, Canada on a sabbatical. He collaborated with Prof. Pagnucco from UNSW and Prof. Levesque from the University of Toronto in the research area of cognitive robotics.
• From September 2010 to December 2010, Prof. Hector Levesque from the University of Toronto is visiting our institute. Prof. Levesque will be collaborating with Prof. Gerhard Lakemeyer on reasoning about knowledge and action.
• From September 2010 to October 2011, Radhakrishnan Delhibabu from Anna University, India is visiting our research group as part of a scholarship he received from the India4EU European-funded project. Mr. Delhibabu’s research interest primarily lie in the view-update problem and belief revision. His current focus is at the intersection of the situation calculus and belief revision.
• Intel Fellowship
From July to December 2010 Tim Niemueller received the Intel Summer Fellowship and worked at the Personal Robotics Lab of The Robotics Institute at the Carnegie Mellon University. His work involved porting his Fawkes Behavior Engine, a system based on Hybrid State Machines to model reactive robot behavior implemented in Lua, to the bi-manual mobile manipulator HERB using the ROS software system. Further work involved modeling internal robot data flow and a generic database for storing vast amounts of run-time generated data on the robot.

• SRI International
Since January 2011 Tim Niemueller is employed half-time at SRI International (Menlo Park, CA, USA) as a robot software engineer. As a member of a joint team of SRI International, Carnegie Mellon University, and Columbia University of New York in the DARPA Autonomous Robot Manipulation – Software (ARM-S) Challenge his work involves robot behavior design and developing a self-diagnosis software to detect, analyze, and report or recover from typical error conditions.

Tournaments and Competitions
RoboCup German Open 2011.
In April 2011, we participated in the RoboCup German Open 2011 in the RoboCup@Home League which took place in Magdeburg.

Demonstrations
Schüleruniversität 2011.
The KBSG demonstrated the domestic service robot Cae-sar and two humanoid Nao robots to students participating the Schüler-Universität in August 2011. We explained some principal methods in autonomous mobile robotics and we let students try controlling humanoid robots to play soccer.
Talks and Publications

Talks


Stefan Schiffer: RoboCup: Robotic Soccer and Beyond, Fachschaftstagung Mathematik/Informatik des Cusanuswerk: “No sports ... without math”, Eichsfeld, Uder, Germany, June 1-5, 2011.


Publications


Jens Claßen, Gabriele Ro¨ ger, Gerhard Lakemeyer, and Bernhard Nebel: PLATAS – Integrating Planning and the Action Language Golog, Künstliche Intelligenz 26(1), 2012. (in press)


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:

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

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

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

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

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

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

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

- speech recognition
  - large vocabulary recognition
  - multi-lingual speech recognition
  - speaker independent and adaptive speech recognition
  - robust speech recognition
- machine translation of spoken and written language
- natural language processing
  - document classification
  - language understanding
  - spoken dialogue systems
- part-of-speech tagging and text annotation
- image recognition
Most of these research activities have been or are carried out in the framework of European and international projects (see below). In addition, there are bilateral research projects with companies.

**Machine Translation**

The goal of machine translation is the translation of a text given in some natural source language into a natural target language. The input can be either a written sentence or a spoken sentence that was recognized by a speech recognition system. At ‘Lehrstuhl für Informatik 6’, we apply statistical methods similar to those in speech recognition. Stochastic models describe the structure of the sentences of the target language - the language model - and the dependencies between words of the source and the target language - the translation model (see figure below). The translation model is decomposed into the lexicon model which determines the translations of the words in the source language and the alignment model forming a mapping between the words in the source language string and the words in the target language string. These models are trained automatically on a corpus of bilingual source/target sentence pairs. In this approach, it is not necessary to manually design rules for the translation or the construction of sentences. A search algorithm determines the target language sentence that has the highest probability given the source language sentence.

The statistical approach to machine translation is particularly suitable for the translation of spontaneous speech, where the translation approach has to cope with colloquial language and speech recognition errors.

![Architecture of a Statistical Machine Translation System](image)

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 used with the cube growing and cube pruning algorithms in decoding. It performs similar to the phrase-based system and thus has been extensively used in evaluations. Further extensions to this are being investigated.

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

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

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

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

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

Speech Recognition

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

Today, state-of-the-art systems for automatic speech recognition are based on the statistical approach of Bayes decision rule. The implementation of Bayes decision rule for automatic speech recognition is based on two kinds of stochastic models: the acoustic model and the language model which together are the basis for the decision process itself, i.e. the search for the most probable sentence. These modules of an automatic speech recognition system (cf. Figure above) are characterized as follows:
The acoustic model captures the acoustic properties of speech and provides the probability of the observed acoustic signal given a hypothesized word sequence. The acoustic model includes:

- The acoustic analysis which parameterizes the speech input into a sequence of acoustic vectors.
- Acoustic models for the smallest sub-word units, i.e. phonemes which usually are modeled in a context dependent way.
- The pronunciation lexicon, which defines the decomposition of the words into the sub-word units.
- The language model captures the linguistic properties of the language and provides the a-priori probability of a word sequence. From an information theoretic point of view, syntax, semantics, and pragmatics of the language could also be viewed as redundancies. Statistical methods provide a general framework to model such redundancies robustly. Therefore state-of-the-art language models usually are based on statistical concepts.
- The search realizes Bayes decision criterion on the basis of the acoustic model and the language model. This requires the generation and scoring of competing sentence hypotheses. To obtain the final recognition result, the main objective then is to search for that sentence hypothesis with the best score, which is done efficiently using dynamic programming. The efficiency of the search process is increased by pruning unlikely hypotheses as early as possible during dynamic programming without affecting the recognition performance.

(a) Speech waveform of the utterance “Sollen wir am Sonntag nach Berlin fahren”, (b) the corresponding FFT spectrum

At ‘Lehrstuhl für Informatik 6’, the following research directions related to all main areas of automatic speech recognition (ASR) were pursued in 2008/09:

- The generation of the European Parliament Plenary Session (EPPS) corpus for speech recognition and speech-to-speech translation was continued for the main European languages. This corpus consists of transcribed speech and parallel texts in the languages English, French, German, Italian, Spanish, Greek, Portugueses, 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.

**Handwriting Recognition**

The RWTH-OCR system is based on the open-source speech recognition framework RWTH-ASR - The RWTH Aachen University Speech Recognition System, which has been extended by video and image processing methods.
RWTH developed a novel confidence-based discriminative training for handwriting recognition. In particular, a writer adaptation approach for an HMM based Arabic handwriting recognition system to handle different handwriting styles and their variations has been presented in TOCITE-ICDAR-DT.

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

**Face Recognition**

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

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

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

**Image Distortion Models**

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

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

Global Autonomous Language Exploitation (GALE)

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

In 2011, the "Lehrstuhl für Informatik 6" participated as a member of the ROSETTA team, led by IBM. RWTH contributes translations from Arabic to English from two translation engines to this project. In addition, RWTH provides consensus translations generated from translations of all team members in this language pair.

Quaero

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

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

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

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

JUMAS (Judicial Management by Digital Libraries Semantics)

The project Judicial Management by Digital Libraries Semantics (JUMAS), which was completed end of January 2011, aimed at researching and developing tools for assisting the judicial process, specifically related to court room activities. The goal was 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 was the development of automatic speech recognition (ASR) systems for recordings of court trials. RWTH contributed to the project by developing an ASR system for Polish court room recordings. Research challenges included dealing with the varied quality of the audio signal in a real life court room, without excessive degradation of signal quality. An ASR system was integrated into a working pilot system meant for officials of the Polish court system.

**SCALE**

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

SCALE stands for Speech Communication with Adaptive LEarning, and specifically supports initial training for doctoral and post-doctoral students working on adaptive learning approaches within all areas of speech processing, with specific focuses on automatic speech recognition and synthesis, signal processing, human speech recognition, and machine learning. In particular, SCALE covers three principal scientific objectives: bridging the gaps between speech recognition and speech synthesis, between human and automatic speech recognition, and between signal processing and adaptive learning.

**SignSpeak**

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

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

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

T4ME / META-NET

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

Publications


PhD Thesis

B. Hoffmeister. Bayes Risk Decoding and its Application to System Combination. July 2011. External Evaluator: Dr. Jean-Luc Gauvain HDR.
Logic & Theory of Discrete Systems

Staff

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  Dipl.-Inform. Michael Holtmann
  Dipl.-Inform. Martin Lang
  Dipl.-Inform. Daniel Neider
  Dipl.-Inform. Jörg Olschewski
  Dipl.-Inform. Frank Radmacher
  Dipl.-Inform. Stefan Schulz
  Dipl.-Inform. Michaela Slaats
  Dipl.-Inform. Alexandra Spelten
  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).

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

Strategies in Infinite Games


Funded by: DFG, ESF (European Science Foundation, LogICCC project GASICS)

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.

• Logic, Language Theory and Strategies in Infinite Games
In this project, the “complexity” of winning conditions of infinite games is related to the corresponding concept of complexity for possible winning strategies. As complexity measure, the definability in systems of (monadic second-order or first-order) logic is taken, or equivalently, language theoretical notions of definability for subclasses of the class of regular languages are applied. We obtained results of two kinds: First, we exhibited cases where a definability concept for winning conditions can be taken again for the specification of corresponding winning strategies. Second, we showed that in certain cases one needs to increase the level of “complexity” (by one or two levels of quantifier alternation) when passing from winning conditions to corresponding winning strategies. The results were presented at DLT 2011 (see [2]).

In related research, M. Gelderie developed an automata theoretic setting (based on the cascade product construction) for the classification of regular languages (see the LATA-paper [9]).

• 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 the dissertation of M. Holtmann [13], the solvability of regular infinite games by such “strategies with delay” is analyzed. For example, 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. Another contribution is the study of memory-optimal winning strategies (see also the paper [10]).

• Optimality Concepts for Strategies in Infinite Games
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 [21]).

In a different setting, J. Olschewski studied a classification of winning strategies in infinite games via the measure of nondeterminism. In a cooperation of the project GASICS, especially with the group of ENS Cachan (P. Bouyer, N. Markey), it was shown that optimal strategies in this sense (called permissive strategies) can be guaranteed [1]. Current work deals, for example, with the question of finite presentations of such strategies.
• **Winning Infinite Games in Finite Time**
In a cooperation with J. Fearnley (Warwick), M. Zimmermann extended results of McNaughton on conditions which allow to stop infinite games after a finite time with correct outcome regarding the winner. A refined analysis of the problem showed the surprising result that McNaughton’s “score function” (giving such a condition on termination of plays) can be bounded to values up to 3; see [3]. In cooperation with R. Rabinovich (group of Prof. E. Grädel), D. Neider and M. Zimmermann extended these results by supplying an innovative concept of game reduction that allows (in contrast to known notions of reducibility) to decrease the level of a game with respect to the fundamental hierarchy in this context, the Borel hierarchy (see [16,17]).

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### Automata Theory and Infinite-State System Verification

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

Funded by: DFG

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• **Compositional Methods in Model-Checking**
In the doctoral project of I. Felscher, the model-checking problem over products and sums of structures is analyzed. A fundamental background result is the “Feferman-Vaught Theorem” of first-order model theory which allows to derive information about a product (or sum) structure from properties of the components and certain information about the way they are composed. The obtained results clarify under which circumstances (and with which computational complexity) the model-checking problem over a product can be reduced to its components when the involved second-order quantifiers are path quantifiers that allow to capture also conditions on lengths of paths; see the conference contribution [4] and the accompanying report [5].

• **Logics over trees**
In the doctoral work of A. Spelten, the power of logics that quantify over paths (such as path logic, chain logic, or branching time logics over tree structures) is studied, with a special emphasis on questions of decidability, and making use of the “equal level predicate” over trees which adds a feature of synchronization. In work with S. Winter and W. Thomas (presented at the Infinity Workshop in Taipei in October 2011), the boundary between decidability and undecidability for the model-checking problem of the infinite and infinitely branching tree was clarified.

• **Reachability over infinite graphs**
In his doctoral research project, Stefan Schulz obtained new results on decidability and undecidability of reachability properties over infinite graphs. The operation of set based unfolding is analyzed, and it is shown that it transforms graphs with a decidable monadic second-order theory into a graph with a decidable first-order theory with regular reachability predicates (see the FSTTCS paper [18]).
Context-Free Infinite Games

W. Fridman, C. Löding, D. Neider

Funded by: DFG, B-IT Research School

Context-free games are a setting in which algorithmic solutions to the synthesis problem (rather than the model-checking problem) are developed over infinite state spaces given by pushdown automata.

It is well-known that many decidability results carry over from the finite-state setting to the infinite-state setting of context-free games.

In two studies, results were obtained that give a contrast to this elementary observation. The first addresses the question of winning strategies that specify moves with a delay in comparison to moves of the opponent. Surprisingly, it was shown in [6, 7] in work of W. Fridman, C. Löding, and M. Zimmermann that context-free games behave here radically different from regular games: Neither is the solvability of context-free games by strategies with finite delay decidable, nor is there even an elementary bound for the growth rate of the delay (in case where winning a context-free game with finite delay is possible).

The second study was concerned with the distributed solvability of context-free infinite games. In work with B. Puchala (group of Prof. E. Grädel), very sharp results were found on the architectures that allow an algorithmic solution of the distributed synthesis problem (see [8]).

A Game Theoretic Approach to Dynamic Networks

F. Radmacher W. Thomas

Funded by: 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”, the doctoral thesis work of F. Radmacher introduces several models of dynamic networks in a game-theoretic framework. In a framework developed in [11, 12], we analyze the solvability of games that are played between a “destructor” (deleting or occupying connections) and a “constructor” (repairing such edge or node failures), with the requirement for constructor to keep the network connected. The possibility to decide solvability of such games (and the corresponding computational complexity) was clarified in a number of scenarios.

In a cooperation with the UMIC group of Jun.-Prof. James Gross, the conditions are analyzed 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. This work is under submission.
The fastly developing field of automata theory requires continuous work on exposing the known, especially the recent results in a uniform and well-organized manner. Our group participated in this type of work by contributing three survey papers on different subareas of automata theory. C. Löding wrote two survey papers, one on the current state of the automata theoretic approach to infinite games [14], and a second one on the state-of-the-art of the theory of automata on finite trees [15]. In a survey for the same volume as [15], published in India, W. Thomas exposed automata theoretic methods in the analysis of infinite-state transitions systems [20], a theory needed as a foundation of infinite-state model-checking. Another survey paper (on the uniformization problem in the context of infinite games) was delivered as an invited address at the 4th Indian Conference on Logic and its Applications (see [19]).
Other Activities

W. Thomas

- Chairman of the senate of RWTH Aachen
- Speaker of the DFG-Research Training Group (Graduiertenkolleg) 1298 “Algorithmische Synthese reaktiver und diskret-kontinuierlicher Systeme”
- Member of 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)
  ◦ Logical Methods in Computer Science
  ◦ RAIRO Theoretical Computer Science and Applications
  ◦ Discrete Mathematics and Theoretical Computer Science
- Chairman of Section Grundlagen der Informatik of GI (Gesellschaft für Informatik), and member of the extended executive board of GI
- Member of the Executive Committee of the project GASICS (Games in Analysis and Synthesis of Interactive Computational Systems)
- Member of the Steering Committee for the conference STACS (“Symposium on Theoretical Aspects of Computer Science”)
- Member of the program committees of the conferences:
  ◦ FSTTCS 2011 (Foundations of Software Technology and Theoretical Computer Science)
  ◦ CSR 2012 (Computer Science in Russia)
  ◦ DLT 2012 (Developments in Language Theory)
  ◦ LATA 2012 (Language and Automata Theory and Applications)
  ◦ LPAR 2012 (Logic for Programming, Artificial Intelligence and Reasoning)
- Member of Academia Europaea

W. Oberschelp

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

C. Löding

- Student Advisor for Teachers’ Curricula and for the subject “Computer Science” in the Curriculum of “Technical Communication”
- Member of the program committees of the conferences:
  ◦ AFL 2011 (13th International Conference on Automata and Formal Languages),
  ◦ MFCS 2011 (36th Int. Symp. on Mathematical Foundations of Computer Science)
Talks and Publications

Talks

N. Chaturvedi: Languages vs. ω-Languages in Regular Infinite Games, DLT 2011, Milan, Italy, Juli 2011


I. Felscher: Compositional Failure Detection in Structured Transition Systems, CIAA in Blois, France, July 2011

W. Fridman: Degrees of Lookahead in Context-free Infinite Games, AlgoSyn Workshop 2011, Dagstuhl, March 2011

W. Fridman: Degrees of Lookahead in Context-free Infinite Games, CSL 2011, Bergen, Norway, September 2011

M. Gelderie: Memory Reduction via Delayed Simulation, iWIGP (international workshop on interactions, games and protocols) ETAPS 2011, Saarbrücken, Germany, March 2011

M. Gelderie: Classifying Regular Languages via Cascade Products of Automata, LATA 2011, Tarragona, Spain, May 2011

M. Holtmann: Memory and Delay in Regular Infinite Games, Informatik Oberseminar, Aachen, May 2011

C. Löding: Uniformization in automata theory, 14TH Congress of Logic, Methodology and Philosophy of Science, Nancy, France, July 2011

C. Löding: Strategy Synthesis for Infinite Games, On the Posterity of Büchi, Lausanne, Switzerland, March 2011

C. Löding: Automata on Infinite Trees, Highlights of AutoMathA, Vienna, Austria, November 2010

J. Olschewski: Permissive Strategies in Parity Games, 4th GASICS Meeting, Paris, France, November 2010

J. Olschewski: Languages vs. ω-Languages in Regular Infinite Games, GASICS Meeting, Mons, Belgium, May 2011

S. Schulz: Finite-Memory Strategies in Visibly Pushdown Games, Seminar of AlgoSyn Research Training Group, Aachen, October 2010

S. Schulz: Decision Problems for First-Order Logic with Reachability, LogInf 2010, Leipzig, Germany, November 2010

S. Schulz: Decision Problems for First-Order Logic with Reachability, FSTTCS’10, Chennai, India, December 2010

S. Schulz: Finite-Memory Strategies in Pushdown Games, AlgoSyn Workshop 2011, Dagstuhl, March 2011

S. Schulz: Testing Pushdown Machines for Regularity, Graduate School Workshop, Dagstuhl, June 2011
Publications


Mathematical Foundations of Computer Science

Staff

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  Silke Cormann

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  Dipl.-Inform. Faried abu Zaid (since March 2011)
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  Dipl.-Gyml. Wied Pakusa (since June 2011)
  Dipl.-Math. Bernd Puchala
  Dipl.-Inform. Roman Rabinovich
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, F. Abu Zaid, D. Fischer, W. Pakusa, B. Puchala, R. Rabinovich

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

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

It includes about 150 researchers throughout Europe.

Algorithmic Synthesis of Reactive and Discrete-Continuous Systems (AlgoSyn)

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

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 focuses on foundational projects on infinite games. In particular, we aim at extending game-based methodologies from two-player games to multi-player games and to games that involve infinitary winning conditions.
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.

The central open problem of finite model theory is the question whether there exists a logic that captures polynomial time, in the sense that a property of finite structures is definable in the logic if, and only if, it can be decided in polynomial time. Natural candidates for such a logic are suitable extensions of the fixed-point logics LFP (least fixed-point logic) and IFP (inflationary fixed-point logic). A well-known such extension is fixed-point logic with counting which captures polynomial time on several interesting classes of structures including planar graphs, structures of bounded tree-width and all classes of graphs with forbidden minors, but fails to do so on the class of all finite structures. It has recently been shown that solving systems of linear equations is a problem that separates polynomial time from fixed-point logic with counting. This motivates the extension of fixed-point logic by operators from linear algebra such as ranks of definable matrices, similarity of matrices and so on. At this point it is not known whether such extensions lead to a logic that captures polynomial time.

Further, we study definability and complexity for finitely presented infinite structures, with a focus on structures presented by automata. As recent highlight are new structural properties of omega-automatic presentations and new methods for determining whether a given structure is omega-automatic. As a consequence we prove for instance that the field of reals does not admit an omega-automatic presentation.
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
- Member of the Programme Committee GAMES 2010, CSL 2011, IWIGP2011, GandALF2011, GAMES 2011
Talks and Publications

Talks


E. Grädel, Games and Automata for Synthesis and Verification, PESC-ESF-Meeting, Dubrovnik, April 2011.


D. Fischer, Model Checking the Quantitative $\mu$-Calculus on Linear Hybrid Systems, DFG Research Training Group AlgoSyn, Aachen, July 2011.

D. Fischer, Model Checking the Quantitative $\mu$-Calculus on Linear Hybrid Systems, Annual Workshop of the ESF Networking Programme on Games for Design and Verification, Paris, September 2011.


B. Puchala, Concurrent Graph Searching, Young Researchers Workshop on Concurrency Theory, Aachen, September 2011.


R. Rabinovich, Graph Searching Games with Multiple Robbers and Games with Imperfect Information, Annual Workshop of the ESF Networking Programme on Games for Design and Verification, Paris, September 2011.
Publications


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  Dipl.-Inform. Henrik Zimmer *(funded by IKT.NRW, Ziel 2)*
• **Student Researchers**
Overview

The Chair of Computer Graphics, Computer Vision, and Multimedia at RWTH Aachen University has three major focus areas within the field of Visual Computing: Geometry Processing, Mobile Multimedia, and Computer Vision.

The Geometry Processing Unit addresses research questions in the context of the generation, reconstruction, optimization, and modification of digital 3D models most often represented by polygonal meshes. The typical application domains for the algorithms developed in our group are CAD/CAM in architecture and engineering, simulation sciences, rapid prototyping, as well as medical applications. Our recent activities in Geometry Processing were concerned with the automatic generation of high-quality quad meshes and the robust, efficient, and exact implementation of geometric operators like Minkowski sums and sweep surfaces.

The Mobile Multimedia Unit emerged from our activities in various third party funded projects, including the excellence cluster UMIC. Here we are investigating fundamental functionalities that make high performance graphics and vision capabilities usable on mobile devices. In particular we are looking into ways how to overcome the restrictions implied by limited resources (e.g. compute performance, memory, transmission bit-rate) and how to recover and exploit the location context of the mobile user for novel application scenarios.

The Computer Vision Unit is concerned with the reconstruction of faithful 3D models from images and video as well as with the detection and recognition of objects. For 3D reconstruction we distinguish different classes of objects, i.e. human faces in motion, static medium sized 3D objects, and entire urban environments. On the detection, tracking, and recognition side, we aim at creating computer vision systems that scale up to the many challenges of performing visual scene understanding in complex real-world settings. Some topical overlap with the Mobile Multimedia Unit exists in the area of image-based self-localization, where the location of a mobile user is determined by feature-based comparison of his view with a large database of street-level photographs.

Our research is applied basic research in the sense that we develop fundamental algorithms and apply them to practical real-world problems. This is why our results are on the one hand published in academic papers at the major international conferences and journals, while on the other hand they are being used in practical applications by our industrial partners.

A fully integrated Geometry Processing Pipeline is one of the long term goals on our research agenda. It requires methods for capturing the shape and texture of real objects, turning them into efficient computer models and enhancing the quality of the raw data with respect to surface roughness, sharp feature preservation and topological consistency. More sophisticated algorithms are able to even detect and extract structural information (e.g. in technical objects composed by shape primitives such as cylinders and spheres) or they turn unstructured polygon meshes into CAD-type quad meshes where the orientation and alignment of the quad faces reflects the intrinsic geometric structure of the given surface.

Eventually we also need algorithms for the interactive visualization of the potentially massive datasets. To achieve this goal we are investigating new techniques to measure three dimensional data with digital cameras and laser range scanners. Once this data is obtained we have to integrate measurements from several sources into a single 3D computer model and thereby remove erroneous and redundant data.

Besides the reconstruction of existing objects, we are also investigating new algorithms and concepts for the generation, modelling, and manufacturing of new designs. This is supported
by novel algorithms for the efficient, robust and precise computation of geometric operators like Boolean operations, Offsets, Minkowski sums and sweep surfaces.

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

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

To promote this fresh and highly relevant research area we have started an international symposium series on Geometry Processing which after its successful inauguration in Aachen in 2003 has now established as the major international forum specialized to this field. On the national level, we founded a “Geometry Processing” section as a sub-organization of the national Gesellschaft für Informatik. As the speaker of this section, Leif Kobbelt's goal is to join the forces of the various research groups in industry and academia.

On the Computer Vision side, our main research theme is the connection of different areas of vision and graphics into so-called “cognitive loops”, collaborative feedback cycles in which multiple modalities mutually support each other in order to solve a bigger task than any could do on its own. Object recognition and categorization take a key role in those integrations, since they can deliver a semantic interpretation of the image content, which considerably simplifies other tasks such as segmentation, 3D reconstruction, and tracking. For this goal, we have developed efficient approaches for object categorization in difficult real-world scenarios. By combining those approaches with components for ego-motion estimation and tracking, we are building mobile vision systems for localizing other traffic participants (cars, pedestrians, bicyclists) in a vehicle’s field-of-view and for tracking them over time. This research has direct applications for automatic scene interpretation in mobile robotics and automotive platforms.

In addition, we are developing core components for large-scale 3D city reconstruction and mobile visual search applications. Cameras have become a ubiquitous accessory in mobile phones. The goal of this work is to make it possible for people to use their cell phone’s camera as an interface to the real world, recognizing objects of interest in the mobile user’s
immediate surroundings and feeding back information and 3D visualizations to the mobile device. As above, this research aims at leveraging the connections between multiple vision modalities, in this case object recognition and 3D reconstruction. Thus, we are developing technologies for using recognition to help create compelling 3D reconstructions and for using the resulting 3D data to again improve mobile recognition.

Our teaching curriculum currently comprises a number of basic and advanced courses covering the most important sub-disciplines in Graphics and Vision. Besides the “Introduction to Computer Graphics” course, Prof. Kobbelt is offering advanced courses on “Geometry Processing”, “Global Illumination” and “Polynomial Curves and Surfaces”. In addition, Prof. Leibe is offering courses on “Computer Vision” and “Machine Learning”. On the undergraduate level we offer an introductory seminar and practical exercises on topics in Computer Graphics.

This year our group was again able to publish quite a few innovative research papers on internationally recognized conferences and journals in Computer Graphics and Computer Vision.

Prof. Leibe received a Best Paper of the Year award by the ISPRS Journal of Photogrammetry and Remote Sensing for a joint paper with Konrad Schindler, Andreas Ess, and Luc van Gool from ETH Zurich.

In the last year, Prof. Leibe has received three very attractive external offers from the University of Bern, the University of Stuttgart, and the Technical University of Darmstadt. However, eventually he turned down all three of them because of a generous counter-offer for a tenured professor position by RWTH, which will provide the funding and infrastructure for an optimal environment around his future research activities.

On the following pages, we are going to give a brief overview of our current research projects.
For sophisticated geometric modeling and processing applications like, e.g., CAD/CAM and numerical simulation, quad meshes are often preferred over triangle meshes. However, the generation and handling of quad meshes is significantly more difficult due to the anisotropic nature of quadrilaterals. While for high quality triangle meshes it is usually sufficient to have a fairly regular vertex distribution, good quad meshes have additional orientation and consistency constraints to satisfy. In fact the optimization of quad meshes is an inherently global problem since local changes in the mesh structure usually propagate globally across the mesh. This is not the case for triangle meshes where mesh optimization can be performed based on local operations.

In this project we developed a fully automatic algorithm which optimizes the high-level structure of a given quadrilateral mesh in order to achieve a coarser quadrangular base complex (see Figures (a) and (d)). Such a topological optimization is highly desirable, since state-of-the-art quadrangulation techniques lead to meshes which have an appropriate singularity distribution and an anisotropic element alignment, but usually they are still far away from the high-level structure which is typical for carefully designed meshes manually created by specialists and used e.g. in animation or simulation (cp. Figure (d)).

The quality of the high-level structure is negatively affected by helical configurations within the quadrilateral mesh (see Figure (b)). Consequently we designed an algorithm which detects helices and is able to remove most of them by applying a novel grid preserving simplification operator (GP-operator) (Figure (c)) which is guaranteed to maintain an all-quadrilateral mesh. Additionally it preserves the given singularity distribution and in particular does not introduce new singularities.
Before being fabricated, architectural free-form shapes are usually tessellated into a finite set of discrete panels approximating the surface. In general all panels are different leading to high production costs. The goal of rationalization is to find a small set of representative production molds to maximize mold re-use and minimize production costs. While several rationalization methods exist for flat and slightly curved panels, this project deals with the rationalization of so called point-folding elements – non-planar, pyramidal panels, usually formed from thin metal sheets, which exploit the increased structural capabilities emerging from folds or creases. In mechanical engineering and architecture, such structural elements with low material consumption and high load-bearing capabilities are essential for light-weight and even self-supporting constructions.

Given a triangulated free-form surface, a corresponding point-folding structure is a collection of pyramidal elements basing on the triangles. As with other types of panels, user-specified or material-induced geometric constraints often imply that each individual folding element of the structure has a different shape. We developed a rationalization method for such structures which respects the prescribed aesthetic and production constraints and finds a minimal set of molds for the production process, leading to drastically reduced fabrication costs. For each base triangle we compute and parametrize the range of feasible folding elements that satisfy the given constraints within the allowed tolerances. Then we pose the rationalization task as a geometric intersection problem of 3D bounding volumes, which we solve so as to maximize the re-use of mold dies. Major challenges arise from the high precision requirements and the non-trivial parametrization of the search space.

We evaluated our method on a number of architect designed shapes where we achieved rationalization gains of more than 90%. For example only 21 different molds were used to cover the 270 panels in the folding structure shown in the image above.
Efficient methods to compute intrinsic distances and shortest paths on 3D models have been presented for various types of digital object representations, most importantly polygon meshes. These meshes are usually assumed to be well-structured and manifold. In practice, however, they often contain defects like holes, gaps, intersections, degenerate polygons, non-manifold configurations – or they might even be just a “soup” of polygons without any connectivity information. The task of repairing these defects is computationally complex and in many cases exhibits various ambiguities whose resolution demands tedious manual efforts.

In this project we developed a computational framework that enables the computation of plausible approximate intrinsic distances and geodesic paths on raw meshes in a way which is highly tolerant to such defects. Holes and gaps are bridged up to a user-specified tolerance threshold such that distances can be computed plausibly even across multiple connected components of inconsistent meshes. Furthermore, we found ways to locally parameterize a surface based on geodesic distance fields, easily facilitating the application of textures and decals on raw real-world meshes. All this is done without explicitly repairing the input, thereby avoiding the costly additional efforts. In order to enable broad applicability we developed two different implementation variants, one optimized for performance, the other optimized for memory efficiency.

The basic idea is to abstract from the mesh structure (and all its potential defects) and to perform all computations in a crust volume tightly enclosing the input mesh. Topology-sensitive, hole-filling morphological operations are applied to this crust volume in order to make computations tolerant to gaps and holes.

Using the presented framework many existing applications from the fields of Computer Graphics and Computational Geometry can readily be extended to deal with imperfect meshes. Examples of such applications are shape matching, symmetry and regularity detection, surface parameterization, texturing, and tool-path generation.

The image shows a visualization of a distance field as well as a plausible shortest path between two points computed by our method on a corrupted polygon mesh.
OpenFlipper – An Open Source 3D Geometry Modeling Framework

Jan Möbius, Leif Kobbelt

Two years ago we started our 3D geometry processing and modelling Framework called OpenFlipper. Since that time a lot of improvements and new functionality have been added to the framework. OpenFlipper has been extended to support a variety of new data types. These involve common types such as polygonal or triangular meshes as well as spline curves and surfaces. As point based rendering is also a field of research, a splat data type and renderer have been integrated (cf. left image).

Due to OpenFlipper being open source software and the upload to the Mac App Store (~ 4000 downloads) we significantly increased our user base.

For today’s animation films, content creation involves animating a vast number of different characters. Usually these animations are based on skeletons which are created and bound to a characters surface mesh which is called the skin. When the skeleton is moved, the skin is deformed and follows the motion of the skeleton. This significantly reduces the work required to create animations, as only the skeleton has to be modified while the skin is automatically updated. We integrated these skeleton based animations into OpenFlipper to easily investigate algorithms for creating the binding between skin and skeleton and to automatically create skeletons from surface meshes (cf. right image).

Furthermore we added a new subdivision plugin to OpenFlipper with a variety of different algorithms (Interpolating and Non-Interpolating √3, Butterfly).

The rendering system has been modified to be more flexible. Alternatively to the integrated default renderer, developers can now implement new renderers in separate plugins. Therefore the coding effort for developing and integrating new rendering techniques has been significantly reduced. Furthermore a post processing step has been added to the rendering pipeline. This step is also implemented as additional plugins and is used to run image processing algorithms on the rendering algorithms output. As an example an edge detection algorithm can be run on the generated images to analyse specific properties of the renderer or the post processing step can be used to implement deferred shading.

To be more flexible in data acquisition, we integrated new importers and exporters for a variety of file formats, including the well-known Visualization Toolkit format (VTK) and the Biovision file format (BVH) for reading and writing animations.
The complexity and detail of geometric scenes that are used in today's computer animated films and interactive games have reached a level where the manual creation by traditional 3D modeling tools has become infeasible. This is why procedural modeling concepts have been developed which generate highly complex 3D models by automatically executing a set of formal construction rules. Well-known examples are variants of L-systems which describe the bottom-up growth process of plants and shape grammars which define architectural buildings by decomposing blocks in a top-down fashion. However, none of these approaches allows for the easy generation of interconnected structures such as bridges or roller coasters where a functional interaction between rigid and deformable parts of an object is needed.

Our approach mainly relies on the top-down decomposition principle of shape grammars to create an arbitrarily complex but well structured layout. During this process, potential attaching points are collected in containers which represent the set of candidates to establish interconnections. Our grammar then uses either abstract connection patterns or geometric queries to determine elements in those containers that are to be connected. The two different types of connections that our system supports are rigid object chains and deformable beams. The former type is constructed by inverse kinematics, the latter by spline interpolation. We demonstrate the descriptive power of our grammar by example models of roller coasters (cf. upper image) and wall-mounted catenaries (cf. bottom image).
In radio wave propagation simulations there is a need for modelling antenna patterns. Both the transmitting and the receiving antenna influence the wireless link. We use spherical harmonics to compress the amount of measured data needed for complex antenna patterns. We developed a method to efficiently incorporate these patterns into a ray tracing framework for radio wave propagation. One problem that arises is how to efficiently generate rays according to the transmitting antenna pattern. We solve this by applying a sample warping technique known from computer graphics. The ray tracing simulation computes a compressed irradiance field for every point in the scene. The receiving antenna pattern can then be applied to this field for the final estimation of signal strength.

The approximation quality achieved by the spherical harmonic compression is very good. The errors produced depend on the complexity of the antenna pattern and the number of basis functions used. The following plot shows the reconstructed antenna pattern on the left and the error plot between the measured pattern and the reconstruction:

Our approach allows to model antenna patterns of varying complexity. Simple single-lobed antennas as well as antenna patterns with multiple lobes are easily modelled. The following image shows patterns of varying complexity. Simple patterns require fewer spherical harmonic basis functions for adequate approximation complexity.
Modeling with constraints is an important tool for the construction and modification of 3D geometric models. Especially in the case of modeling man-made structures like architecture or machine parts, geometric constraints are able to create and preserve ubiquitous alignment properties like element parallelism, collinearity, fixed angles and distances, or symmetry relations. The automatic satisfaction of these constraints greatly simplifies the modeling process by reducing the degrees of freedom and furthermore strongly improves the quality of the results. The central problem of interactive constrained editing is, given a user modification in the form of re-positioning a set of vertices, to adjust the positions of the remaining vertices such that all constraints are satisfied. Various solutions to handle this problem have been proposed, however, the main challenge of any incremental editing approach is not handled satisfactorily: In order to not destroy the results of earlier (manual or automatic) editing operations, it is of crucial importance to modify the positions of as few additional vertices as possible during the automatic constraint satisfaction phase. Furthermore, the whole constraint resolution pipeline is required to run in real-time to enable a fluent, interactive workflow.

To address both issues, we have developed a novel constraint analysis and solution scheme based on a key observation: While the computation of actual vertex positions requires nonlinear techniques, under few simplifying assumptions the determination of the minimal set of to-be-updated vertices can be performed on a linearization of the constraint functions. Posing the constraint analysis phase as the solution of an under-determined linear system with as few non-zero elements as possible enables us to exploit an efficient strategy for the Cardinality Minimization problem known from the field of Compressed Sensing, resulting in an algorithm capable of handling hundreds of vertices and constraints in real-time. Our constraint resolution scheme has been integrated into an interactive reconstruction and modeling system for 3D building models based on oblique aerial images to demonstrate that this approach works very well in practice.

The figure below illustrates the interactive editing process. For an editing operation performed by the user (red arrow), the system automatically determines a set of vertices (blue dots) that have to be adjusted in order to satisfy all constraints.
Image-based large scale reconstruction or representation of entire urban environments is considered a key part in many computer graphics applications including 3D city modeling and visualization. The technique of generating high-quality image geometry for facades in 3D city models from aerial photos is essential for image-based urban site modeling. A variety of related facade segmentation and reconstruction methods were developed for obtaining or recovering detailed geometry structures of building facades. However, current vision-based methods are not sufficiently robust to be applied to aerial facade images. The reason for this is the image noise level in the available photo material which does not allow for a proper handling of strongly distorted facade elements (windows, doors, balconies, etc).

In order to overcome the shortcoming, we introduce a fully automatic approach to the analysis and segmentation of single aerial facade image in order to recover their semantic structures as well as rendering high-quality images. The motivation for our work is to address following problems: (1) precisely detect low-level semantic elements (windows, doors, balconies, wall, etc.) on noisy facades of low resolution (average resolution is around 100×100 pixels) without applying any building architectural constraints (is fragile when taken on complex facades) or machine learning-based segmentation (the accuracy is highly dependent on proper training dataset), (2) automatically analyse high-level facade structures (such as horizontal floor positions, vertical wall column sizes, similar windows alignment and entire facade symmetry ) in order to generate procedural description of given facade based on the detected low-level information, (3) realistically render facade geometry of higher resolution and visual quality than the given aerial image. As current super-resolution techniques are not enough to distinguish noise around structure edges from correct image data, the proposed method is designed to raise the visual quality by synthesizing high-resolution textures with the procedural model generated.

As illustrated in the schematic figure above, our technique will transform a low-resolution facade image into a textured high-quality geometry that can be effectively exploited for urban reconstruction based on aerial imagery.
The display of complex 3D scenes in real-time on mobile devices is difficult due to the insufficient data throughput and a relatively weak graphics performance. Hence, we propose a client-server system, where the processing of the complex scene is performed on a server and the resulting data is streamed to the mobile device. In order to cope with low transmission bitrates, the server sends new data only with a frame rate of about 2 Hz. However, instead of sending plain frame buffers, the server decomposes the geometry represented by the current view's depth profile into a small set of textured polygons. This processing does not require the knowledge of geometries in the scene, i.e. the outputs of Time-of-flight camera can be handled as well. The 2.5D representation of the current frame allows the mobile device to render plausibly distorted views of the scene at high frame rates as long as the viewing direction does not change too much before the next frame arrives from the server. In order to further augment the visual experience, we use the mobile device's built-in camera or gyroscope to detect the spatial relation between the user's face and the device, so that the camera view can be changed accordingly. This produces a pseudo-immersive visual effect. Besides designing the overall system with a render-server, 3D display client, and real-time face/pose detection, our main technical contribution is a highly efficient algorithm that decomposes a frame buffer with per-pixel depth and normal information into a small set of planar regions which can be textured with the current frame. This representation is simple enough for real-time display on today's mobile devices.
Non-Parametric Facial Feature Localization using Segment-based Eigen Features

Hyun-Chul Choi, Dominik Sibbing, Leif Kobbelt, Se-Young Oh

Vision-based face tracking has found a large number of applications since region detection and tracking algorithms have been proposed. Beyond the detection of a rectangular face region, the localization of facial feature points gives a useful hint to recognize the facial pose, expression, and identity. Detecting facial features, seen by a multiview-stereo camera setup, helps to reconstruct human face in 3D.

We build a database with approximately thousand images showing human faces with known locations of facial features. These facial features are, e.g., corners of the eyes, mouth and certain points around the nose. The training images are regularly sampled and at each sample point we compute a descriptor, which encodes the local appearance of the image. We build a database by storing for each sample point the descriptor and offset vectors pointing towards facial features. Such a database is quite large and it would be difficult to store it on devices with low memory, like e.g. smartphones. Fortunately the database contains a lot of redundant information, since we only consider human faces. Therefore it is possible to reduce the size of the codebook using a principal component analysis (PCA), while simultaneously keeping its expressiveness. Detecting facial features for a new input image is quite easy. We regularly sample the input image and extract descriptors at every position. The codebook is used to extract possible directions pointing towards facial features, from which we can compute the location of facial features in a robust way. In experiments we show that the algorithm computes more accurate facial feature localization than state-of-the-art approaches, while at the same time it consumes much less memory and computational time.

At each regularly placed sample point we compute an image descriptor (top left). Examples from a database allow to predict the location of facial feature (top right). Bottom row: Exemplary results of our facial feature detector.
The project Mobile ACcess aims at developing cost effective, collaborative, secure mobile wireless networks with accompanying services and applications. These are intended for mobile users and utilize context and location based information. These prototypical application scenarios drive fundamental research, as during development new challenges and problems arise.

Important components in such a system are location-based services such as public transportation or cultural event information. Our system allows the user to localize himself by taking a picture of his surroundings that is then send to a localization server which returns the user’s position. Given this location, all events within a certain radius and in a user specified timeframe can by queried from an event server and are rendered into a 3D city model based on their queried tags. Further functionality includes browsing through various event categories and restricting the displayed events to a specific category. Selecting a single event allows us to retrieve detailed event information such as an elaborate description, the exact time, contact information, and – if provided by the event’s organizer – promotional images.

Given that the user decides to attend a certain event, he can easily obtain the required public transportation information that describes how to travel from his current location to the respective event location. This is achieved by including the ASEAG public bus services into our system. The travel information is acquired by sending the current user location together with the selected event location to the server. The returned travel information is finally post-processed for displaying it in a device- and user-friendly manner.

The amount of data represented by the city model geometry as well as the event data requires new remote rendering techniques. Embedded devices such as smartphones have only limited capacity for rendering and visualization. Hence our research focuses on making the above mentioned services and applications possible.
Ad-Hoc Multi-Display for Mobile Games
Jan Robert Menzel, Ming Li, Leif Kobbelt

The marketshare of smartphones among all mobile phones is constantly growing. These devices are in fact general purpose computers, i.e. they use adapted versions of common desktop operating systems and are programmable using standard programming languages. Second, they all have relatively large touch sensitive screens which cover the largest part of the devices surface. Third, they have advanced 3D graphics capabilities, supporting OpenGL ES or even shader based programmable graphics pipelines. Lastly, all those smartphones have different kinds of wireless communication system built in, either GSM or 3G based, WiFi or Bluetooth.

Apart from mobile phones, a new class of technically very similar devices is getting more and more popular, e.g. tablet computers like Apple iPad. As a third class of mobile computers, some kinds of mp3 players, like the iPod Touch, are basically smart phone without a GSM modem.

Until recently, those devices and especially the applications running on them rarely utilized peer to peer communication between multiple devices of a kind. In our Mobile Multi Display project we implemented ways of connecting an arbitrary number of such devices together to form one larger display to act as one big multi touch screen.

More recently we enhanced the ability of creating an initial calibration of the devices by using image recognition and better calibration patterns that were needed when combining devices of different sizes (like phones and tablets). After this calibration we try to track the movements of the devices to adjust the underlying virtual screen. For example slight device rotations can occur when the user accidentally touches one phone. Such rotations can be automatically detected and the view can be adjusted.

To find out more about the genres of applications that can benefit from a flexible and quickly configured multi display, we developed an additional game. Here we want to evaluate the metaphor considering the devices as windows into a larger virtual canvas that's much larger than the union of the individual screens. We developed a game where the distance of the devices represent the distance in the gaming world in an environment where large non-visible gaps are tolerable.
Augmented Reality is a technique to add virtual content into the physical environment. The basic requirements are a method to localize the user in the real world, a way to output the augmentation, and a computer powerful enough to simulate the virtual environment. A very common way is to use a smartphone to augment the vision by overlaying the video stream from the camera with virtual objects on the screen. As most smartphones are already equipped with a GPS sensor, a very rough localization can be performed.

GPS however has a number of drawbacks as a localization method. For example, the accuracy in an urban environment can be very low due to high buildings which block the direct view to the satellites. It is also strictly limited to be used outdoors.

We want to explore the possible uses of augmented reality in urban environments in combination with a much more capable localization method: Image-based localization. This technique can yield to a much better localization and also makes seamless indoor-outdoor AR applications possible.

Augmented reality utilizing image-based localization is still in a stage of fundamental research when it comes to complex outdoor scenarios. To guide the evaluation of our techniques and algorithms developed for these scenarios, two prototypical applications were developed: One AR navigation system that overlays the route into the camera view of a driver standing on a personal transporter and one game that can be played to learn about a city and can act as a personal tourist guide.

The navigation system uses AR to reduce distraction of the driver as he can see the real road even when looking at the phone. Also the mental workload should get reduced by not having to understand an abstract map and creating a mental link between that map and the real environment. Some special challenges occur when designing a navigation system for a personal transporter: like all vehicles but unlike pedestrians the driver can't stop anywhere to look up the route, but the driving speed and sometimes even the routes are more like those of a pedestrian. Also unlike in a car, on this vehicle the driver is not separated from the environment so audio feedback is problematic. That's why we also investigate haptic feedback.

The AR game is somewhere in between an adventure game and a tourist guide as it forces the player to visit different interesting spots in the city and also teaches some city history. But the game not just tells the story, the user itself gets involved and gets to be a part of the history. The high degree of immersion possible by augmented reality helps to remember the learned facts later on so we believe that this kind of application can also be used for educational purposes.
Structure-from-Motion (SfM) techniques reconstruct the 3D structure of a scene from a set of photos taken from slightly different viewpoints. These compact scene representations can then be used for accurate image-based localization, where the position and orientation of a new photo not included in the reconstruction is determined relative to the reconstructed 3D model of the scene. This estimated pose could then be used for further processing, for example in an Augmented Reality application.

Traditionally, SfM reconstructions have been very time-consuming, limiting the size of the scenes that can be reconstructed. Recently developed approaches enable the creation of large-scale 3D models of urban scenes in a comparably small time frame (around a day’s time of computation). Since it is now possible to use these large-scale models for image-based localization, localization approaches have to be developed that are able to efficiently handle such large amounts of data.

An important bottleneck in the localization pipeline is the computation of 2D-to-3D correspondences between feature points in the image and 3D points in the model, which are required for the pose estimation of an image. Current state-of-the-art approaches use indirect matching techniques to accelerate this search by limiting the search space. In this work we demonstrate that direct 2D-to-3D matching methods have a considerable potential for improving registration performance. We derive a direct matching framework based on visual vocabulary quantization and a prioritized correspondence search. Through extensive experiments, we show that our framework efficiently handles large datasets and outperforms current state-of-the-art methods both in registration performance as well as in the time needed to register images.

The image on the left shows an example for our image-based localization method. We show both the 3D model of the scene, reconstructed from around 1,000 images, and the query image for which we want to estimate the camera pose. The blue pyramid depicts the position and opening angle of the camera used to take the image as estimated by our method. The red points show the 2D features and 3D points used to estimate the pose. We further show the 3D model projected into the query image.
Robust multi-person tracking is an important prerequisite for the use of mobile service robots in busy urban settings. In this project we address the problem of stereo vision based multi-person tracking from a mobile platform with reduced object detector evaluations.

Classical tracking-by-detection approaches require a robust object detector that needs to be executed in each frame. However, the detector is typically the most computationally expensive component, especially if more than one object class needs to be detected. We therefore investigate how the usage of the object detector can be reduced by using stereo range data for following detected objects over time. To this end we have proposed a hybrid tracking framework consisting of a stereo based ICP (Iterative Closest Point) tracker and a high-level multi-hypothesis tracker. Initiated by a detector response, the ICP tracker follows individual pedestrians over time using just the raw depth information. Its output is then fed into the high-level tracker that is responsible for solving long-term data association and occlusion handling. In addition, we constrain the detector to run only on some small regions of interest (ROIs) that are extracted from a 3D depth based occupancy map of the scene. The ROIs are tracked over time and only newly appearing ROIs are evaluated by the detector. We have additionally proposed a Poisson process attention model that allows our approach to evaluate ROIs in constant time. As a result of those improvements, our approach reaches state-of-the-art tracking performance at a significantly reduced run-time that is suitable for real-time applications.
Visual object detection is a core component for many applications. The capability to efficiently recognize objects in one’s field of view is of interest for many fields, including automotive driver assistant systems and mobile robotics. This is especially true for important object categories such as pedestrians or cars. In recent years, a large number of more complex detection approaches have been proposed in the literature. Current visual object recognition technology is reaching a level where satisfactory detection rates are becoming feasible. However, processing speed is still a major issue.

In this work, we have derived a general algorithm for incorporating ground plane constraints directly into the design of a sliding-window object detector. For each object type, we assume that it can only occur in a fixed relative height to the ground plane, i.e., pedestrians are always standing on the ground. This allows our approach to significantly reduce the search region to be processed by the object detector. We have combined this approach with a real-time implementation of the popular HOG detector. The resulting groundHOG approach achieves the same detection accuracy for pedestrian detection as the original HOG detector, while running at 83 fps for a street scene scenario, and it can be sped up to a multiple of this value at a small loss in detection accuracy. We have recently made our detector implementation publicly available to the research community as open source project in order to foster further research in this area.
Many higher-level vision tasks require detailed segmentations of persons, e.g., to provide detailed input for body pose analysis and articulated tracking or for video editing. Accurate segmentation of articulated persons however becomes very difficult in front of cluttered backgrounds. Common approaches often use global appearance models for the foreground and background regions, respectively. This results in a rather weak appearance model, because realistic images contain many colors that are moreover often similar for foreground and background, thus those regions cannot be distinguished very well.

In this project we are working on improvements for a level set tracker that aim at obtaining better appearance representations and, as a consequence, higher-quality object segmentations. Firstly, we subdivide each person’s foreground and background regions to obtain more powerful localized appearance models. The separating contour between those regions is modeled as an additional level-set functional, which is optimized together with the contour’s main functional in the regular level-set segmentation step. This allows us to more accurately represent a person’s different clothing items and thus to obtain a better appearance representation. Secondly, we use top-down shape information, which is obtained through a Hough Forest ISM detector, as a dynamic shape prior for more accurate segmentation. Both of those contributions are seamlessly integrated into the probabilistic level-set tracking framework and considerably improve the accuracy of the resulting segmentations, as shown in the images below.
Semantic image labeling is an important component towards visual scene understanding from mobile platforms. The capability to assign a semantic label to each of the image pixels can help improving the geometric reconstruction of the scene and the recognition of the objects that are present in the scene. Thus, combinations between semantic image labeling, object detection and geometric reconstruction have the potential of producing system that allow mutual benefit for the individual components.

In this project, we propose a novel formulation for the scene labeling problem which is able to combine object detections with pixel-level information in a Conditional Random Field (CRF) framework. Since object detection and multi-class image labeling are mutually informative problems, pixel-wise segmentation can benefit from powerful object detectors and vice versa. The main contribution of the current work lies in the incorporation of top-down object segmentations as generalized robust $P^N$ potentials into the CRF formulation. These potentials present a principled manner to convey soft object segmentations into a unified energy minimization framework, enabling joint optimization and thus mutual benefit for both problems. As our results show, the proposed approach outperforms the state-of-the-art methods on the categories for which object detections are available.
Discovering Favorite Views of Popular Places
Tobias Weyand, Bastian Leibe

Community photo collections such as Flickr or Panoramio have become a valuable source of large amounts of tourist photos, densely covering entire cities. In particular, they provide rich imagery of the world’s landmark buildings, statues, monuments and paintings. In order to automatically discover such popular places, we have developed a novel algorithm that summarizes photo collections in a set of iconic images, or iconoids, corresponding to favourite views of popular places, and a set of clusters, each containing all images overlapping with a particular iconoid.

In contrast to previous approaches from the literature, we consider the task of finding iconic images as a mode estimation problem. Building on medoid shift, an iterative mode estimation algorithm for arbitrary metric spaces, we propose a new algorithm called Iconoid Shift. This algorithm uses a distance measure for images based on the mutual overlap of a planar homography region fitted to matching image structures. This draws the mode search algorithm towards images that have maximum overlap with the images in their neighbourhood. Starting with a given view of a landmark building, Iconoid Shift tends to quickly converge to a view that is favored by photographers.

The resulting iconoids and their clusters have many interesting applications. Since the clusters each contain photos of a particular building taken under various viewing angles and lighting conditions, they can be used for robustly recognizing buildings in pictures taken with a cell phone. By mining photo titles, tags, and geotags from community photo collections, we can provide the user with information such as the name of the building, the corresponding Wikipedia article, and further related content. Using structure-from-motion techniques, the photos of a building can also be used for reconstructing 3D models of the most photographed buildings of a city.
Other Activities

Prof. Dr. Leif Kobbelt

Committees

• Member of the International Program Committee: Eurographics 2011
• Member of the Program Committee of 2011 SIAM/ACM Joint Conference on Geometric and Physical Modeling
• Member of the International Program Committee: Pacific Graphics 2011
• Member of the International Program Committee: Symposium on Geometry Processing, SGP 2011
• Member of the International Program Committee of the 16th Vision, Modeling, and Visualization Workshop, VMV 2011
• Member of the International Program Committee of the 24th Conference on Graphics, Patterns and Images, Sibgrapi 2011
• Member of the International Program Committee of the 12th International Conference on CAD & Graphics 2011 (China)
• Member of the International Program Committee: 3D Imaging, Modeling, Processing, Visualization and Transmission, 3DIM/3DPVT conference 2011
• Member of the International Program Committee: Shape Modeling International, SMI 2011
• Member of the International Program Committee: ACM Symposium on Interactive 3D Graphics and Games, I3D 2011

Other Academic Activities

• Monitoring Officer for the Eurographics 2014 Conference, 2011-2014
• Member of the Eurographics Award Committee
• Head of the Commission for Teaching and Education (Kommission für Lehre)
• Member of the Scientific Advisory Board of the Wales Research Institute of Visual Computing (RIVIC)
• Elected Member of the Executive Committee of the Eurographics Association
• Associate Editor, Computers & Graphics Journal, Elsevier
• Member of the Editorial Board of the Graphical Models Journal (Elsevier)
• Member of the Editorial Board of the IEEE Transactions on Visualization and Computer Graphics Journal
• Member of the Pacific Graphics Steering Committee (sole non-Asian member)
• Vertrauensdozent der Studienstiftung des deutschen Volkes
• Member of the Center for Computational Engineering Science (CCES)
• Co-Editor of the Springer book series “Geometry and Computing” (Computer Science & Mathematics)
• Chair of the GI-Fachgruppe “Geometry Processing”
• Member of the Scientific Board at the Virtual-Reality Center Aachen (VRCA)
• Head of the Steering Committee: Symposium on Geometry Processing
• Organizational Member of the Eurographics Association
• Member of the regional industry club REGINA e.V.
• Director of the Steinbeis Transfer Center for “Geometry Processing and CAGD”
• Dominik Sibbing: Student Advisor, main study period computer science

Awards
• D. Bommes, T. Lempfer and L. Kobbelt
  *Global Structure Optimization of Quadrilateral Meshes*
  **Best Student Paper Award**, Eurographics 2011

Prof. Dr. Bastian Leibe

Committees
• Program committee member, IEEE Workshop on Modeling, Simulation and Visual Analysis of Large Crowds (MSVL’11), Barcelona, Spain, November 2011
• Program committee member, IEEE Workshop on 3D Representation and Recognition (3DRR’11), Barcelona, Spain, November 2011
• Program committee member, IEEE Workshop on Challenges and Opportunities in Robotic Perception (CORP’11), Barcelona, Spain, November 2011
• Program committee member, IEEE Workshop on Computer Vision in Vehicle Technology: From Earth to Mars (CVVT’11), Barcelona, Spain, November 2011
• Area chair, International Conference on Computer Vision (ICCV’11), Barcelona, Spain, November 2011
• Area chair, IEEE Conference on Automatic Face and Gesture Recognition (FG 2011), Santa Barbara, USA, March 2011
• Program committee member, IEEE Conference on Computer Vision and Pattern Recognition (CVPR’11), Colorado Springs, USA, June 2011
• Program committee member, Canadian Conference on Computer and Robot Vision (CRV 2011), St. Johns, Canada, May 2011
• Program committee member, International Conference on Energy Minimization Methods in Computer Vision and Pattern Recognition (EMMCVPR’11), St. Petersburg, Russia, July 2011
• Program committee member, British Machine Vision Conference (BMVC’11), Dundee, UK, August 2011
• Program committee member, DAGM Annual Pattern Recognition Symposium (DAGM’11), Frankfurt, Germany, September 2011
• Program committee member, Workshop on Interactive Human Behavior Analysis in Open or Public Spaces (InterHuB’11), Amsterdam, Netherlands, November 2011
• Program committee member, International Workshop on Vision, Modeling, and Visualization, Berlin, October 2011
• Reviewer for Eurographics 2011, Llandudno, Wales, April 2011
• Reviewer for SIGGRAPH Asia 2011, Hongkong, December 2011
• Reviewer for IEEE International Conference on Robotics and Automation (ICRA’11), Shanghai, China, May 2011
• Reviewer for IEEE International Conference on Robotics and Automation (ICRA’12), St. Paul, USA, May 2012
• Reviewer for IEEE Intelligent Vehicle Symposium (IV’11), Baden-Baden, Germany, June 2011
• Reviewer for IEEE Transactions on Pattern Recognition and Machine Intelligence
• Reviewer for IEEE Transactions on Robotics

Other Academic Activities
• Associate Editor, Image & Vision Computing Journal
• 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)

Awards
• Best Paper of the Year 2010, ISPRS Journal of Photogrammetry and Remote Sensing

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
“Layout-Design für anisotrope Faserverbundstoffe zur Herstellung von Freiformgeometrien“, Seed Fund Projekt (Teil des Zukunftskonzeptes der RWTH), 2011
“Research and Development of Algorithms for the Reconstruction and Animation of Digital Models” Verold Ldt. (Toronto, Canada), 2011
“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
Prof. Dr. Bastian Leibe

“EUROPA – European Robotic Pedestrian Assistant”
Principal investigator

“Situated Vision to Perceive Object Shape and Affordances” German Research Foundation (DFG), D-A-CH lead agency program
Principal investigator

“Segmentation based Real-Time Tracking of Multiple Objects in Street Scenes”
RWTH Seed Fund Project
Principal investigator
Talks and Publications

Invited Talks
B. Leibe: „Object Categorization Interleaved with Figure-Ground Segmentation – An Algorithmic Perspective“, IGSN Symposium, Ruhr University Bochum, November 8, 2010.


B. Leibe: “Mobile Scene Understanding in Highly Dynamic City Environments”, Mini Symposium on Computer Vision, Pattern Recognition, and Machine Learning, University of Bern, March 31, 2011.


B. Leibe: “Mobile Scene Understanding in Highly Dynamic City Environments”, Computer Science Colloquium, University of Duisburg-Essen, April 27, 2011.


B. Leibe: “(Better Ways to Do) Object Recognition in Video”, 2nd IST Workshop on Computer Vision and Pattern Recognition, IST Austria, October 7, 2011.

Conference presentations
E. Dekkers, A Sketching Interface for Feature Curve Recovery of Free-Form Surfaces, Geometric Modeling (Dagstuhl Seminar 11211), Dagstuhl, Germany, May 2011

T. Sattler, Fast Image-Based Localization using Direct 2D-to-3D Matching, 13th International Conference on Computer Vision, Barcelona, Spain, November 2011

M. Li, Pseudo-Immersive Real-Time Display of 3D Scenes on Mobile Devices, 3D Imaging, Modeling, Processing, Visualization and Transmission (3DIMPVT), Hangzhou, China, May 2011

C. Schreter, J. Sun, L. Kobbelt, Online Estimation of B-Spline Mixture Models from TOF-PET List-Mode Data, 11th International Meeting on Fully Three-Dimensional Image Reconstruction in Radiology and Nuclear Medicine, Potsdam, Germany, July 2011


M. Campen, Hybrid Booleans, Eurographics 2011, Llandudno, United Kingdom, April 2011

M. Campen, Walking On Broken Mesh: Defect-Tolerant Geodesic Distances and Parameterizations, Eurographics 2011, Llandudno, United Kingdom, April 2011

D. Bommes, Global Structure Optimization of Quadrilateral Meshes, Eurographics, Llandudno, United Kingdom, April 2011

A. Schmitz, Efficient and Accurate Urban Outdoor Radio Wave Propagation, EEE ICEAA 2011, Torino, Italy, September 2011

D. Mitzel, *Real-Time Multi-Person Tracking with Time-Constrained Detection*, British Machine Vision Conference (BMVC’11), August 2011


E. Horbert, *Level-Set Person Segmentation and Tracking with Multi-Region Appearance Models and Top-Down Shape Information*, International Conference on Computer Vision (ICCV’11), November 2011


D. Mitzel, *Real-Time Multi-Person Tracking with Detector Assisted Structure Propagation*, IEEE Workshop on Challenges and Opportunities in Robot Perception, (CORP’11), November 2011

K. Rematas, *Efficient Object Detection and Segmentation with a Cascaded Hough Forest ISM*, IEEE Workshop on Challenges and Opportunities in Robot Perception, (CORP’11), November 2011

**Publications**


L. Krecklau, L. Kobbelt, Titelbild des “Informatik Spektrum”’, Band 34, Heft 3 (Juni 2011), ISSN 0170-6012 (gedruckte Version), ISSN 1432-122X (elektronische Version)


E. Horbert, K. Rematas, B. Leibe, *Level-Set Person Segmentation and Tracking with Multi-Region Appearance Models and Top-Down Shape Information*, International Conference on Computer Vision (ICCV’11), November 2011


D. Mitzel, B. Leibe, *Real-Time Multi-Person Tracking with Detector Assisted Structure Propagation*, IEEE Workshop on Challenges and Opportunities in Robot Perception, (CORP’11), November 2011

K. Rematas, B. Leibe, *Efficient Object Detection and Segmentation with a Cascaded Hough Forest ISM*, IEEE Workshop on Challenges and Opportunities in Robot Perception, (CORP’11), November 2011
Data Management and Exploration

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Overview

Research at Computer Science 9 aims at data mining and database technology for multimedia and spatio-temporal databases. In many applications, more and more digital information is generated and needs to be stored, processed, explored and analyzed. In our projects, we consider data from mechanical engineering, civil engineering, mobile communication, medical diagnostics, molecular biology, environmental sciences and multimedia scenarios in general.

Data Analysis and Knowledge Extraction. Increasingly large data resources require automatic techniques for gaining knowledge which means extracting interesting, unknown patterns from the data. In scenarios with many attributes or with noise, these patterns are typically hidden in subspaces of the data and do not show up in the full dimensional space; therefore, we develop new data mining techniques including subspace clustering or outlier detection. For data streams which constitute endless data resources, we develop specialized algorithms that can handle both the infinite amount of data and the limited and often varying amount of time available between two stream data items. Typical tasks are clustering of streaming data or classification on data streams. Besides mining vector data, we focus on extracting interesting patterns from complex data sources as graph databases.

Exploration of Multimedia Databases. Today's scientific, commercial, and entertainment applications produce large amount of multimedia data. In order to get insight into these data, new exploration models are needed. Aiming at reflecting the user's perception, we develop new content-based similarity models based on adaptable distance functions, novel relevance feedback concepts that allow exploring comprehensive multimedia databases, and new interactive visualization techniques to make the exploration process more accessible and more intuitive for the user. These models are computationally expensive and we develop new methods for efficient query processing.

Fast Access to Spatial-Temporal Data. Tasks as similarity search or data analysis demand for fast access to spatio-temporal data. For this, we develop new techniques, as for example index structures, approximation methods and efficient query processing algorithms for complex objects including high dimensional data, time series, or interval data.
UMIC (Ultra High-Speed Mobile Information and Communication) is a research cluster established under the excellence initiative of the German government. The goal of this cluster is the interdisciplinary design of communication systems providing an order of magnitude improvement of the perceived quality of service for the next-decade mobile Internet. We are participating in two of the four research areas: Mobile Applications and Services (B) and Cross Disciplinary Methods and Tools (D).

**Mobile Stream Data Mining.** This project investigates exchange and analysis of continuous data streams. Health-net applications for example monitor vital functions of patients, such as blood pressure or pulse by means of various mobile sensors. Continuously measuring and collecting of these sensor values leads to huge volumes of data which are impossible to store or even transmit using mobile devices. In this context we focus our research on mobile stream data mining and develop new techniques for the aggregation of measurements, continuous modeling of streaming data and the detection of anomalies in order to enable fast reactions, e.g. emergency situations in the above mentioned Health-net scenarios.

In an advanced version of this project we considered mining for the rules available within the data coming from multiple streams and use these rules for predicting the future values of some stream of interest. By considering multiple streams that represent a certain context, a novel context-aware prediction method together with a storage-aware data structure was introduced. The whole model was tested in an energy efficient client-server scenario for analyzing the current context extracted from multiple streams within a real runner-trainer scenario in the Lousberglauf 2011.
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.
The aim of the SFB 686 is a model-based control of homogenized low-temperature combustion for efficient and low-emission energy provision. This requires the cooperation of several fields, in order to build up a thorough understanding of the complex physical processes, as well as the investigation and breakdown of the whole chain of effects, which leads from flow and mixture to ignition and then combustion, to finally end up with the combustion instabilities. To make the gained understanding usable, a description of the physical effects on the basis of mathematical models follows.

**Investigation of the fuel injection process.** The fuel injection process is responsible for mixture formation (of air and fuel) and, thus, sets the initial conditions for the subsequent combustion process within engines. This process is examined by performing experiments detached from the engine in a pressure chamber and employing optical measurement techniques. The idea is to use the experimental data to gain a deeper insight into the fuel injection process. New technologies enable the generation of increasing amounts of experimental data, hence the so far employed manual evaluation becomes infeasible. In this context we are developing methods for the automatic evaluation of data. A distance-based similarity model was developed for both single spray images (see example in Figure 4: Similarity Search in a Database of Spray Images). This is meant to support the researchers to efficiently search the measurement database, to compare different experiments, and to obtain a better understanding of the process.

**Control of low temperature combustion engine.** Because of the highly nonlinear process behavior of the low-temperature combustion, a process control is necessary in order to operate the engine in this combustion mode. The goal is to manipulate the system inputs in order to obtain the desired system outputs. The Model Predictive Control (MPC) framework requires a model of the process, which correlates the input to the output signals. Within this context, our challenge is the modeling the nonlinear process behavior of the low-temperature combustion
into a piecewise affine (PWA) model. For this purpose we employ correlation clustering algorithms on the measurement data to identify local correlations, and support vector machines to generate a partitioning of the input space (Figure 5: Model Predictive Control (MPC) for highly dynamic and high-dimensional processes exemplarily illustrates obtained PWA models for a PCCA Diesel engine). The current research is oriented towards extending the MPC framework to deal with the dynamical aspect.

Figure 5: Model Predictive Control (MPC) for highly dynamic and high-dimensional processes

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 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).

MOA – Massive Online Analysis

Philipp Kranen, Hardy Kremer

MOA (Massive On-line Analysis) is a framework for data stream mining. It includes tools for evaluation and a collection of machine learning algorithms. It is related to the WEKA project,
is also written in Java, but scales to more demanding problems. The goal of MOA is a benchmark framework for running experiments in the data stream mining context by providing

- storable settings for data streams (real and synthetic) for repeatable experiments,
- a set of existing algorithms and measures form the literature for comparison and
- an easily extendable framework for new streams, algorithms and evaluation methods.

Subspace Mining for High Dimensional Data

Stephan Günnemann, Ines Färber, Emmanuel Müller, Hardy Kremer

Increasingly large data resources in life sciences, mobile information and communication, e-commerce, and other application domains require automatic techniques for gaining knowledge. One of the major knowledge discovery tasks is clustering which aims at grouping data such that objects within groups are similar while objects in different groups are dissimilar. In scenarios with many attributes or with noise, clusters are often hidden in subspaces of the data and do not show up in the full dimensional space. For these applications, subspace clustering methods aim at detecting clusters in any subspace.

We propose new subspace clustering models which remove redundant information and ensure the comparability of different clusters to enhance the quality and interpretability of the clustering results. At the same time the efficiency of the clustering process is guaranteed by the development of new algorithms. Additionally we focus our research on the evaluation and visualization of patterns to benefit from human cognitive abilities for the knowledge generation.

![Figure 7: Multiple hidden concepts in subspaces of a high dimensional database](image-url)
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.

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/.

Figure 9: OpenSubspace evaluation framework

Clustering in Attributed Graphs
Stephan Günnemann, Brigitte Boden

The aim of data mining approaches is to extract novel knowledge from large sets of data. These data can be represented in different manners: high-dimensional attribute data to characterize single objects and graph data to represent the relations between objects. While the first data type is analyzed by subspace clustering approaches, the second one is analyzed by dense subgraph clustering methods. For many applications both types of data (attributes and relationships) are available and can be modeled as graphs with attributed nodes. Analyzing both data sources simultaneously can increase the quality of mining methods. However, most clustering approaches deal only with one of these data types. In our works, we develop novel methods that use both data types simultaneously and thereby obtain better clustering results.
Creative invention and commercialization are two integral tasks of innovation. Rather than relying on internal R&D only to carry out these tasks, organizations are reported to increasingly rely on external sources of innovation. In high-tech domains like nano science and technology, universities and public research institutes are important sources of creative scientific results and technological inventions, which may then get commercialized by industry.

In this project, we seek to challenge the general assumption of sequential labor division between university-led creative science and industry-led commercialization, by relating technology transfer to the following two aspects: (1) division of labor within the two domains, i.e. academic or industry scientists that engage in both basic creative research and commercialization respectively; (2) simultaneous co-production of scientific and technological knowledge by cooperating academic and industry scientists.

We seek to capture these facets of university-industry relationships by assuming a network perspective that is constructed from co-citations and co-authorships among nano patents and scientific publications. As general-purpose technology, the nano field will provide a rich basis to measure both the creativity and commercial success of individual researchers and how their network position between the two “worlds” of basic science and cross-industry applications may facilitate these seemingly contradictory outcomes. We will develop new techniques to analyze the network data extracted from the patent and publication data. In the analysis of these data, we lay special focus on the detection of clusters in the networks and their evolution over time.

The joint project 4C-Nanonets is conducted in collaboration with the Lehrstuhl für BWL, insb. Technologie- & Innovationsmanagement (TIM) and the Institut für Soziologie, Lehr- und Forschungsgebiet Technik- & Organisationssoziologie, RWTH Aachen.
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.

Figure 11: Multistep query processing for fast EMD search

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 new techniques for the Earth Mover’s Distance (EMD) and for the Quadratic Form Distance (QF) that reflect the users’ perception in the search process. In addition to an effective and efficient search process, we develop new interactive visualization techniques to make the exploration process more accessible and more intuitive. The interaction allows exploration of large amount of data with modest effort for the user.

![Feedback loop for interactive database exploration](image12.jpg)

**Figure 12:** Feedback loop for interactive database exploration

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**Signature Quadratic Form Distances for Efficient Multimedia Database Retrieval**

*Christian Beecks*

Partially funded by the Excellence Initiative of the German federal and state governments, RWTH Aachen Seed Funds 2009

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.

![Color&location signature representation of color images](image13.jpg)

**Figure 13:** Color&location signature representation of color images
Rapid technological development and the desire for custom solutions have led to an enormous information flood in manufacturing engineering. In spite of high-performance database systems, it is getting more and more complicated for companies to generate knowledge from stored information and therefore to use this knowledge for improving productivity. This project aims for making a contribution to make knowledge management feasible in the manufacturing engineering.

To achieve this aim it is intended to develop new methods and utilities which make the available implicit technology knowledge explicit and in this way noticeably speed up industrial engineering. Exemplarily this task shall be solved for machine tool industry. One of the envisioned results of the project is the creation of a semantic search engine which is able to combine different types of databases and generates new knowledge from different information sources.

The joint project MachInNet is conducted in collaboration with the CIM Aachen GmbH and the EXAPT Systemtechnik GmbH.

BioKeyS
(in collaboration with BSI, Fraunhofer IGD, Hochschule Darmstadt, LMU München)

Ines Färber, Sergej Fries

The identification of a person is a common task in many day-to-day situations. Withdrawing money or shopping on the internet are only two scenarios where a person has to identify and authenticate himself or herself in order to gain access to some resource. In most cases the identification process is based on ID-cards and passwords which a person has to enter. However, both have to be owned either physically or mentally by the person and therefore suffer from the problem that they can get forgotten, lost, distributed or stolen which may result in potential identity abuse.

The aim of this project is to provide a solution for this problem by using something that every person has and cannot forget - fingerprints. Since the fingerprints of each person in the world are unique, the identification of a person by his or her fingerprint is a much more secure way than using passwords. However, one of the problems concerning the collection of fingerprints in databases is the possibility of the misuse and privacy concerns in general. For that reason one of the objectives this project is aiming at is a secure way of storing the fingerprints such
that the only way of using such databases is for identification or authentication purposes, i.e., no reconstruction of fingerprints should be possible.

The joint project BioKeyS is conducted in collaboration with the “Bundesamt für Sicherheit in der Informationstechnik” (BSI), Fraunhofer Institut für Graphische Datenverarbeitung Darmstadt (IGD), Hochschule Darmstadt (h_da) and Ludwig-Maximilians-Universität München (LMU).

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 database 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.

Fast Access to Spatial-Temporal Data

High Dimensional Indexing

Stephan Günnemann, Hardy Kremer

Recent applications demand fast query response times on high dimensional data. For this purpose index structures were introduced. Existing multidimensional indexes like the R-tree provide efficient querying for only relatively few dimensions. Therefore we develop new index structures for efficient retrieval and similarity search.

Due to massive overlap of index descriptors, multidimensional indexes degenerate for high dimensions and access the entire data by random I/O. Consequently, the efficiency benefits of indexing are lost. By exploiting inherent properties of the indexed data, our new index structures, the TS-Tree and the OF-Tree, can index high-dimensional data in an overlap-free manner; during query processing, powerful pruning via quantized separator and metadata
information greatly reduces the number of pages which have to be accessed, resulting in substantial speed-up.

Due to the increasing main memory capacity of modern computers, a high percentage of datasets fits into main memory. We develop novel main memory based index structures that use individual dimensions for each data object by applying the method of subspace clustering. By a local selection of dimensions we increase the information content for objects compared to a global approach; this higher information content enables a better pruning of the search space.

Figure 14: Representation in data space (left) and data structure (right) of an overlap free R-tree.
Other Activities

Teaching

Winter term 2010:
• Lecture on “Data Mining Algorithms” (V3)
• Lecture on “Content-based Similarity Search” (V3)
• Lab course “Data Mining Algorithms”
• Seminar on “Data Mining and Multimedia Retrieval”
• Softwarepraktikum “Neue Algorithmen in Data-Mining-Frameworks

Summer term 2011:
• Lab course “High Performance Data Mining with MapReduce”

Dissertations


Institutional Collaborations

• B-IT Research School
• REGINA Regional Industry Club Informatics Aachen, Aachen
• SFB 686 Modellbasierte Regelung der homogenisierten Niedertemperatur-Verbrennung
• THESEUS Program Research Consortium
• UMIC Research Cluster of Excellence
• IMP Pathfinder 4C-NANONETS: From Clusters and Cooperation to Creativity and Commercialization in Nano Science and Technology Networks

Collaborations with industrial partners

• CIM Aachen GmbH, Aachen
• EXAPT Systemtechnik GmbH, Aachen
• Fraunhofer Institut für graphische Datenverarbeitung, Darmstadt

Collaborations with academic partners

• Univ. Aalborg, Dänemark (Dr. Assent, Prof. Jensen)
• Univ. Antwerp, Belgium (Prof. Goethals)
• Hochschule Darmstadt (Prof. Busch)
• LMU München (Prof. Kriegel, Prof. Böhm)
• Nanyang Technological University, Singapore (Prof. Gopalkrishnan)
• Univ. Trento, Italy (Prof. Palpanas)
• RWTH Civil Engineering (Prof. Nacken)
• RWTH Computer Science (many colleagues)
• RWTH Electrical Engineering (UMIC partners)
• RWTH Life Sciences (Prof. Deserno, Prof. Zenke)
• RWTH Mechanical Engineering (Prof. Abel, Prof. Kneer, Prof. Peters, Prof. Schmidt)
• RWTH Virtual Reality Center Aachen (Prof. Bischof, Prof. Kuhlen)
• RWTH Technology and Innovation Management Group (Prof. Piller, Dr. Ihl)
• RWTH Sociology (Prof. Häußling)
• Waikato University, New Zealand (Dr. Bifet, Prof. Pfahringer, Prof. Holmes)

**Reviewing Activities**

Prof. Seidl is an Associate Editor of the VLDB Journal (Int. Journal on Very Large Data Bases), and he is Member of the Scientific Advisory Board of the ArchaeoBio-Center at LMU München.

**Members of the group performed reviews for the following Journals:**
- Data Mining and Knowledge Discovery (DMKD)
- Information Systems (IS)
- Information Sciences
- Knowledge and Data Engineering (TKDE)
- Statistical Analysis and Data Mining (SAM)
- 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 2011)
- European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (PKDD 2011)
- GI-Fachtagung Datenbanksysteme für Business, Technologie und Web (BTW 2011)
- IEEE International Conference on Data Engineering (ICDE 2011)
- International Conference on Extending Data Base Technology (EDBT 2011)
- International Symposium on Spatial and Temporal Databases (SSTD 2011)
- Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD 2011)
- SIAM International Conference on Data Mining (SDM 2011)

**Prof. Seidl was a member of the Program Committees of the following workshops:**
- Fifth International Workshop on Ranking in Databases (DBRank 2011)
- 2011 KDML Workshop Knowledge Discovery, Data Mining and Machine Learning (KDML 2011)
Workshop Organization

- Organization of the 2nd Workshop on Discovering, Summarizing and Using Multiple Clusterings (MultiClust 2011) in conjunction with the European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML PKDD 2011) in Athens, Greece

Awards

- Ivanescu A., Albin T., Abel D., Seidl T.: Employing Correlation Clustering for the Identification of Piecewise Affine Models. Workshop on Knowledge Discovery, Modeling and Simulation (KDMS 2011) in conjunction with the 17th ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD 2011), CA, San Diego, USA (2011) Best Student Paper Award
- Kirchhoff S.: Quadratische Form-Distanz für Wahrscheinlichkeitsverteilungen zur inhaltsbasierten Suche. GI-Informatiktage, Bonn. (2011) Best Paper Award

Other Activities

- 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 committee for finances and structure)
- Tutorial on “Discovering Multiple Clustering Solutions: Grouping Objects in Different Views of the Data” at SIAM International Conference on Data Mining (SDM 2011), Mesa, Arizona, USA. (2011)
Talks and Publications

Publications


Beecks C., Skopal T., Schöffmann K., Seidl T.: Towards Large-Scale Multimedia Exploration. Proc. 5th International Workshop on Ranking in Databases (DBRank 2011), Seattle, WA, USA (2011)


Günneumann S., Kremer H., Laufkötter C., Seidl T.: Tracing Evolving Clusters by Subspace and Value Similarity. Proc. 15th Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD 2011), Shenzhen, China (2011)


Günneumann S., Kremer H., Seidl T.: An Extension of the PMML Standard to Subspace Clustering Models. Workshop on Predictive Model Markup Language (PMML) in conj. with the 17th ACM Conference on Knowledge Discovery and Data Mining (SIGKDD 2011), San Diego, CA, USA (2011)


Hassani M., Kranen P., Seidl T.: Precise Anytime Clustering of Noisy Sensor Data with Logarithmic Complexity. Proc. 5th International Workshop on Knowledge Discovery from Sensor Data (SensorKDD 2011) in conj. with 17th ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD 2011), San Diego, CA, USA (2011)


Ivanescu A., Albin T., Abel D., Seidl T.: Employing Correlation Clustering for the Identification of Piecewise Affine Models. Workshop on Knowledge Discovery, Modeling and Simulation (KDMS 2011) in conjunction with the 17th ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD 2011), CA, San Diego, USA (2011) (Best Student Paper Award)

Ivanescu A., Wichterich M., Seidl T.: ClasSi: Measuring Ranking Quality in the Presence of Object Classes with Similarity Information. Workshop on Quality Issues, Measures of Interestingness and Evaluation of Data Mining Models (QIMIE) in conjunction with the Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD), Shenzen, China (2011)

Kirchhoff S.: Quadratische Form-Distanz für Wahrscheinlichkeitsverteilungen zur inhaltsbasierten Suche. GI-Informatiktag, Bonn. (2011) (Best Paper Award)


Kruliš M., Lokoč J., Beecks C., Skopal T., Seidl T.: Processing the Signature Quadratic Form Distance on Many-Core GPU Architectures. Proc. 20th ACM Conference on Information and Knowledge Management (CIKM 2011), Glasgow, UK (2011)

Lokoč J., Beecks C., Seidl T., Skopal T.: Parameterized Earth Mover’s Distance for Efficient Metric Space Indexing. Proc. 4th International Conference on Similarity Search and Applications (SISAP 2011), Lipari, Italy (2011)

Lokoč J., Hetland M. L., Skopal T., Beecks C.: Ptolemaic Indexing of the Signature Quadratic Form Distance. Proc. 4th International Conference on Similarity Search and Applications (SISAP 2011), Lipari, Italy (2011)


Müller E., Günnewann S., Färber I., Seidl T.: Discovering Multiple Clustering Solutions: Grouping Objects in Different Views of the Data. Tutorial at SIAM International Conference on Data Mining (SDM 2011), Mesa, Arizona, USA. (2011)


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  (partly funded by MINT research grant, excellence program of RWTH since February 2010)
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Overview

At the Computer-supported Learning Research Group (Informatik 9), we are mainly dealing with learning technologies and the development of innovative learning systems and environments. Our focus in research and teaching covers various topics in technology enhanced learning, intelligent Web and mobile systems, and didactics of Computer Science. These include educational technologies, learning theories, ubiquitous learning, learning analytics, assessment and feedback, and gender and diversity studies.

The Center for Innovative Learning Technologies of RWTH Aachen University (CiL) has further established its services and advanced the learning portal L²P. The L²P usage continues to be very successful with an increasing number of regular courses using the system (more than 2,200 per term). Within the four and a half years since its launch, L²P continues to be an established, stable and well-adopted eLearning platform. These numbers put RWTH Aachen University into the top universities in Europe concerning its adoption of a blended learning approach.

In addition to continuing our projects L²P, InfoSphere, SAiL-M, and go4IT!, we started a BMBF-funded gender and diversity project IGaDtools4MINT in collaboration with the Integration Team - Human Resources, Gender and Diversity Management and TU Berlin in February 2011. We successfully applied for two Exploratory Teaching Space (ETS) projects funded by the excellence teaching initiative of the Stifterverband for the German science system. The preliminary course ETS project redesigns the existing course structure with respect to modern technologies and innovative learning concepts to improve the quality of teaching and to ease the transition from school to university. The Personal Exploratory Learning Environments (PELE) ETS project aims at giving students the opportunity to learn self-paced, project-oriented and active in groups, following a student-centered blended learning approach.

Informatik 9 organized the EduCamp in Aachen with over 100 participants from different disciplines. We also co-organized the Mobile Learning Workshop at DeLFI 2011 and the Mobile Learning Day 2010 in Hagen. Prof. Schroeder gave an invited talk at the 19th Leading International Trade Fair and Convention for Vocational Education, Learning and IT, LEARNTEC 2011, which attracted over 5700 visitors to Karlsruhe in February 2011. He also gave a keynote at ITiCSE 2011, the largest international conference on computer science education.

31 students successfully finished their Diplom-, Master- and Bachelor theses with our team. This is a new peak value for our team and will result in new research projects and publications.

In terms of teaching, in addition to the regular specialist courses and seminars offered by our group in the areas of technology enhanced learning and didactics of computer science, we restructured the Web Technologies course, which attracted more than 100 students in the winter semester 2010/2011, to put the students at the center of the learning experience. We followed a student-centered approach by providing a learning environment where the students took an active role in the organization and assessment of the course. The concept was well accepted by the students as a new form of teaching, which fits in well with the vision of student-centered teaching which is at the core of the program for Excellence in Teaching of RWTH Aachen University.
After successfully defending his doctoral thesis with the topic "Personalization in Technology Enhanced Learning: A Social Software Perspective" at Informatik 5, Dr. Mohamed Amine Chatti joined our group as a senior researcher to coordinate the research and teaching activities in the group.
Research Projects

L²P – eLearning and eTeaching Portal of RWTH Aachen University
Ulrik Schroeder, Philipp Rohde, Anna Lea Dyckhoff, Patrick Stalljohann, Christoph Dederichs, Harald Jakobs, Christopher Lie, Christoph Gingter, René Wagner (CiL) in cooperation with CCC of RWTH Aachen University

The Center for Innovative Learning Technologies (CiL) (http://www.cil.rwth-aachen.de/), being responsible for the sustainable introduction of eLearning elements into the university study programs, designs the technological, instructional and administrative framework for blended learning at RWTH Aachen University. Main focus of 2010/2011 activities were the further design, development, deployment and advancement of the central learning management system L²P in cooperation with the Computer and Communication Center and the Computer-supported Learning research group. Several new functionalities were successfully tested and introduced. Furthermore, supportive measures such as first level support for all questions concerning L²P as well as a target-oriented eLearning training program including individual, on-demand training courses were helpful for newcomers and advanced learners to the field of technology-supported teaching. The training program included introductory courses as well as specialized courses on e-tests, web conferencing systems, copyright laws (in cooperation with the University Library) and ways of using wikis, blogs and discussion boards in higher education.

In winter term 2010 the CiL also contributed lectures on web portal programming and an introduction to media didactics to the trainee program for Mathematical Technical Software Engineers (MaTSE). Finally the CiL-project by P. Rohde and A. Dyckhoff on “Monitoring Tools for L²P” was funded by the program for Excellence in Teaching as one of the projects for the Exploratory Teaching Space. This project aimed at developing and evaluating a web based monitoring tool for courses in L²P delivering – while preserving the students’ anonymity – an overview of their learning behavior and relating it to their records. The tool uses methods of data mining and learning analytics to give lecturers data on the effectiveness of their teaching.

SAiL-M: Semi-automatic Analysis of Individual Learning Processes
Ulrik Schroeder, Daniel Herding, Hendrik Thüüs (funded by BMBF) in collaboration with M. Zimmermann, A. Hoffkamp, G. Moll, Ch. Bescherer, A. Fest (PH Ludwigsburg), Ch. Spannagel (PH Heidelberg), P. Libbrecht, U. Kortenkamp (PH Karlsruhe), S. Rebholz, S. Noll, W. Müller (PH Weingarten)

The Federal Ministry of Education and Research funds this 3-year project within its program of empirical educational research.
In university courses with hundreds of participants, it is impossible for the tutors to take extensive care of each student. On the other hand, completely automated learning environments often do not offer the feedback that weaker students require in order to catch up. Therefore, the goal of the project is to develop concepts and tools that allow for a semi-automated analysis of individual learning processes in mathematics and other disciplines.

In order to evaluate our tools, we used the Jacareto capture and replay toolkit. Jacareto is a framework that offers the functionality necessary for capturing user-program interaction on graphical user interfaces written in Java. The protocol of the interactions is represented symbolically. Thus it can be automatically analyzed and structured, and to some extent also interpreted and statistically evaluated. This enabled us to detect usability problems and to analyze the usage of the feedback system.

In the last year, we have continued the evaluation of the eLearning tools we have developed in the course of this project. The ColProof-M application gives feedback and hints to students who are doing proofs by deduction. The SetSails! application uses an integrated term replacement system to support students in transforming terms in set algebra. SetSails! was also extended to support transformations in boolean algebra. Both tools have been used and evaluated in mathematics courses of our project partners at Ludwigsburg University of Education and at Heidelberg University of Education.

To show the transferability of the concepts, a new application with the focus on computer-science has been implemented. This application, called WebDale, gives semi-automatic feedback to students who are learning to implement websites using HTML, PHP, and an SQL database.

The BMBF decided to extend the SAiL-M project for 5 months. This time will be used to evaluate the newly implemented applications regarding the benefit that students experience while using them.

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**go4IT!**

*Ulrik Schroeder, Thiemo Leonhardt (partly funded by private sponsors: THINK ING of Gesamtmetall, Inform, regio iT, Regina e.V.)*

Since January 2009, our team offers regional schools free robot workshops for girls to awaken interest in MINT subjects 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 the 8th grade to increase the interest of the pupils in school at a high stage and to 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 University. 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 100 workshops were held since 2009. Thus, over 900 girls attended the workshops in the two years.
To get sustainable results to increase the self-efficacy of all students, we want to develop further courses for students which already have a successful participate of a go4IT-course. Our research in this project indicates that first of all the students and especially the girls are interested in mobile phones and smartphones. So on the one hand, we take the effective concept of the go4IT courses, and on the other hand, we combine this with new technology. Thus, we want to use the students’ knowledge about the sensors of the Lego Mindstorms robot and transfer it to similar tasks using the sensors of the smartphones. Our goal is to use all sensors of the smartphones to give the students the opportunity to develop complex tasks on their own. In this way the students understand programming as an opportunity to design their environment, and this is in our opinion the main factor to increase the self-efficacy of students in STEM and to associate computer science with creativity and innovation.

Informatics School Laboratory (InfoSphere) – Extracurricular Place of Learning for Pupils of all Ages

Ulrik Schroeder, Nadine Bergner, Jan Holz, Thiemo Leonhardt

The school laboratory for computer science (InfoSphere) opened in summer 2010 at RWTH Aachen University. It offers several ways to numerous facets and applications of computer science for children and teenagers. It should even awake interest in those who are not tech-savvy. InfoSphere offers a wide range of courses and modules for half a day, a full day, or several days. These modules provide experimental and action-oriented learning with connection to everyday experiences. Examples of such modules include “A journey into a computer”, “Android programming” and “artificial intelligence”.

InfoSphere has been designed as a research laboratory for teachers to test and practice different learning experiences. Moreover, it offers a plethora of modern media and technology to help teachers and students implement innovative learning scenarios. Furthermore, teachers get the chance to acquire crucial media competences in practice.
Despite extensive research and following pilot projects and support programs in STEM fields, the number of women in the respective subjects is only rising slowly. With reference to the successful project of the American Carnegie Mellon University (CMU) which was able to increase the percentage of women among first semester students of computer science from 7% in 1995 to 42% in 2000, a transfer and advancement of this scheme for computer science degrees in Germany shall be implemented.

The goal of IGaDtools4MINT is the development of a concept which contributes to the increase of the percentage of women as well as to a reduction of the drop-out rate in STEM subjects (science, technology, engineering, and mathematics). This concept is based on the analysis of existing best practice measures and is supposed to lead to a comprehensive catalogue of measures. By this means, gender-equal didactics and an opening of the faculty culture for diverse women and men is intended.

The findings are used for the development of a gender and diversity toolkit which will be transferred to the TU Berlin during the run of the project. This toolkit is supposed to offer action guidelines as well as implementation strategies and methods for universities. It aims to increase the percentage of women and other hitherto underrepresented groups (i.e. people with non-academic family background, students with migration background etc.) in computer science. The project will conclude with an international conference in Berlin where the toolkit will be presented.

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 learning analytics 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. They will be tested and evaluated by teachers and learners of RWTH. In a first step to reach this goal, a basic monitoring tool, which is compliant to the German Data Protection Act, has been designed and implemented in L²P. The dissertation project is placed in an interdisciplinary context, since research methods and expertise of the different disciplines computer science, psychology, and sociology are considered and combined.

**Mobile and ubiquitous learning in higher education with respect of gender and diversity constraints**

_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 personal environment in the educational context. As a prerequisite, a personal learning environment specifically for the interaction on mobile devices is designed in a user-centered manner. The research involved students and faculty of RWTH Aachen University, who traditionally come from diverse social and cultural backgrounds. In order to test the learning network, we investigate and evaluate the impact on the audience’s organization and motivation and learning outcomes. 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.

**Gender-sensitive interdisciplinary computer science approaches for school education in MINT subjects**

_Thiemo Leonhardt (funded by a MINT research grant within the excellence program of RWTH Aachen University) and Ulrik Schroeder_

Teachers play a significant role in supporting young women to follow their interests. Unfortunately, they also increase the social prejudice that young women are not suitable for mathematics, computer science, natural science and technology. Our conviction is that teachers hold a key position for changing the cultural assignment of males to engineering. For this reason our focus is to implement gender-sensitive teaching practice seminars as a regular part of the didactic teaching module of teacher training at RWTH Aachen University. In
addition to the effect that more teaching material will be developed, tested at school and scientifically evaluated, it is our goal to raise the awareness of students completing teaching degrees for secondary school for gender and diversity issues in the MINT field.

Therefore, the central objective of this doctoral thesis project is to develop further learning units exemplarily based on results of the evaluated, successful project Roberta – “Mädchen erobern Roboter”. As a priority, results of gender and diversity research and concrete examples will be integrated conceptually into lectures and seminars of the didactic computer science module. In this case, gender-sensitive learning materials for lecture series and workshops are designed by the students. Thus, we teach the theoretical knowledge about gender and diversity research results to enable all students to develop gender and diversity awareness in the classroom.

All learning units for the schools are didactically designed in such a way that pupils can discover, test, and enhance their computer science and technology skills. This includes perception, observation, testing and activity planning. At the same time, team work and communication skills are trained and "social skills" are fostered by collaborative knowledge acquisition, and group presentations.

In a second step, we expand the practical school studies by testing and evaluating the learning materials in everyday school life and in new specific workshops. This way, graduates get experience in gender-sensitive teaching practice, and can transfer this into their professional life to further teaching units. They also take these experiences and materials to the learners in school, so that awareness can be raised and a multiplication of the approach is possible.

We are convinced that these theoretical and practical measures (self-reflection on own behavior and teaching) can improve the teacher training in computer science at the RWTH Aachen significantly. On the other hand, we try to transfer the above research results regarding girls in the MINT.

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**A Generic Platform for Open Assessment Management in Higher Education**

*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 develop web-based modules for the learning and teaching portal L²P of RWTH Aachen University which allow the management of assessment processes within a central place. 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 the management of all relevant assessment activities of a course by the definition of criteria that a student has to fulfill to pass the course.
Other Activities

Services

Prof. Schroeder major administrative and service activities in 2010-2011 included:

- Assistant chairman of GI expert group eLearning (http://www.e-learning.gi-ev.de/)
- Member of steering committee of GI department Computer Science Education (http://www.e-learning.gi-ev.de/)
- Scientific director of CiL (http://www.cil.rwth-aachen.de/) – Center for Innovative Learning Technologies at RWTH Aachen University
- Scientific director of InfoSphere (http://schuelerlabor-informatik.de/) the out-of-school Computer Science Lab for Pupils
- Member of the advisory board for teachers’ education at RWTH Aachen university
- Development of B.Sc./M.Sc. examination regulations for teacher education in computer science

Editorial Boards and Conference Organization

Nadine Bergner ran several courses at the Informatics School Laboratory “InfoSphere” and was co-organizer of the “Aachener Informatik Tage” and “Schüleruniversität Informatik 2011”.


Jan Holz was co-organizer of the “Aachener Informatik Tage” and “Schüleruniversität Informatik 2011”.

Thiemo Leonhardt was co-organizer of the “Aachener Informatik Tage” and “Schüleruniversität Informatik 2011”.

Ulrik Schroeder served as a reviewer for CSCW journal, Springer Verlag, i_COM, Oldenburg Verlag, Informatik 2011, and Zeitschrift für eLearning. He was member of the program committee of the 14th IASTED International Conference on Computers and Advanced Technology in Education (CATE’11), 9th International Conference on Computer-supported Cooperative Learning (CSCL’11), 4th International Conference on Computer-Supported Education (CSEDU’11), 9th conference on eLearning in Computer Science (DeLFI’11), 5th International Conference eLearning Baltics (eLBa’11), 10th International Conference on Web-based Learning (ICWL’11), 11th IEEE International Conference on Advanced Learning Technologies (ICALT’11), and 1st Mobile Learning Workshop at DeLFI’11.
Talks and Publications

Talks


Ulrik Schroeder: *Measures to promote Interest in Computer Science*. Keynote at the the 16th Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE 2011), Darmstadt, June 27, 2011.


Publications


Rebecca Apel, Tobias Berg, Jan Holz, Philipp Brauner, Ulrik Schroeder, Andrea Wolffram, Carmen Leicht-Scholten: Preliminary findings of a gender and diversity screening at a technical university: impressions of the project "IGaDtools4MINT". In Informatik 2011, 41. Jahrestagung der Gesellschaft für Informatik, Berlin.


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Overview

The Media Computing Group 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, wearable 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 tablet devices or electronic books, often distinguish themselves through their capability for interaction. Their user interfaces, however, lag far behind their 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. We established the Fab Lab Aachen where we simply print out new physical devices. This empowers research in the fields of novel interaction techniques with wearable, tangible, and deformable interfaces. But it also raises the question how these new production facilities can become accessible and usable to non-technical users.

Our group builds upon these results and continues to chart new territory in interactive multimedia research, in collaboration with international partners in research and industry, including Berkeley, MIT, UCSD, INRIA, Apple Computer, and others. We are a member of the DFG-funded UMIC Excellence Cluster in Ultra-Highspeed Mobile Information and Communication. We partner with researchers in Humanities in the DFG-funded Brain|Concept|Writing and eHealth HumTec programs, and also offer courses and research opportunities within the Media Informatics Master’s Program at the Bonn-Aachen International Center for Information Technology (B-IT). This center, established in 2002 and

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located in Bonn, offers highly selective International Master’s Programs 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. In 2011, we also founded the Human-Computer Interaction Center (HCIC) with partners from technical communication, communication sciences and architecture, which focuses on R&D in usability and new user interfaces.
Research Projects

DiskPlay: DiskPlay: In-Track Navigation for Digital Audio on Turntables
Florian Heller, Justus Lauten, Jan Borchers

DiskPlay is a system to enhance in-track navigation with digital vinyl systems (DVS). Traditional records provide a lot of information through their physical structure, such as track start and end, or the mood of the song. Due to their generic nature, the structure of timecode records does not map to the song loaded in the software. Thus, the DJ has to switch focus between the visualization on the computer and the turntable he manipulates.

PowerSocket
Florian Heller, Jan Borchers

Power consumption is measured in W and Wh, but what do these units mean? Water consumption can easily be understood, as we all know what a liter of water looks like. Common power meters rely on the physical units or their translation to costs as display. We classified existing displays and ambient visualizations in a taxonomy that focuses on the characteristics of power consumption displays. We adapted representatives of the different categories of displays to an on-outlet display and compared these using a combination of soft-and hardware prototyping.
Dragon: Direct Manipulation Video Navigation
Thorsten Karrer, Moritz Wittenhagen, Jan Borchers

Dragon is a novel technique for video interaction and introduced the growing field of “Direct manipulation video navigation” (DMVN) systems. Based on the concept of direct manipulation, Dragon allows users to navigate in video scenes more easily and precisely than previous approaches: they just click and drag the object in the video scene directly instead of using a timeline slider at the bottom of the video frame.

Problems arise for DMVN systems when dealing with temporal ambiguities where a time span is projected onto a single point in image space, e.g., when objects stop moving (a). Existing DMVN systems (b) deal with these cases by either disabling navigation on the paused object or by allowing jumps in the timeline. Both of these workarounds are undesirable as they introduce inconsistency or provoke loss of context. We analyze current practices regarding temporal ambiguities and introduce two new methods to visualize and navigate object pauses: embedded timeline (c), the pause is distributed over a part of the trajectory; loop (d), the trajectory form is altered to contain a loop representing the pause. User tests show that the new approaches are better suited for navigation in scenes containing temporal ambiguities and are rated higher in terms of user satisfaction.

Getting the timing and dynamics just right is key to creating believable and interesting animations. However, using traditional keyframe animation techniques, timing is a tedious and abstract process. We developed Dragimation, a novel technique for interactive performative timing of keyframe animations, inspired by direct manipulation techniques for video navigation that leverage the natural sense of timing all of us possess. We conducted a user study with 27 participants including professional animators as well as novices in which we compared our approach to two other interactive timing techniques, timeline scrubbing and sketch-based timing. Dragimation is comparable regarding objective error measurements to the sketch-based approach and significantly better than scrubbing and is the overall preferred technique by our test users.
The key idea of Pinstripe is to build a user interface upon two affordances of textiles: grasping and deforming. Most clothes exhibit loose folds in different areas when worn, and Pinstripe makes use of this fact: It lets wearers provide input by pinching a part of their clothing between their thumb and another finger, creating a fold in the garment, and then rolling this fold between their fingers.

It is a textile user interface element for eyes-free, continuous value input on smart garments that uses pinching and rolling a piece of cloth between your fingers. Input granularity can be controlled by the amount of cloth pinched. Pinstripe input elements are invisible, and can be included across large areas of a garment. Pinstripe thus addresses several problems previously identified in the placement and operation of textile UI elements on smart clothing.

Patients suffering from hand tremor have difficulties in interacting with touch screens. Tremor also limits the possibilities of UI design, requiring larger buttons in more spacious layouts. In cooperation with the Institute of Industrial Engineering and Ergonomics at RWTH Aachen, we developed and evaluated “swabbing”, an input technique for discrete target selection on touch screens. Swabbing is an input technique in which users slide their finger over the screen towards a target on an edge of the screen to select.

We found that using swabbing, tremor users can select a touch screen target more accurately than via tapping. The measurement of finger oscillation shows that the oscillation is reduced while sliding the finger. We believe that the reduced oscillation and increased accuracy give tremor patients more control.
SLAP Widgets

On-screen controls are flexible but directly manipulating them using fingers introduces occlusion and precision issues. Furthermore, the user must focus on the control instead of the data she manipulates. SLAP Widgets address these issues by combining the benefits of physical widgets and on-screen controls. SLAP Widgets are general-purpose controls made from silicone and acrylic. They provide haptic feedback and allow a precise eyes-free interaction while using the table’s back projection to change their appearance dynamically. They are untethered, low-cost, and easy to prototype. Our widget set contains keyboards, sliders, knobs, and keypads.

Madgets

SLAP Widgets provide a physical communication in only one direction: from the user to the system. The table cannot change the physical state of a control. This can cause visual-physical inconsistencies. Madgets, magnetic widgets, extend SLAP Widgets with the ability of actuation. Our interactive table integrates electromagnetic actuation and fiber optical tracking in a single device without using external projectors or cameras. The table can move and configure Madgets consisting of multiple parts. Our system enables well-known GUI concepts for tangible tabletop controls, such as undo or remote collaboration, as well as new actuation dimensions, like height, force feedback, or power transfer.

FingerFlux

FingerFlux is a haptic output technique that provides near-surface haptic feedback on interactive tabletops. It combines an electromagnetic display with a permanent magnet attached to the user's index finger. The display consists of an array of electromagnets whose polarization and strength can be controlled individually. As the magnetic fields reach well beyond the surface, we can employ the array to influence the magnet at the user's finger and, therefore, create a haptic sensation. Using the permanent magnet, users can feel the magnetic fields the table produces.
MudPad

Yvonne Jansen, Jan Borchers

Touch screen interfaces are intuitive to use and their visual interface can easily be changed or re-arranged. But so far they do not offer localized tactile feedback for individual points of interaction. Several studies published in the last years point to performance increases on touch screen devices when tactile feedback is provided. Unfortunately, none of these studies had access to a device that could actually produce said feedback at the point of interaction on the screen.

MudPad is an overlay for pressure sensitive touch screens that provides localized active haptic feedback at multiple points. We can therefore enrich the entire interface with a haptic layer as each display area can be individually controlled to ‘display’ a distinct tactile feedback pattern depending on the information displayed.

BendDesk

Malte Weiss, Simon Völker, Jan Borchers

For most people from many different disciplines a desk is the main workspace. A typical desk is composed of at least one or more vertical displays that show digital content and a larger horizontal area, containing input devices, such as mouse and keyboard, paper-based documents, and everyday objects. These two areas are clearly separated which make the direct exchange of objects nearly impossible. Furthermore the interaction techniques for each area are very different from each other. For example for drawing on the vertical displays the user has to use the mouse, but for drawing on the horizontal table she has to use a pen.
**BendDesk** is a multi-touch desk environment that seamlessly combines a vertical and a horizontal surface with a curve into one large but still reachable interactive workspace. This workspace can be used to display any digital content like documents, photos, or videos. Furthermore, the multi-touch technology allows the user to interact with the entire system by direct manipulation. Due to the seamless combination of both surfaces, the user can choose separately which area to use for each task. BendDesk is only designed as a workspace; it is also designed as a piece of furniture to replace a normal desk with all requirements users have such as placing everyday objects on it, or seating comfortably at it.

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**TaPS: Tangible Private Spaces**  
*Maximilian Möllers, Stephan Deininghaus, Patrick Zimmer, Jan Borchers*

Interactive tabletop systems resemble convenient environments for collaborative work. In these multi-user environments, private spaces are an important issue. However, treating information with different privacy levels on the same surface is difficult to realize with current technology. Existing approaches usually apply wearable devices, such as shutter glasses or head-mounted displays, which are expensive and cumbersome to wear.

We present *TaPS*, lightweight transparent widgets through which light only passes from a particular direction, effectively creating Tangible Private Spaces that shield the content beneath them from the view of other users. These widgets add tangible control over privacy to interactive tabletops while using low-cost hardware. They are crafted from acrylic with several layers of scattering foil on top. Each of those layers blurs the content beneath, when viewed from a specific 30-degree-wide angle. Combining multiple layers allows us to shield content for an arbitrary large angle.

The widgets themselves are lightweight and can be picked up in order to reposition them or hand them over to other participants. With this, as well as with sliding the widgets over the table, we return to tangible, more natural hand-over gestures. Because content is only displayed while the widgets rest on the table, all these trade gestures warrant privacy of the handled data.
Instant User Interfaces: How People Re-appropriate Everyday Objects

Max Möllers, Christian Corsten, Jan Borchers

Instant User Interfaces (IUIs) is a new interaction metaphor that lets users re-appropriate everyday objects ad hoc to interact with technology in their environment. IUIs harness existing interaction knowledge and build on physical object affordances. We study which common everyday objects can be used in IUIs, and test with users how they create IUIs for various tasks. Discrete input is often re-appropriated using objects that have (physical) buttons, whereas continuous input is performed by rebuilding the UI akin to the Voodoo principle.

Direct Manipulation and the Third Dimension: Co-Planar Dragging on 3D Displays

Max Möllers, Patrick Zimmer, Jan Borchers

Recent advances in touch and display technologies are supporting a wide-spread use of a) touch-based direct manipulation techniques as well as b) 3D displays that give a perspective- correct view. Both techniques have consistency constraints including the following: a) Moving a finger should drag an object along the finger movement. b) Moving the head should update the object’s projection to preserve the 3D impression, e.g., leaning around a house should reveal its backyard. Unfortunately, these two contradict each other, making a combination, e.g., moving the head while touch- ing or dragging an object, non-trivial. We introduce a design space of interaction methods to cope with this limitation.
To thoroughly comprehend application behavior, programmers need to understand the interactions of objects at runtime. Today, these interactions are often poorly visualized in common IDEs except during live debugging. In an exploratory user study we could confirm, that programmers are often unsatisfied with available tools for code browsing, because the common file-based representation of source code does not reflect how methods call each other at runtime to create the application behavior developers intended. The information about the call graph can mostly be obtained from the source code. We developed two novel visualization and navigation techniques for this information, Stacksplorer and Blaze. Both are implemented as plugins for Xcode, Apple’s standard IDE.

The left hand part of the figure shows the user interface of Stacksplorer. The central editor is equivalent to Xcode’s standard editor, retaining all its features and functionality. The method, in which the cursor is placed, is called focus method. The left column shows methods calling the focus method, the right column shows all methods called from the focus method. Besides navigating through a class by scrolling vertically in the editor, our design allows navigating horizontally through the call stack, by clicking a methods in the side columns.

**Blaze** implements an approach orthogonal to Stacksplorer. While Stacksplorer shows the complete neighborhood of the focus method at a time, Blaze (right hand side of the figure) shows just one path including the focus method, but this path completely. By default, the path updates, like Stacksplorer, when the focus method changes. If users already have a hunch about what is important, they can exchange entries on the path with possible alternatives, to make sure the most interesting path is shown, and lock this path during their exploration.

We compared Blaze and Stacksplorer with Eclipse’s call hierarchy tool and an unmodified Xcode installation. Using Blaze or Stacksplorer could reduce task completion times for certain maintenance tasks significantly, compared to the status quo. The combination of automatic updates, integration with the source code editor, and selection of a meaningful slice of information to display from the call graph made both tools very appealing to developers.
In pair programming, two software developers work on their code together in front of a single workstation, one typing, the other commenting. This frequently involves pointing to code on the screen, annotating it verbally, or sketching on paper or a nearby whiteboard, little of which is captured in the source code for later reference. CodeGraffiti lets pair programmers simultaneously write their code, and annotate it with ephemeral and persistent sketches on screen using touch or pen input.

Our design rationale is to give the navigator a way to support team conversation by sketching directly on the shared screen. Sketching and annotating should be as easy as picking up a pen to draw or write on paper or a whiteboard. The driver is still the only person entering syntactical code while the navigator enters semantic graphics that do not compile, making it easy to quickly jot down a sketch, explain a design idea or point out a typo to the driver. We integrated CodeGraffiti into the Xcode software development environment, to study how these techniques may improve the pair programming workflow.

Programmers frequently create diagrams to grasp the structure and to understand design patterns of unknown source code. We present Code Gestalt, a source code visualization tool that uses the vocabulary used in a code base to assist building and recording a mental model. Code Gestalt introduces tag overlays and thematic relations, two extensions to class diagrams that display similarities in the vocabulary used in the underlying source code. In a user study, Code Gestalt offered a competitive alternative to traditional pen and paper tools.
Fly: A Canvas Presentation Software
Thorsten Karrer, Leonhard Lichtschlag, Thomas Hess, Christian Corsten, Jan Borchers

Slide-based visual presentation support, such as Microsoft’s PowerPoint or Apple’s Keynote, is prevalent when looking at talks in research, industry, education, government, and many other areas. But, this format has been criticized repeatedly for the limitations it imposes on authors and presenters.

We developed Fly, an canvas presentation software that moves from the current linear and slide-based presentation style to dynamic concept maps. The presentation authors place either their individual elements (1) on an infinite canvas. They then define viewports and transition paths (2) across the canvas to create the presentation sequence (3). We evaluated how authors adapt their authoring process to these new tools and how audiences process information presented in this manner. The results show that the canvas presentation model is better suited for presentation than the slide deck format.

Personal Orchestra Reloaded
Jan Borchers, Thorsten Karrer, Leonhard Lichtschlag, Moritz Wittenhagen

On Nov 27th 2009, the House of Music Vienna launched our redesigned Personal Orchestra exhibit. Using an infrared baton, visitors can conduct the Vienna Philharmonic by controlling speed, volume, and the emphasis of different instrument sections. The new system now features our PhaVoRIT continuous real-time high-quality audio stretching, six new recordings of the orchestra in full HD video, an electronic music stand displaying the score, and helpful hints by maestro Zubin Mehta. Our original exhibit was installed in 2000, and has been used by 1.5 million visitors since, making it the most successful station in the house, and a top tourist attraction. It continues to be the major tourist attraction in the museum in 2011.
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. With one of these exhibits, the Aixplorer, we study novel interactions for museum visitors.

The Aixplorer is a mobile audio tour guide that seamlessly detects the visitor’s position indoors and outdoors by combining a variety of tracking algorithms. While it currently provides detailed information for each historical room in the city hall, it will interconnect the different citywide stations of the Route Charlemagne in the future. This process of extending the device will happen from September 2010 until August 2013, funded through a 1.5M€ federal grant. During that time, the Aixplorer will serve as platform to research user experience with ubiquitous mobile indoor and outdoor location aware devices, group interactions, and city wide games.

**GroupAixplorer**

Museum Audio guides often isolate visitors from each other with little regard for the social needs of a group. We developed a collaborative game for small groups as an extension to Aixplorer. It features a quest-game to encourage collaboration and social interaction in the group, while mediating stories, anecdotes and knowledge around the exhibits in synchronous audio clips. A user study showed that communication and social interaction among visitors were encouraged instead of hindered and that even quests without much interaction on the device were still popular. It also demonstrated that our concept of having a group leader responsible to start and finish quests as well as organize group progress during the game does not impair the group experience per se, but that careful selection of the member fulfilling that part may be important.
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 an 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. 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. During last year, the Media Space has been used for regular group meetings, presentations, video conferences, and student projects.

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.).
Silhouettes is an interactive collaborative gesture-based experience for the German-Chinese House at the World EXPO 2010 in Shanghai. It was developed by Prof. Peter Russell's CAAD group and Prof. Jan Borchers' Media Computing Group at RWTH Aachen University. Echoing the theme of EXPO 2010, the German-Chinese House and its host, the German-Chinese government initiative Germany and China – Moving Ahead Together, EXPO visitors can create a virtual city neighborhood together by interacting with a large-scale display wall using only their body silhouettes. Their city neighborhood becomes part of a growing 3D virtual city that can be seen online. The system was developed under Mac OS X and runs on an array of Apple Mac Pro and Mac mini computers.

The exhibit opened on May 1st along with the rest of World EXPO 2010, and was on display until October 31st. On the first day, more than 2,000 visitors enjoyed the interactive experience, and the German-Chinese House estimated more than 340,000 visitors during the first 2 months Silhouettes and the house were open. Germany's Federal President Horst Köhler and his wife visited the German-Chinese House at EXPO 2010 in Shanghai on May 19th, and played the Silhouettes city building game with a group of German school children.
Other Activities

Courses

**Winter semester 2010/11**
- Lecture: Designing Interactive Systems I
- Lecture: iPhone Programming
- Lab: Media Computing Project
- Seminar: Post Desktop User Interfaces

**Summer semester 2011**
- Lecture: Designing Int. Systems II
- Lecture: Current Topics in Human Computer Interaction
- Lab: Multimodal Media Madness
- Proseminar: Human Computer Interaction

Prof. Jan Borchers was nominated *Computer Science Teacher Of The Year 2010* as one of four nominees selected among all faculty in the CS department, based on student nominations.

HCI Center

On November 10, we announced the opening of the new HCI Center (HCIC) at RWTH Aachen University. The HCI Center conducts academic research in usability, and designs, develops, and evaluates innovative user interfaces for clients from industry. The HCI Center is a new kind of interdisciplinary institution established by four RWTH faculty and P3 Communications GmbH: Prof. Dr. Jan Borchers, Media Computing Group (founding director), Prof. Dr. phil. Eva-Maria Jakobs, Text Linguistics and Technical Communication, Prof. Dipl.-Ing. M.Arch Peter Russell, Computer Aided Architectural Design, Prof. Dr. phil. Martina Ziefle, Communication Science, and Dipl.-Ing. Markus Jordans, P3 Communications GmbH.
iTunes U

iTunes U is a site for free course videos from all major universities internationally, available through the Apple iTunes Music store. In January 2009, RWTH Aachen University joined iTunes U as one of only four German institutions selected for Apple's European pilot program. Our group initiated and coordinated this initiative, and continues to provide the project management and technical coordination, in close collaboration with the Computing Center (http://itunes.rwth-aachen.de).

Our lectures “iPhone Application Programming” and “Programmierung für Alle” have become particularly popular on iTunes U globally, reaching the worldwide 2nd and 4th of the most viewed lectures in October 2010.

World Usability Day

In November 2011, we organized the sixth World Usability Day Aachen Local Event in cooperation with P3 Solutions at the RWTH Aachen SuperC Building. The main purpose of this annual event is to provide an introduction to the topic and create awareness of the problem of inadequate usability. With close to 200 guests, we used the day this year to present a keynote by world-renowned usability specialist and Apple pioneer Bruce Tognazzini, founder of the original Human Interface Group at Apple, and to open the new HCI Center.

Fab Lab Aachen

On December 7th, 2009, we opened the doors to the first FabLab in Germany. It is part of a worldwide network of more than 50 fabrication laboratories and open to the general public every Tuesday from 11am to 7pm at no cost except for materials. A FabLab is a small workshop with tools that allow digital fabrication. In Aachen, we have multiple 3D printers (e.g., Dimension Elite), a lasercutter (Epilog Zing), and a CNC milling machine (LPKF Protomat S62). With the 3D printers, we can print 3D objects made of ABS plastic, the lasercutter can cut and mark almost any material, and the CNC milling machine can produce high quality printed circuit boards (PCBs) in a few minutes. The Fab Lab Aachen is also used by our students in classes, for our research projects (Madgets, Mudpad, etc.) and by other
institutions at RWTH Aachen University. We regularly host pupils (e.g., during Girls Day 2011, RWTH TandemKids, and Kinderferien spiele der RWTH, Wissenschaftsnacht). In Feb 2011, we offered the first German *3D Printer Master class*, where 10 participants built their own 3D printer. All Fab Lab projects are documented on our blog at http://fablab.rwth-aachen.de.

**Software**

Jonathan Diehl developed the *official UIST 2011 Conference App*. After CHI, UIST is the most influential conference in Human-Computer Interaction according to Microsoft Academic Search.

What’s for lunch today? Check the *iEat Mensa Menu Plan* at RWTH Aachen University directly on your Mac, iPhone, or iPod Touch! iEat is free, and it covers all RWTH Mensas, bistros and cafeterias. The Mac version installs itself in the menu bar. The iOS version displays dishes by day and location in a simple and intuitive way. Thorsten Karrer and Jan-Peter Krämer developed iEat for Mac, Jonathan Diehl for iPhone.

A lasercutter is a central device in Personal Fabrication, especially in FabLabs. Currently working with a laser-cutter requires many unnecessary steps and much experience. Thomas Oster’s *Visicut* optimizes this workflow by removing unnecessary steps and make the most common jobs more easy. A driver for lasercutters named *liblasercut* abstracts from the specific lasercutter model.

**Dorkbot Aachen**

Since May 2009, we have been hosting *Dorkbot Aachen*, a new local chapter of an international network of people doing interactive art, design, and electronic hacks. Dorkbot is a fun monthly meeting of hackers, designers, and artists working on interactive technologies (http://hci.rwth-aachen.de/dorkbot).

**CocoaHeads**

Since April 2008, we have been hosting CocoaHeads, an international group devoted to discussion of Apple’s Cocoa Framework for programming Mac OS X and iPhone OS. During this year, in monthly meetings participants again presented their projects and offered tutorials on various programming topics (http://hci.rwth-aachen.de/cocoaheads).
1st RWTH Computer Science Starcraft Cup

We hosted the 1st RWTH Computer Science Starcraft II Cup on July 9th. 29 participants from 7 different CS chairs and the student association (Fachschaft) competed with live commentary. The audience room was packed, the broadcasters provided great live commentary, and Christian Samsel from i4 took home the first prize, followed by our very own Patrick Zimmer from i10 and Bernd Schambach from i1.

AATC/e: Apple Authorized Training Center for Education

In early 2009, our group became an Apple Certified Training Center for Education at RWTH Aachen University. This year, we again organized several Apple-certified courses. Example courses include Apple Support, Server Essentials, Directory Services, and Deployment. All our trainers are experienced administrators and scientists from different faculties of RWTH Aachen University. Our goal is to provide certified, high-quality training for Apple systems to our students, staff members, and anyone else interested (http://aatc.rwth-aachen.de/).

Infrastructure

Our infrastructure evolves constantly, but at the time of writing consists of 8 XServe servers with two XServe RAIDs, 18 desktop machines (10 Mac Pros, 8 Mac minis) with 23” and 30” Cinema Displays and iSight cameras for the student laboratory, and individual MacBook Pros and 30” Cinema Displays for our staff. The Media Space contains five 40” mobile interactive LCD screens, an eight-channel networked surround audio setup with four discrete amplifiers and dedicated Firewire audio interface, high-fidelity videoconferencing and a variety of non-standard input and output technologies (infrared batons, various sensors, Bluetooth devices, etc.). The Fab Lab (see above) is another crucial part of our research infrastructure. We create this environment to facilitate experimentation with time-based multimedia and nonstandard interaction techniques for our students and staff. We have also acquired a high-end VICON 3D tracking system to analyze movements in user studies.

In 2011, we worked as reviewers for the top ACM conferences on HCI such as CHI, UIST, ITS, MobileHCI, as well as various other conferences and journals in Media Computing and HCI. We also host the hcipatterns.org home page as heads of the IFIP task group.
Talks and Publications

Talks


Jan Borchers. Von Smart Spaces und Dummen Dinge(r)n. Invited Speaker, Telecooperation Research Group, Technical University of Darmstadt, June 30, 2011.


In addition, talks by the respective authors accompanied the publications below.

Publications


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• Faculty
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• Researchers
  Kamal Barakat, M.Sc.
  Dipl.-Inform. Eva Beckschulze
  Dipl.-Inform. Ibtissem Ben Makhlouf
  Dipl.-Inform. Sebastian Biallas
  Dipl.-Inf. Jörg Brauer
  Hilal Diab, M.Sc.
  Marc Förster, M.Sc. (since 01.06.2011)
  Dipl.-Inform. Dominik Franke
  Dipl.-Inform. Dominique Gückel (until 31.10.2011)
  Dipl.-Inform. Paul Hänsch
  Igor Kalkov, M.Sc. (since 10.10.2011)
  Dipl.-Inform. Volker Kamin
  Dipl.-Inform. Jianmin Li (parental leave)
  Dipl.-Inform. Daniel Merschen
  Dipl.-Inform. Ralf Mitsching (until 30.04.2011)
  Dipl.-Inform. Jacob Palczynski (until 31.01.2011)
  Dipl.-Inform. Andreas Polzer (until 31.01.2011)
  Dipl.-Inform. John F. Schommer
  Dipl.-Ing. Andre Stollenwerk
  Dr. rer. nat. Carsten Weise (until 30.04.2011)
• **Guest Researchers**
  Thomas Reinbacher, M. Sc., TU Vienna (January-March)
  Dr. Axel Simon, TU Munich (February)
  Chakrit Wannachakrit, M.Sc., TOT, Bangkok (until September)

• **External Researchers**
  Dipl.-Ing. Sebastian Grobosch, VEMAC GmbH, Aachen
  Dipl.-Inform. Alexander Michailidis, Daimler AG, Sindelfingen
  Dipl.-Ing. Michael Reke, VEMAC GmbH, Aachen

• **Student Researchers**
Overview

The Chair “Informatik 11 – Software für eingebettete Systeme”, or short i11, in English, Embedded Software Laboratory, 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.

In the reporting period, the first researchers from the second generation, i.e., those who started in 2006 and already did their Diploma thesis with us, left the laboratory. These are Ralf Mitsching, Jacob Palczynski, and Andreas Polzer. Additionally, Dr. Carsten Weise moved back to industry after having built up our research group in mobile software validation and testing as a part of the UMIC Excellence Cluster. We are happy that we can fill the gaps at least partially by our new researchers Marc Förster and Igor Kalkov. I am grateful to the whole team for the great work and all the valuable contributions to our research, teaching and organisational activities.
The growing complexity of applications, architectures, protocols and hardware in the mobile world makes it increasingly more difficult to develop bug-free software for mobile communication and information systems. The intention of the UMIC Quality Initiative is to seek for methods that are applicable for mobile software to improve the quality of the software engineering process and the quality of the products. This project aims at the development of methods and tools for mobile development, as well as the identification and design of design patterns and architectures for mobile applications, in order to improve the quality of the mobile software. The first step towards this target is capturing the status quo and a clear problem statement. This has already started in a pathfinder project for this Software Quality Initiative project. Within the pathfinder project, it turned out that a quality model for mobile software is basically non-existent, but is needed to clarify the problems, explain solutions, and in the end also to measure the gains that come with the new methods and tools, design patterns and architectures. To manage the special requirements of mobile software, one goal of this UMIC Software Quality Initiative is to create design patterns and methods for improving quality of massively distributed mobile software.

Another goal is the analysis and improvement of mobile application lifecycles. Since lifecycles of mobile applications are stressed in a different way than lifecycles of desktop applications (e.g. incoming calls or SMS already lead to state changes in the application lifecycle) we used formal methods to analyze lifecycles of different mobile platforms and to build tools that deal with lifecycles at development time. Based on this analysis we developed a tool to support Android developers during the implementation of the Android Activity lifecycle. This tool is currently being extended in its functionality and capability to manage lifecycles of different mobile platforms, like iOS and Windows Phone 7. So in the next step this tool shall support Android, iOS and Windows Phone 7 developers implementing the corresponding application lifecycles correctly.
particular by building a formal model of the proposed protocol and the network structure for which we use the pi-calculus formalism. A compiler for the pi-calculus formal model is implemented considering our extension for timing. Our compiler generates metadata that can be interpreted by a second piece of software (the interpreter) in order to be able to simulate the proposed model with all the features of the calculus, such as alpha-conversion, polyadic parameter passing and timing. This compiler is the central building block for future constructs such as a transformation tool for verification using external systems like UPPAAL and a visualization tool for representing modeled protocols interactively using web browsers.

In parallel to our work on QoS formal verification, we are using OPNET® modeler as our wireless protocol simulator for verifying our proposed QoS enhancements on the Network Mobility protocol [NEMO – RFC3963]. We have elected test scenarios from the IP Multimedia Subsystem (IMS) standardization [3GPP-22259] that directly deal with QoS and network reconfiguration issues of Personal Area Networks (PANs) in order to enhance the user experience. As a result, we hope to present NEMO as a viable implementation for PANs in IMS.

Adaptive and Reliable Software Architectures for Heterogeneous Networks of Embedded and Non-Embedded Application Software

John F. Schommer

Funded by UMIC Research Centre (EXC-89)

Traditionally, embedded systems were small-scale systems performing specific control and measurement tasks, designed for robustness and unattended operation. This implied a radical different approach in design when compared to standard software systems. Nowadays, embedded systems often appear as part of networked systems. Often, this leads to heterogeneous networks, where some nodes are meant for the application and some nodes are embedded systems. However, the normal software components can also live on the same node as the embedded one. A focus lies on the issue that in such heterogeneous networks embedded-related requirements are propagated from embedded nodes to the whole network.

The goal of the project is to derive new patterns and methodologies for the design of software for heterogeneous networks. The focus of this project is on the nodes and the applications run on the network nodes. In the current stage of the project, first the investigation of existing
platforms, architectures, middleware and applications along with test implementations are performed. Second evaluation of hardware and look at how far current devices are capable of the propagated requirements are ongoing.

In the upcoming stage of the project, the development of new patterns and methodologies to improve platforms, architectures and applications will be done. This accompanies further evaluation, suitable prototypes, reference implementations and documentation.

**Controlled Extracorporeal Lung Assistance (Smart ECLA)**

*André Stollenwerk*

*In cooperation with Philips Lehrstuhl für Medizinische Informationstechnik; Lehr- und Forschungsgebiet Kardiovaskuläre Technik, Lehrstuhl für Angewandte Medizintechnik, Helmholtz-Institut; Klinik für Anästhesiologie*

Funded by DFG (PAK 138)

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 (Translation units) 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.

| Dependable Reuse and Guarded Integration of Software Components in the Automobile |
| Marc Förster |
| Funded by Forschungsvereinigung Automobiltechnik (FAT) |

The integration of components to a correct and dependable whole is an important task in the development and maintenance of automotive software. This task appears in many different situations, from the distributed development of new components (either within one company, or among different manufacturers and suppliers) via the reuse of preexisting components to the exchange of components, for example, in an after-sale functional upgrade. Recent years have seen a shift of design tasks from OEMs to suppliers, and this has tended to increase the late discovery of system-level faults during the integration phase performed by OEMs. Industry initiatives such as AUTOSAR aim at alleviating these problems by providing a standardised framework for the integration of software components in the automobile industry. AUTOSAR, however, predominantly addresses the formal interoperability of components: API functions for data exchange and communication (“Virtual Function Bus”, “Real-Time Environment”); an XML format for interface documentation; standardisation of services etc.

While these are necessary prerequisites for an operational component system, they still solely consider syntactical, static compatibility aspects of the system: a semantical, dynamic approach to component integration is missing. Such a method could be used to determine, in advance of an actual integration, if the composite system will show the required behaviour, deducible from the properties of its components (functional as well as nonfunctional aspects included). For this purpose, not just the models but also the reasoning performed on them should be modular. Interfaces need to be enriched with semantical descriptors and, going further, the specification of relationships and dependences among and between inputs and outputs.
Approaches enabling modular reasoning on software properties have been a topic of research for decades, starting with Hoare’s *Axiomatic basis for computer programming* (1969). They are known, for example, as “Rely/guarantee”, “Assume/guarantee”, “Assumption/commitment”, “Programming by contract” etc. Until today, none of these approaches has found its way to routine application in embedded systems development. This FAT research project, therefore, aims at facilitating the adoption of conditional reasoning and similar approaches by the automobile industry. In the first phase the state of the art has been reviewed; for further phases we plan case studies applying selected approaches and techniques to relevant integration scenarios and component frameworks (for example, AUTOSAR). Results of this project will enable industrial partners (1) to evaluate principles and possibilities of the investigated approaches; (2) to determine promising combinations of approaches and application scenarios; and (3) to familiarise themselves with selected approaches by practical application.

**Hybrid Verification of a Controlled Platoon of Vehicles with a Topological Changing Communication Network**

*Ibtissem Ben Makhlouf, Hilal Diab, Paul Hänsch*

Partly funded by DFG in the Temporary Graduate School AlgoSyn (GK 1298) and the Focussed Research Program Theory of Networked Control Systems (SPP 1375)

The infrastructure of highways in most major countries is congested because of the rapid increase of the traffic flow in the last years. 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.

The objective of our project work is to analyze the effects of the communication faults on the safety of the vehicles within the platoon. Within our cooperation with the control engineering institute (IRT) in Aachen, different controllers for the vehicular platoon were designed. Our task was on the one hand to proof the safety of the proposed controllers by formal verification methods and on the other hand to provide a hardware platform for testing.
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.

We adapted already existing techniques for reachability analysis of linear uncertain systems based on overapproximation of reachable sets represented by zonotopes. The most challenging task was to control the increasing complexity of computation, which is closely related to the number of generators describing the zonotope. Therefore, it was necessary to implement order reduction techniques. Further geometric set operations such as the intersection of a zonotope with a hyperplane were implemented to extend the approach to hybrid systems. We were able to check the safety of practically relevant scenarios.

Further, we also studied more fundamental questions, one of which was to reduce the reachability problem of linear systems with input to the reachability problem of systems without input. We showed that this method is correct for stepwise constant inputs and we also have proven that it is equivalent to already existing techniques. Another fundamental question we attended to was how much information about the reachable states of a linear dynamic system one can extract from the eigenstructure of the system matrix. This approach is completely different from the numeric time-discretizing approaches that we followed in the past. The biggest benefits are that no time horizon has to be fixed and that round-off errors as well as numerical errors can be avoided much easier. Eigenstructure based approaches have been proposed repeatedly already decades ago to solve problems over linear dynamic systems, however, the most publications aim at decidability results and only a few consider overapproximations of reachable states and take into account a set of initial states. We reviewed and considerably strengthened the results that we found in the literature that suited our needs best. The resulting method was applied to the truck platoon model giving us results that are in the same order of magnitude as the numerical results, which is indeed a surprisingly good performance for a rather symbolic approach.

A hardware implementation of the whole system is realized. We designed a 1:14 scaled platoon of four trucks. Each truck is equipped with sensors which provide the required information for the controller in order to guarantee a safe inter-vehicular distance. In our implementation, we use WLAN for the exchange of information between the trucks. Besides, a monitoring system of the networked platoon is supported. This platform was used in testing cooperative vehicle platoon controllers, especially to investigate the effects of communication problems on the controller of the platoon of vehicles and to study their influence on the safety. To perform more complex driving scenarios the actual position of the vehicle was needed. Therefore we implemented an indoor positioning system which is able to provide the position to an arbitrary number of objects in a test environment independently. By using the sensor data of the vehicles we were able to increase the accuracy of the position measurements.
Nowadays, in order to survive in the highly dynamic automotive market it is essential for companies to offer innovative products and to customize them to the target group or even to the individual customer. At the same time a high quality of the products has to be ensured. These aspects especially hold for the embedded software which gains more and more importance to realise the functionality. In the context of a cooperation with the Daimler AG we examine a model-based embedded software product line of on-board electronics. The product line continuously evolves which means that the artefacts, i.e. the implementation model, the requirements and the test cases, become more and more complex leading to the necessity of comprehensive tool support for the engineer with the adaption of affected artefacts, e.g. in the context of a change request, i.e. to identify which subsystems in a Simulink model have to be changed and which test cases are affected. To support the engineer we are currently developing a framework to analyse the artefacts in automated manner. To this end, we create models of the Eclipse Modeling Framework (EMF) for all artefacts and apply model transformations to perform different kinds of analysis. In particular, we strive to establish development-process-related analyses. To do so, a methodology is elaborated which integrates the different artefacts into one tool-independent, central model repository based on a common meta model which describes both the internal structure of the artefacts and the dependencies among them. Furthermore, we focus on establishing traceability and consistency among the related models with the help of an annotation concept.
Static analysis by means of abstract interpretation is a formal method used to prove certain properties of a program. In case some property could not be proven, a static analyzer advises the user to potential problems or bugs. The most famous examples of bugs found by static code analyzers are array out of bounds problems and null pointer dereferences.

In embedded applications the programming language used most often is still C. However, there are some differences compared to typical C Code run on a desktop PC. In embedded programs there are usually many write accesses to absolute addresses (registers). These can influence the behaviour of the microcontroller, e.g. set a port to input or enable interrupts.

In the static analyzer we implement, we tailor analysis algorithms to the specifics of microcontroller C code. The goal is to apply precise algorithms that produce few false alarms but are nevertheless efficient with respect to time and memory. Current research focuses on flow- and context-sensitive value-range analyses.

We developed the [mc]square model checker, which model checks microcontroller binary code. In its current state, [mc]square checks code for ATMEL ATmega and Intel MCS-51 microcontrollers. We are currently extending [mc]square to support the Renesas R8C\23. Beside model checking microcontroller assembly code, [mc]square is also able to verify programs for programmable logic controllers (PLCs).

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.

“Integrated Multi-formalism Tool Support for the Design of Networked Embedded Control Systems” (MULTIFORM)

Volker Kamin
Funded by EU, Seventh Framework Programme (FP7)

MULTIFORM focuses on the development, the integration and the interoperation of techniques and tools to provide coherent tool support for the integrated control design of large and complex networked systems. It is supported by the Seventh Research Framework Programme of the European Commission under grant agreement number INFSO-ICT-224249.

Within this project, the Embedded Systems Laboratory at RWTH Aachen extends the model checker [mc]square to be able to handle complex control software. Firstly, abstraction techniques are developed that constrain the state explosion that usually prohibits the creation of the state space of complex systems. These techniques make use of domain knowledge such as detailed hardware descriptions in order to minimize the loss of information. Secondly, the automatic detection of spurious counter-examples is researched. The goal is to dynamically refine abstraction techniques and/or model checking algorithms to block those counter-examples from yielding invalid results.

In addition to the extension of [mc]square, the Embedded Systems Laboratory collaborated with VEMAC GmbH to create tool support for software developers during requirements analysis. The tool supports optimal hardware choice – and thereby a better cost estimate – by verifying a microcontroller’s ability to run a certain software configuration without violating real-time constraints.

Finally, the Embedded Systems Laboratory is cooperating with the University of Applied Sciences Bonn-Rhine-Sieg. The goal is to verify safety critical software components and to establish an industrial process for doing so.
The [mc]square model checker verifies microcontroller programs by means of a simulator. The simulator is used to execute the program to be verified, and thus to create the state space. As the model checking algorithm is separated from the microcontroller simulator, it is possible to add support for new platforms by adding new simulators. However, there are certain constraints which prevent us from using just any simulator, such as the ones provided by device manufacturers. Manually implementing simulators is possible, but time-consuming and error-prone.

The goal of our ongoing research is to improve the development process in the aforementioned two aspects. For this purpose, we have developed a synthesis system, centered around a new language called State Space Generator Description Language (SGDL). The system is now in its third year of existence. In the first year, the primary goals were to establish the system as such, to create a first description of a microcontroller manufactured by Atmel, and to translate this description into an operative simulator that can simulate any program for this device. During the second and third year, we focused on several different goals: creating simulators for more platforms, creating platform-specific static analyzers, and adding automatic abstraction to reduce the gap between fine-tuned manually created simulators on the one and generated simulators on the other hand. With regard to abstraction, these goals have been met up to the point that synthetic simulators can now rely on a variety of abstractions, virtually eliminating the aforementioned gap. Currently, there are three SGDL-based simulators and attached static analyzers, two for the Atmel ATmega16 and ATmega644 and one for the Intel MCS-51. Furthermore, we have started to analyze hardware descriptions themselves by means of static analysis, in order to automatically derive as much information about a device as possible. The goal of this research is to eliminate the need for simulator developers to explicitly provide, for instance, abstract semantics of instructions, or dependencies between memories.

This DFG supported project focuses on the formal verification of programmable logic controller (PLC) programs. PLCs are used in the automation industry for controlling plants, machines and assembly lines. As such, they operate in many safety critical circumstances were formal verification of correct program behavior is desired or recommended.
To verify such programs, a PLC simulator is used to create a model that can be checked against logic formulae. For larger programs, abstraction techniques are required to represent all possible program behavior in a compact form. The progress of the project is integrated into [mc]square, a model checker and static analysis tool for microcontroller programs which is developed at the Embedded Software Laboratory at RWTH Aachen.

Current results of the project were presented at the AUTOMATION congress and 3rd International Workshop on Dependable Control of Discrete System (DCDS).

CEVTES: CounterExample Validation and Test Case Generation Framework for Verifying Embedded Software

Jörg Brauer, Stefan Kowalewski, Thomas Reinbacher, Martin Horauer, Andreas Steininger

Funded by FIT-IT and BMVIT

CEVTES is a joint project involving the Embedded Software Laboratory at RWTH, the Technical University of Vienna, and the University of Applied Sciences Technikum Vienna. The project is primarily funded by the initiative FIT-IT of the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) and the Austrian Research Promotion Agency (FFG).

The key idea of this cooperation is to combine formal verification of binary programs with faithfully selected test traces that are executed on a real microcontroller. Since verification computes over-approximations of the behavior of the real program to overcome undecidability, it suffers from the presence of spurious warnings. In this project, counterexamples – that is, error traces exhibiting a potential failure of the program – are executed on a microcontroller core simulated on a FPGA, with a special device attached to monitor the microcontroller. The traces observed on the FPGA are then used to rule out spurious error traces.

Results of the project have been described in several papers, which have been presented at MEMICS 2010, MESA 2011, FMICS 2011, RV 2011, and EMSOFT 2011. The papers "Test Case Generation for Embedded Binary Code using Abstract Interpretation" and "Past Time LTL Runtime Verification for Microcontroller Binary Code" have received best paper awards from MEMICS 2010 and FMICS 2011, respectively.

Automatic Abstraction for Binary Code

Jörg Brauer and Andy King

In August 2009, Jörg Brauer and Andy King have started a joint project to advance the state-of-the-art in abstract interpretation of binary code. Andy King, who is working with the University of Kent in Canterbury and Portcullis Computer Security Limited, is a widely
appreciated expert in reasoning about low-level program semantics using SAT solving. The key observation this project is based on is that binary code behaves very differently compared to programs presented in high-level programming languages such as C, and thus requires different verification methods. In particular, a single assignment in C is frequently compiled into a sequence of instructions, which leads to a tight coupling between the semantics of different instructions. Similarly, control logic is typically formulated in terms of Boolean relations over single bits. Following these two observations, the use of SAT-solving appears natural to reason about binary code.

The key contribution of this cooperation lies in novel methods for synthesizing optimal abstract interpretations of binary programs, with a special focus on the integration of overflows that occur in machine arithmetic. The results have been published in several major conferences on program verification, namely

- the 23rd International Conference on Computer Aided Verification (CAV, USA),
- the 3rd NASA Formal Methods Symposium (NFM, USA),
- the 20th European Symposium on Programming (ESOP, Germany),
- the 17th International Static Analysis Symposium (SAS, France), and

Two journal papers are currently under review and Jörg has given several invited talks on the results of this project. The project has been supported by the Royal Society, by the UMIC cluster of excellence, and by the DFG graduate school AlgoSyn.

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**Carolo Cup 2011**

*Benedikt Rieke, Thomas Gatterdam, Bernhard Kirchen, Benjamin Hilgers, Matthias May,*  
*supported by Hilal Diab*

**Funded by the Undergraduate Funds of the Science Faculty**

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In 2011 the team GalaXIs (www.galaxis.rwth-aachen.de) supported by the embedded software laboratory won the second place in carolo cup of developing autonomous model cars. The Team consists of five students (Benedikt Rieke, Thomas Gatterdam, Bernhard Kirchen, Benjamin Hilgers and Matthias May).

In this year the team from Ulm (Spatzenhirn) has won the competition and the team from Zwickau (S.A.D.I.) was placed third. The team from Aachen (GalaXIs) has placed second on both the static and dynamic tasks. Using its camera based control algorithm the car from our team called Orion showed a smooth drive around the track for the autonomous driving with obstacles.
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. A lot interesting videos can be found on the homepage (www.carolo-cup.de).

IMAV 2011

Christian Dernehl, Junjie Zhang, Andreas Schumacher, Safoura Lakani and Kamil Czarnogorski, supported by Dominik Franke

Funded by the Undergraduate Funds of the Science Faculty

The International Micro Air Vehicle Conference and Flight Competition (IMAV) is an annual event in which different research groups from academic and industrial context participate. This year it was the first time that the RWTH Aachen University joined this event with an interdisciplinary group of students, called the MAVerix team. The team consists of students from the Institute of Flight System Dynamics, represented by Niklas Schreiber, Stefan Rofalski, David Osten, Wolfgang Rottner, Max Keller and Torben Klougt, and the Embedded Software Laboratory, represented by Christian Dernehl, Junjie Zhang, Andreas Schumacher, Safoura Lakani and Kamil Czarnogorski.
The Institute of Flight System Dynamics have designed and built-up a plane, while the students from the Embedded Software Laboratory took care of the hardware and software for the plane. Both institutes worked together on the flight control components. The resulting plane follows the tiltwing concept. It is capable to fly fixed wing, tilt its wing and then hover like a helicopter. This concept for an autonomous air vehicle was unique at the IMAV 2011 and found great attention and feedback from the other participants. But such a complex concept is also very challenging. Thus in the first year of participation in the IMAV 2011 the MAVerix team was not able to win against good challengers with multiple years of IMAV-experience like DLR (Deutsches Zentrum für Luft- und Raumfahrt, Germany), ENAC Paparazzi (École Nationale de l’Aviation Civile, France) or Akaflieg (Academic Flight Club Bremen, Germany). However, with their interesting and promising approach the MAVerix team is attending to participate next year once again in the IMAV 2012.
Other Activities

Courses

Winter semester 2010/11
- Lecture „Einführung in die Technische Informatik“
- Lecture “Formale Methoden für eingebettete Systeme”
- Lecture “Dynamische Systeme für Informatiker“
- Praktikum “Hardwarenahe Programmierung”
- Praktikum „Modellbasierte Analyse von Simulink-Modellen“
- Proseminar “Design Patterns für Mobile Eingebettete Systeme”
- Seminar “Automatisierungstechnik”

Summer semester 2011
- Lecture “Einführung in eingebettete Systeme”
- Lecture “Safety and Reliability of Software-Controlled Systems“
- Praktikum “Systemprogrammierung”
- Praktikum “Entwicklung NXT gesteueter Systeme mit Java”
- Seminar “Wireless Technologies for Embedded Systems”

Stefan Kowalewski
- Vice-Dean, Faculty of Mathematics, Computer Science and Natural Sciences, RWTH Aachen University, since 2010
- Member of the Board, „Forum Informatik“ (until 04/2010) and „Forum Mobilität und Verkehr“ (since 06/2011) of RWTH Aachen University
- Member of the Board, Regional Competence Network for Information Technology “REGINA”, Aachen, Germany, since 2006
- Steering Board Member, Technical Committee “Automotive Software Engineering”, German Society for Computer Science (GI), since 2005.
- Member of the Editorial Board, at-Automatisierungstechnik (German Journal on Control and Automation Theory), Oldenbourg, Munich, since 2005.
Jörg Brauer


Marc Förster

- Member of the Industry committee of the International Symposium on Software Reliability Engineering, ISSRE 2011, Hiroshima.

Awards

- Martin Lang placed second at the AKM Award for his Bachelor thesis „Entwicklung eines dezentral implementierten Sicherheitskonzeptes für intensivmedizinische Anwendungen“.
Talks and Publications

Talks


Publications


Barakat, K., "Introducing Timers to Pi-Calculus", RWTH Aachen, AIB-2011-18, 2011.


Grobosch, S., Kamin, V., Krikkawin, K., and Kowalewski, S., "Using Timed Automata in Requirements Analysis for Engine Control Units", in Proc. 18th World Congress of the International Federation of Automatic Control (IFAC), 2011, IFAC, pp. 12503-12508.


Institute for Scientific Computing

Staff

• **Faculty**
  Univ.-Prof. Christian H. Bischof, Ph.D. (until 06/2011)
  Apl. Prof. Dr.-Ing. H. Martin Bücker

• **Secretary**
  Gabriele Meessen

• **Research Assistants**
  Dipl.-Math. Oliver Fortmeier
  Dr. Kathrin Fuchss Portela (until 06/2011)
  Dipl.-Inform. Michael Lülfesmann (until 10/2011)
  Dipl.-Inform. Johannes Willkomm (until 06/2011)
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](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".

ADiMat—Automatic Differentiation of MATLAB Programs

J. Willkomm, C. Bischof, M. Bücker

The MATLAB problem solving environment is widely used in the natural and engineering sciences. Its popularity is mainly due to its wealth of high-level data types and powerful mathematical operators, as well as to its flexibility and ease-of-use. The goal of this project is the design and implementation of an automatic differentiation tool for MATLAB. The ADiMat tool allows augmenting MATLAB programs with additional statements such that derivatives are computed along with the original function. ADiMat implements a hybrid approach combining source transformation and operator overloading techniques in order to achieve high performance while allowing for MATLAB's dynamic type system.

FLOWRUN—Numerical simulation and optimization of flood-induced flow phenomena using a parallelized SPH-code

J. Willkomm, C. Bischof, M. Bücker

The objective of this JARA research project is to carry out a novel, coupled, numerical investigation of hydromechanical flow phenomena via an interdisciplinary approach of the disciplines hydraulic engineering, informatics, and mathematics. In this feasibility study the flow over a stepped, pooled spillway is computed on a parallel computer and combined with a sensitivity analysis based on automatic differentiation. For this application an implementation of the SPH-method (Smoothed Particle Hydrodynamics) is intended, which will enable the
efficient numerical computation of relevant flows in the long term. In particular in fluid mechanics, high-performance computing has gained in importance due to the long-term and large-scale applications in hydraulic engineering. The participating scientists from Hydraulic Engineering and Water Resources Management (IWW), Scientific Computing (SC) and Continuous Optimization (OPT)

Novel methods for exploration, development, and exploitation of geothermal reservoirs - a toolbox for prognosis and risk assessment

K. Fuchss Portela, C. Bischof, M. Bücke

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. 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 Kolloqium 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:

- **11th European Workshop on Automatic Differentiation, Swindon, UK, December 9-10, 2010.** (Co-organized by Martin Bücker)

Martin Bücker served on the program committee for:

- **13th IEEE International Conference on Computational Science and Engineering (CSE-10) held in Hong Kong, China, December, 11-13, 2010.**

- **12th IEEE International Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC-11) held in conjunction with the 25th International Parallel and Distributed Processing Symposium (IPDPS-2011), Anchorage, USA, May 16-20, 2011.**

- **4th Workshop on Language-Based Parallel Programming Models (WLPP) held in conjunction with the 9th International Conference on Parallel Processing and Applied Mathematics (PPAM'2011), Torun, Poland, September 11-14, 2011.**

- **2011 International Conference on Computational Science and its Applications (ICCSA 2011) held in Santander, Spain, June 20-23, 2011.**


Talks and Publications

Talks


Publications


J. Willkomm and H. M. Bücker. Parallel summation of symmetric inter-particle forces in smoothed particle hydrodynamics. In M. Griebel and M. A. Schweitzer, editors, Meshfree


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  Michel Schanen
  Niloofar Safiran
  Viktor Mosenkis

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  Dmitrij Gendler (U. of Hertfordshire, UK)

• Student Researchers
  Klaus Leppkes
  Lukas Razik

• Guests
  Bui Ngoc Lihn
  Hong Ha Nguyen Ti
  Mushin Shodic
  Fridy Mandita
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 $y = F(x), F : \mathbb{IR}^n \rightarrow \mathbb{IR}^m$ into code for computing various derivatives including products of the transposed Jacobian matrix $F' = F'(x)$ with a vector $\bar{y} \in \mathbb{IR}^m$. 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.

The industrial processes are described in mathematical models consisting of algebraic equations, formulated in some high-level modeling language (e.g. gPROMS). The derivatives of these models are highly desirable by the industry.

The first step in the chain of AC-SAMMM is the translation of the algebraic equations into C++. This work is done by AVT. To generate first order derivative code for a given C++ implementation of a numeric function Derivative Code Compiler (DCC) is used. DCC is developed by STCE. It is possible to reapply DCC on its own output to get the derivatives of higher orders. We applied AC-SAMMM on a real-life pharmacological problem, with over 2000 algebraic equations. The resulting C++ code consists of 9,000 lines. Applying DCC to this code yields a derivative code with 44,000 lines. The second order derivative code, generated by DCC, has 180,000 lines.

To simplify the usage of AC-SAMMM we currently develop a library allowing the computation of the first and second derivatives in an automatic way, exploiting the sparsity structure of the Jacobian and Hessian. The user has only to specify a function and a desired order of differentiation.

The JUelich RApid Spectral SImulation Code is a radiative transfer model for the infrared spectral region developed at the Institute for Chemistry and Dynamics of the Geosphere (ICG-1) at the Forschungszentrum Jülich. The main focus of our collaboration is a part of the JURASSIC package called retrieval processor, which tries to estimate the retrieval parameters by minimizing the cost function representing the deviations between real and simulated observations for a given state as well as the differences between the estimated state and an a priori state. Our main investigations so far have been focused on enabling JURASSIC to
compute the gradient of the cost function using forward and reverse mode AD. Further effort has been taken to parallelize the AD solutions using MPI parallel concept.

**Hybrid Approach to the generation of adjoint C++-Code**

*J. Lotz, U. Naumann*

*Collaborators: ICG-1, Forschungszentrum Jülich, Max Planck Institute for Meteorology, Hamburg*

*Funded by: DFG*

In scientific computing a major challenge are derivative computations of implemented mathematical models. For example in (large-scale) Inverse Problems the derivative of the forward model is to be evaluated. AD is a powerful concept for doing this efficiently when the possibility of a reverse (adjoint) execution is provided. This execution reversal can be accomplished by building a computational graph by operator overloading at runtime representing the implemented function. Thereby the derivative is obtained by operations on the created data-structure. Apart from that source code transformation can be used to create C++-Code computing the adjoint. The first approach is robust and suitable for almost any C++-Code but is in comparison relatively slow. Source code transformation on the other hand is applicable only to syntactically simpler code but yields a high efficiency. The aim is to merge both approaches to a hybrid treatment of derivative calculations to combine the advantages, i.e., syntactically complex parts are handled by operator overloading while compact computationally expensive parts are covered by source code transformation. Target application is the Juelich RApid Spectral SImulation Code (mentioned above) and we aim to consider a C-version of a new atmospheric and oceanic general circulation model (ICON) developed by the Max-Planck-Institut für Meteorologie and the German Weather Service.

**CompAD-III**

*U. Naumann, J. Riehme, D. Gendler*

*Collaborators: The Numerical Algorithms Group Ltd., University of Hertfordshire, UK*

*Funded by: EPSRC*

The development of the differentiation-enabled NAG Fortran Compiler is a joint effort of the University of Hertfordshire, UK, and the RWTH Aachen University, Germany. The target is the integration of current (or new) Automatic Differentiation technology into the industrial strength Fortran compiler of the Numerical Algorithm Group (NAG), Oxford, UK. The project is currently in the third period of funding by EPSRC.

The AD-enabled NAG Fortran Compiler utilizes a hybrid approach combining automatic datatype changes (source transformation) with overloading techniques. The compiler provides
a number of differentiation modes (tangent linear, adjoint, tape based adjoint, second order adjoint, ...), each one has its own private compad_module. Every compad_module exports a compad_type (and overloaded arithmetic operations, plus a number of support routines) used by the compiler to perform the datatype changes from floating point into compad_type automatically. Any detail of the AD-implementation of a specific module is hidden within the module, the compiler only rely on the existence of a compad_type. The original semantic analysis of the NAG Fortran Compiler resolves operations on compad_type by inserting calls of overloaded operators from the chosen module.

Although the overloaded approach of the AD-enabled NAG Fortran Compiler is very robust and gives good performance already, the compiler can be used to generate differentiated code: in this pure source transformation mode all calls of overloaded operators are replaced by corresponding differentiated code that is inserted into the internal representation directly. Thus all overhead of calling a subroutine for every single arithmetic operations is eliminated.

Optimization problems in engineering often have non-convex objectives and constraints and require global optimization algorithms. In such cases McCormick relaxations can be used to ease the problem. McCormick Relaxations are certain convex and concave under- and overestimators of the objective function and constraints. Since convex functions are possibly non-smooth, subgradients are used instead of usual derivatives. Subgradients are natural extensions of usual derivatives providing similar information for non-differentiable functions.

AD-methods can be used to propagate the values of McCormick Relaxations as well as its subgradients. A first version implementing AD-forward mode based on operator overloading was developed in C++ by colleagues at MIT's Process Systems Engineering Laboratory and Dept. of Mechanical Engineering. STCE developed a reimplementation in Fortran also providing source code transformation. Recently this was extended by a reverse mode which provides the same advantages as normal adjoints.

The morphodynamic model Sisyphe (developed at EDF Department Laboratoire National D'Hydraulique et Environnement, www.telemac system.com) is used at the German Federal
Waterways Engineering and Research Institute (BAW), Karlsruhe, to simulate river bed evolutions. In morphodynamic modelling input parameters are uncertain due to measurement errors, natural variability, or unsatisfactory parameterisation. However, the propagation of uncertainties in the input data might have serious influence on the simulation results. Therefore, it is necessary to quantify their contributions to the model results in order to appraise the reliability of the simulation.

A tangent linear model of Sisyphe generated by the AD-enabled NAG Fortran Compiler (CompAD-III) is used to calculate the sensitivities of the evolution with respect to different input parameters, which were assumed to be uncertain. These sensitivities allow for a first order reliability analysis (FORM) to be performed that estimates the uncertainties of every chosen input parameter.

The aim of further collaboration with the German Federal Waterways Engineering and Research Institute, Karlsruhe, is to apply the AD-enabled NAG Fortran Compiler to Telemac, a numerical modeling system for free surface hydrodynamics, sedimentology, water quality, waves and underground flows, which can be coupled with Sisyphe.

Elimination Techniques on Linearized DAGs
V. Mosenkis, U. Naumann

Funded by: DFG

The aim of this research is to minimize the number of operations to accumulate the Jacobian of a given numerical program implementing a multivariate function. This problem is called Optimal Jacobian Accumulation (OJA) problem. OJA was shown to be NP-hard by Prof. Naumann. The problem can be formulated on graphs by attaching the corresponding local partial derivatives to the edges of the computational graph of the underlying program yielding a linearized computational graph. A graph-based interpretation of the chain rule of differential calculus allows to compute the partial derivative by multiplying all edge labels along all paths from the corresponding input to the output and adding the results. In practice to reduce the search space graph transformation techniques like vertex-, edge- and face elimination based on associativity of differential calculus are used. Thereby the linearized computational graph is transformed into a bipartite graph whose edge labels correspond to the entries of the Jacobian. This approach yields the problem of finding a vertex, edge or face elimination sequence with minimal number of operations (costs). Even this version of the OJA problem is believed to be NP-hard although the proof is still outstanding. Henceforth we are interested in developing fast heuristics to find an elimination sequence with costs close to minimal.

To support the theoretical research in this field we provide a Branch and bound algorithm which finds an optimal vertex, edge or face elimination sequence. Depth first search is used for the branching step of the algorithm. Lower bounds for the operation number as well as the knowledge of equivalent elimination sequences are used to reduce the search space. Currently we are working on the proof of sharper lower bounds to be used in the algorithm.
We investigate the robust and efficient applicability of reverse mode algorithmic differentiation to numerical simulation codes that use MPI. Since MPI is the de facto parallelization standard in large scale simulation codes, there have been numerous attempts to compute adjoints of MPI parallelized code. Until today, they all heavily rely on manual manipulation of the original code. Our generic approach tries to reverse the entire flow of computation and thus reverse all the MPI communication patterns automatically.

The focus has been on the programming languages C and Fortran. In Fortran, adjoint MPI has been inserted in the development branch of the COMPAD project based on the NAG Fortran Compiler. Additionally, covering the language C/C++, the technique is being used with the in house developed dcc compiler and the dco overloading library.

The outcome should be a generic and versatile adjoint MPI library that may be coupled with any algorithmic differentiation software. It is not restricted to any specific language or tool.

Uncertainty Quantification

M. Beckers, U. Naumann

Collaborators: Prof. B. Christianson, Phd., University of Hertfordshire, UK

Funded by: German Research School for Simulation Sciences

Uncertainty Quantification aims to determine the imprecision in the outputs of numerical programs caused by (measurement) errors in the inputs. For a known error distribution of the inputs, probabilistic methods are used to get information about the distribution of the outputs.

Such investigations are for example desired in the context of engineering or weather simulations. Weather simulations are partly based on measured wind speeds and temperatures used to forecast future weather conditions. Quantifications of the impreciseness in such predictions is needed. Especially if important decisions have to be made based on such simulations, uncertainty information has to be taken into account.

Our approach is based on a Taylor Series Expansion of the function implemented by the simulation, yielding approximations of the mean and variance of the distribution of the output. Because of the complexity of accurate derivative computations mostly first-order methods are used in practice. AD allows the efficient computation of higher order derivatives and therewith more precise approximations. At the moment we apply such higher order
methods to cases were our program represents an iterative optimization algorithm (i.e. steepest-descent or Newtons-method).

**High-Performance AD**

*E. Varnik, E. Charoenwanit, U. Naumann*

Funded by: NSTDA (Thailand)

In this project we aim to exploit HPC architectures in the context of accumulating Jacobians of very large numerical simulation programs in AD. This can be performed by application of some elimination techniques to a graphical representation also referred to as the linearized computational graph (L-DAG) of the underlying numerical simulation program. The construction of such computational graphs at runtime often leads to very large graphs. Derivative accumulation by elimination techniques may fail due to the graph size exceeding the available memory. In this project, we build on an existing tool DALG that has been developed to overcome the memory problem by eliminating intermediate vertices and edges on the fly. Thereby, we attempt to come up with efficient techniques for the process of parallelizing large-scale L-DAGs onto large-scale high-performance computer architectures with respect to memory aspects. In shared-memory systems, we investigate cache-related effects. In distributed-memory systems, we investigate the prospect of exploiting secondary storage in storing and retrieving intermediate computations in an efficient way in terms of time and memory usage.

**Adjoint ICON**

*J. Riehme, K. Leppkes, U. Naumann*

Collaborators: Dr. P. Korn and F. Rauser, Max Planck Institute for Meteorology, Hamburg

Funded by: Max Planck Institute for Meteorology

The Icosahedral Non-hydrostatic General Circulation Model (ICON, icon.enes.org) is developed by the Max Planck Institute for Meteorology (MPI-M), Hamburg, and the Deutscher Wetterdienst (DWD). The AD-enabled NAG Fortran Compiler (CompAD-III) is used to generate a discrete tape-based adjoint version of a geophysical model. It allows to compute the goal sensitivities required for goal oriented dual weight error estimation.

Computing adjoints with a tape based approach consists of two steps: All elemental operations performed by the program execution have to be recorded on a so called tape, and given initial adjoints of the outputs have to be propagated by a reverse tape interpretation step resulting in the desired goal sensitivities. Checkpointing techniques allows to restrict the tape of the whole process, which to is big to be kept in memory, to a (sub-)tape of individual time steps (only one at any time) by introducing additional re-computations.
The tape recording for subsequent time steps is independent of each other, whereas the propagation of adjoints through the tape of time step $i$ can start only after finishing the adjoint propagation of time step $i+1$. We exploit this fact by doing tape recording for time step $i$ and tape propagation for step $i+1$ in parallel by two MPI processes. If more processes are used, every process finished with tape recording spent additional time in waiting for adjoints from the subsequent time step. In this case the additional waiting time is turned into productive waiting by optimizing the tape structure for a faster adjoint propagation afterwards.

In addition a special treatment of the underlying linear solver yield to an improved scalability of the approach and a significant reduction in memory consumption and runtime.

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**Toward Adjoint OpenFOAM**

*N. Safiran, U. Naumann*

The OpenFOAM (Open Field Operation and Manipulation) CFD Toolbox is a free, open source CFD software package produced by OpenCFD Ltd. It is a package which simplifies the implementation of physical models by mimicking the form of partial differential equations in software. It has a large user base across most areas of engineering and science, from both commercial and academic organisations. OpenFOAM has an extensive range of features to solve anything from complex fluid flows involving chemical reactions, turbulence and heat transfer, to solid dynamics and electromagnetics. It includes tools for meshing, a parallelized mesher for pre- and post-processing.

Algorithmic Differentiation (AD) provides accurate derivative values and better runtime performance of the adjoint model compared with finite differences. The aim of this project is to apply AD to OpenFOAM and as a result to obtain the adjoint version of OpenFOAM, i.e., calculating the derivative with adjoint mode of AD by operator overloading using our AD tool dco/c++.

Preliminary studies show how to couple dco/c++ with OpenFOAM and how to use it to calculate the derivatives of simple ODEs with tangent-linear and adjoint mode AD in OpenFOAM [See also: Aachener Informatik Bericht (AIB) 2011-16].

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**Toward Adjoint-Based Optimization in Computational Finance**

*N. Safiran, U. Naumann*

In computational finance, Monte Carlo simulation is a very popular approach for determining the prices of financial options. This is partly due to its computational efficiency for “high-dimensional” problems involving multiple assets, interest rates or exchange rates, and partly due to its relative simplicity and the ease with which it can be parallelized across large computer clusters. On the other hand, because the mathematical models are calibrated to
actual prices observed in the marketplace, it can be argued that prices are largely determined by the market prices of a large range of frequently traded products. Where the Monte Carlo simulation plays a crucial role is in the calculation of the sensitivity of the prices to changes in various input parameters, such as the current asset price, interest rate and level of volatility. Both first and second derivatives are essential for hedging and risk analysis, and even higher derivatives are sometimes used.

Algorithmic Differentiation (AD) is a method for computing derivatives of output of numerical programs with respect to its inputs both accurately (with machine precision) and efficiently. The two basic modes of AD – forward and reverse – and combinations thereof yield products of a vector with the Jacobian, its transposed, or the Hessian respectively. Adjoint codes can be generated from a given numerical simulation program by semantic program transformation, for example, using our derivative code compiler dcc.

The aim of this research is to analyze the sensitivity of financial market models, for example the LIBOR market model with respect to the variations in the model parameters. [ See also: Safran, Niloofar; Naumann, Uwe: Toward Adjoint Based Optimization in Computational Finance, published at www.nag.com, 2011, NAG direct award price winner for best financial math project using NAG.]
Other activities

Courses

Winter semester 2010/11

• Introduction to Computer Science (C++ Programming) (V4, Ü2)
• Computational Differentiation (V3, Ü1)
• Simulation Software Engineering Lab (CES Bachelor) (V1, Ü1)
• Seminar: Optimization Software (S2)

Summer semester 2011

• Combinatorial Problems in Scientific Computing (V2, Ü1)
• Fundamentals of Software Engineering (V1, Ü2)
• Practical Compiler Construction with flex and bison (V1, P3)
• Seminar: Numerische Bibliotheken (S2)

Chair Holder’s scientific activities

• Uwe Naumann is member of the Bioeconomy Science Center
• Uwe Naumann is member of the Advisory Board in the EU Project Flow Head (http://flowhead.sems.qmul.ac.uk/)
• Uwe Naumann is chair of the steering Committee for Service Teaching of the Department for Computer Science
• Uwe Naumann was organizer and conference chair of the 5th SIAM CSC Workshop, Darmstadt, may 2011

Other guy’s scientific activities

• Ebadollah Varnik is member of the steering Committee for Service Teaching of the Department for Computer Science
Talks and Publications

Talks


Nguyen Ti, Hong Ha: Towards a Compiler Generated Adjoint Model of FVCOM. ICSTE 2011, Kuala Lumpur, Malaysia.


Shodic, Mushin: To-Be-Recorded Analysis inside Derivative Code Compiler. ICSTE 2011, Kuala Lumpur, Malaysia.


Publications


Beckers, Markus; Mosenkis, Viktor; Maier, Michael; Naumann, Uwe: Adjoint Subgradient Calculation for McCormick Relaxations. Aachener Informatik-Bericht (AIB) 2011-10.

Förster, Michael; Naumann, Uwe; Utke, Jean: Toward Adjoint OpenMP. Aachener Informatik-Bericht (AIB) 2011-13.


Naumann, Uwe; Beckers, Markus; Lotz, Johannes; Mosenkis, Viktor (editors): Fifth SIAM Workshop on Combinatorial Scientific Computing. Abstracts, Aachener Informatik-Bericht (AIB) 2011-09.


Nguyen Ti, Hong Ha; Riehme, Jan; Schanen, Michel; Naumann, Uwe: Towards a Compiler Generated Adjoint Model of FVCOM. International Conference on Software Technology and Engineering, ASME Press, New York, 2011.

Safiran, Niloofar; Naumann, Uwe: Toward Adjoint Based Optimization in Computational Finance, published at www.nag.com, 2011, NAG direct award price winner for best financial math project using NAG.

Safiran, Niloofar; Naumann, Uwe: Toward Adjoint OpenFOAM. Aachener Informatik-Bericht (AIB) 2011-16.

Schanen, Michel; Förster, Michael; Gendler, Boris; Naumann, Uwe: Compiler-based Differentiation of Numerical Simulation Codes. The Sixth International Multi-Conference on Computing in the Global Information Technology, IARIA, 2011. Best paper award.


**Posters**


Beckers, Markus; Mosenkis, Viktor; Naumann, Uwe: Adjoint Subgradients for McCormick Relaxations, Aachen Conference on Computational Engineering Science, 2011, Aachen, Germany.


Schanen, Michel; Naumann, Uwe, Adjoint MPI, Aachen Conference on Computational Engineering Science, 2011, Aachen, Germany.

Förster, Michael; Naumann Uwe; Utke, Jean: Toward Adjoint OpenMP, Aachen Conference on Computational Engineering Science, 2011, Aachen, Germany.


Lotz, Johannes; Naumann, Uwe; Ungermann, Jörn: Efficient Discrete Adjoint Computation by Exploiting the Inner Structure of a Spectral Simulation Code, Aachen Conference on Computational Engineering Science, 2011, Aachen, Germany.

Andreas Püttmann; Naumann, Uwe; Wiechert, Wolfgang; van Lieres, Eric: Fast and Accurate Parameter Sensitivities for the General Rate Model of Chromatography, ASIM Workshop 2011, Trends in Computational Science and Engineering, Munich, Germany

**Bachelor/Master Theses**

Nguyen Thi, Hong Ha: Towards Compiler generated Adjoint Model of FVCOM

Shodiq, Mushin: To-Be-Recorded Analysis inside Derivative Code Compiler

Quoc Trong, Duong: Optimization and Evaluation of a Multimedia Streaming Service on a Hybrid Telco Cloud
Wilms, Stefan: Durchgängige Automatisierung der CAE-Prozedur von Durchschlagsberechnungen an PKW-Karosserieblechen


Zakalek, Paul: Clusteranalyse von Waferdefekten
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  Dipl.-Inform. Sebastian Ullrich

• Immersive Visualization
  Dipl.-Math. (FH) Daniel Bündgens (Head)
  B.Sc. Andrea Bönsch, Math.-Techn. SW-Entwicklerin
  Andreas Hamacher, Math.-Techn. Ass.

• Trainees
  Gerrit Garbereder (until January 2011), Joachim Herber,
  Sven Porsche, Tatyana Povalyaeva (since September 2011)

• Student Researchers
  Eric Buchwald, Sebastian Freitag, Gerrit Garbereder,
  Markus Joppich, Christian Krawczik, Max Mennicken,
  Peter Schumacher, Stoyan Stoyanov
Overview

The Virtual Reality Group was founded in 1998 and is a member of the Center for Computing & Communication as well as an associate member of the Computer Science Department. Our research goal is to develop new Virtual Reality techniques and methods and to push this technology forward towards applicability in complex scientific applications. As such, our work is characterized by basic as well as application-oriented research in collaboration with other RWTH institutes from multiple faculties, industrial companies, and other research groups from around the world in mostly third-party funded joint projects. As a part of the Center for Computing & Communication, we are in particular involved with providing methodical support and complete solutions. Thus, producing journal papers is not the one and only – although undoubtedly important – goal of our scientific work. Instead, we also aim at making our research work available to our partners, allowing them to explore even complex technical and physical phenomena in an intuitive way. Therefore, a lot of effort goes into the development of comprehensive software frameworks in order to make Virtual Reality technology a valuable tool in the scientists’ daily work.

In principle, Virtual Reality (VR) is a computer-generated scenario (the virtual world) a user can interact with in real time and in all three dimensions. The interface should be as intuitive as possible, and multiple senses like vision, haptics, and audio should be included into the interaction. By special display technology an immersion effect can be achieved, i.e., users have the impression of being a part of the virtual environment, fully surrounded by it instead of just looking from outside.

VR has proven its potential to provide an innovative human-computer interface, from which multiple application areas can profit. The VR applications fields we are working on comprise architecture, mechanical engineering, medicine, life science, psychology, and more. In the field of mechanical engineering, for instance, we provide immersive visualizations from very big objects like complete plants, over mid-size objects like machine tools and robots, down to microscopic scenarios arising in material science.

In recent years, Simulation Science has more and more attracted our attention. At RWTH Aachen, numerical simulation of technical and physical phenomena has traditionally been an important pillar in engineering research. With the excellence initiative, Simulation Science has definitely become a main focus at the University. In Aachen and elsewhere, simulation is an indispensable and essential tool in production technology and the development of, e.g., airplanes, cars, combustion engines, turbines etc. Even in medical projects at RWTH, numerical simulation is going to play an important role, e.g., in the analysis of flow within artificial blood pumps, or in order to understand the air flow within the human respiratory organs. Researchers are going to simulate phenomena of such a high complexity that traditional methods of post-processing, like producing static images or at best animations, are no longer neither an effective nor an efficient approach to understand the simulation results. Instead, engineers demand interactive exploration of their data in 3-D space, what eventually leads in the use of VR technology. As such, the VR Group actively supports RWTH institutes and research groups in CCES, AICES, GRS, JARA-HPC, and the CoE “Integrative Production Technology for High-Wage Countries” in analyzing their data by means of Virtual Reality. From the computer science point of view, the grand challenge is that on the one hand we are facing huge datasets, and on the other hand we have to handle these data in real time. Thus, new concepts for hybrid visualization environments have to be developed, including advanced data management, parallel approaches, novel methods for feature rendering, and,
above all, interaction techniques which allow for an intuitive exploration of complex, transient phenomena in 3-D space.

Since recently, our research is also focusing on VR-based simulators in medicine. In contrast to other research groups mainly working on simulators for minimal invasive surgery, we are concentrating more on open surgery procedures. The challenge here is to realistically simulate deformable objects in real time including haptic stimuli. Other interesting research activities are related to an already long-standing collaboration with (neuro-) psychologists, who are using VR-based experimental setups for brain research. Lust but not least, thanks to an excellent collaboration with the Institute of Technical Acoustics, Professor Vorländer, we claim to have one of the most sophisticated VR audio rendering systems ever developed.

Our teaching curriculum comprises a Virtual Reality lecture always held in winter term, as well as a seminar on advanced VR topics and a practical course on VR in summer term. We are also engaged in the organization of the Virtual Reality Center Aachen (VRCA), which is an interdisciplinary non-profit network founded by Christian Bischof and Torsten Kuhlen in 2000 in order to further bundle and expand the VR activities at RWTH and the region of Aachen. Today, more than 40 RWTH Professors and 15 companies as well as external research institutions are organized in the VRCA, carrying out more than 50 research projects. On the national level, Torsten Kuhlen is the co-speaker of the “Fachgruppe Virtual & Augmented Reality” as a sub-organization of the “Gesellschaft für Informatik”. The goal of this section is to bundle the expertise of the various German-speaking research groups in academia as well as industry.
Research Projects

Integrative Simulation Platform and Explorative Multiple Dataset Analysis in the Cluster of Excellence “Integrative Production Technology for High-Wage Countries”

T. Beer, S. Gebhardt, T. Kuhlen

In the “Cluster of Excellence: Integrative Production Technology for High-Wage Countries” we are developing a flexible platform to enable linked, distributed simulations of entire production processes and appropriate multiple dataset visualization tools to analyze results from those. Our goal is to provide the technological means and methods required to:

• Facilitate automated data exchange and transfer of results from one simulation to another.
• Integrate a data translation unit that is powerful enough to convey all the necessary information, incorporating the heterogeneous data semantics between tools.
• 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.
• Gain further insight and understanding of the process as a whole using leading edge Virtual Reality technology to post-process and visualize the computed results of all simulations involved in the same production process.

To overcome syntactic and semantic differences between data formats employed in the simulation programs, we introduce a data integration component, capable of handling all sorts of data types and field attributes that occur, incorporating tool-specific semantics. Thus the integration component is capable of translating between different formats automatically. 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 process 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. At the same time, tools that allow for interactive navigation in both, temporal and spatial dimensions have to be integrated to facilitate a flexible visual analysis process.
This research project, which until recently has been funded by the DFG, is focusing on the simulation of regional anaesthesia in virtual environments (http://www.rasim.info). It is an interdisciplinary collaboration with anaesthetists (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.

Current activities are related to the development of an ultrasound (US) image simulation component to enable the training of US guided regional anesthesia procedures. The goal is to generate detailed and realistic images using surface representations of the body anatomy as input data. As the user interacts with the virtual patient using haptic devices, i.e. inserting the needle into the soft tissue and injecting anesthesia, the anatomy models should deform accordingly to provide accurate visual and haptic feedback to the trainee at interactive frame rates. Physics-based models are used to estimate the behavior and characteristics of the ultrasound beam within the human body and to recreate the different artifacts that can be normally appreciated in B-Mode US images, e.g., attenuation, reflections, acoustic shadows and enhancement.

This DFG-funded research project is focusing on the development of a virtual reality (VR)-based training simulator for a major maxillofacial surgery procedure. It is an interdisciplinary collaboration of dentists, numerical simulation experts, and computer scientists from the RWTH Aachen University and the University Hospital Aachen. The medical procedure in focus, the bilateral sagittal split osteotomy, permits the relocation of the mandible to correct malpositions like over- or underbite. During the intervention a predetermined breaking point is created on the lower mandible with a bone saw or burr. Chisels are then inserted into the prepared line, which is then carefully broadened by twisting the tools. In cases where complications occur during the division, the mandible and a contained neurovascular bundle could be damaged beyond repair. The developed interactive simulator will provide a training tool to learn the basic manual skills but also to rehearse difficult scenarios.

An important goal of the simulator is the training of specific motor skills. Therefore, one requisite to the system is the reproduction of the real interaction with a high degree of realism. For this purpose we utilize a haptic input/output device enabling the surgeon to put pressure on the virtual jaw, feeling its resistance and deformation. The latter is simulated via an...
extended finite element method (XFEM), which also allows the effective simulation of breaking bone and the handling of the induced structural changes. Mandible material parameters are determined experimentally and function, together with anatomical models extracted from cone beam CT-Scans, as foundation for the physical simulation.

Figure: The interaction in the BSSO Simulator includes 6-DOF haptic feedback.

VATSS - Virtual Air Traffic System Simulation
S. Pick, T. Kuhlen

VATSS is an interdisciplinary research project in cooperation with different institutes of the RWTH Aachen including the Institute of Aeronautics and Astronautics (ILR), the Institute of Technical Acoustics (ITA), the Department of Geography (GEO) and the Chair of Air Transport and Airport Research (VIA). It is funded as an Exploratory Research Space (ERS) Boost Fund Project. The goal of the project is to simulate the different aspects of air traffic and integrate these simulations into an immersive virtual environment that aids the exploration of the effects of air traffic.

As the amount of air traffic continually increases, it becomes necessary to expand airport infrastructures and develop new, more efficient air traffic concepts. These steps involve the analysis of ecological, economical, and social factors which lead to decision-making processes in various areas related to aviation, e.g. airport planning, creation of flight schedules and routes, research & development of new aircrafts and landing procedures, and the communication with local residents (non-experts). With this project, we try to provide assistance in these decision-making processes.

Currently, we are creating a realistic model of the environment around airports, which includes the simulation of the weather condition. Based on this environmental model, several
simulations are developed which accurately reflect different aspects of air traffic, like the movement of aircrafts and their ground noise impact. The results of these simulations are then integrated into an immersive virtual environment that allows experts as well as laymen to explore the effects of air traffic. To allow for an intuitive understanding of aircraft noise, one subtask deals with the development of an approach to accurately synthesize aircraft noise in real-time to provide a realistic, audible signal within the virtual environment. At the same time we implement visualization techniques that allow a precise access to indicators like the ground noise impact. The creation of intuitive interaction techniques for navigation, system control and data annotation is the focus of another subtask.

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

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.
Interactive Visualization of Uncertainty in Probabilistic Tractography

T. Rick, A. von Kapri, T. Kuhlen

In this JARA activity conducted in collaboration with the neuroscientists Prof. Amunts, Prof. Diesmann and Prof. Zilles, we work on interactive visualization of uncertainty information in probabilistic fiber pathways of the living human brain as measured by diffusion tensor imaging (DTI). Probabilistic tractography calculates a local probability distribution of the diffusion direction for each voxel, resulting in voxels with a large number of passed traces to voxels with only a low number of passes. By accounting for the uncertainty, the method of probabilistic tractography allows to draw a clearer picture of the overall fiber architecture within the human brain.

We propose a customized direct volume rendering method through which the probabilities of fiber tracts are conveyed by colors and opacities. By rendering multiple scalar-valued data sets simultaneously we are able to visualize sections where multiple fiber tracts intersect, which is an important methodological issue in DTI tractography (crossing fibers).

Figure: Multi-modal brain visualization displaying brain’s white matter, brain areas, a probabilistic fiber tract and the corresponding seed region. White matter and brain areas are clipped by a magic lens to reveal the fiber tract inside.
Interactive Data Visualization in 3D Electromagnetics
A. Hamacher, D. Bündgens, T. Kuhlen

The interactive exploration of complex simulation data have spurred a renewed interest in visualization techniques, because of their ability to give an intuitively clue for the interpretation of electromagnetic phenomena. In this JARA Seed Fund project, which we are conducting in collaboration with the IEM (Institut für Elektrische Maschinen), a methodology for a bidirectional coupling of VTK-based visualization systems to interactive and immersive visualization systems which are specially adopted for the handling and processing of large and transient simulation data should be established. In this work, the coupling is demonstrated by the flexible Virtual Reality (VR) software framework ViSTA, which is developed by the Virtual Reality Group, and the electromagnetic visualization tool Trinity developed by IEM.

Interactive Analysis of Graph-Theoretically Optimized Crystal Structures
S. Selzer, D. Bündgens, T. Kuhlen

In this Seed Fund project, a software is being developed in cooperation of the VR Group and the chemical and mathematical institutes of the RWTH Aachen University with the goal to interactively analyze static crystal structures on an atomic level in a virtual environment. This software offers basic support of the PDB format and the visualization of and the interaction with molecular structures by means of space-filling calotte models.
Other Activities

As part of the Center for Computing & Communication, the VR Group is hosting and continuously upgrading a high end Virtual Reality and visualization infrastructure, consisting of immersive displays and 3D interaction devices. Typically, we give more than 100 presentations per year in our VR lab for visitors from within RWTH as well as for delegations from industry and research institutions from all over the world.

With the excellence initiative, VR systems are going to be installed not only in the Center for Computing & Communication, but also at multiple RWTH facilities. For instance, the VR Group is supporting the Graduate School AICES with the installation of a large high-resolution wall, providing a stereo projection of about 4096x2048 pixels. Together with JSC Jülich, we have recently established a Cross Sectional Group on Immersive Visualization as a structural and methodical measure under JARA with the goal to integrate advanced visualization and exploration methods into the scientists’ daily work. To achieve this goal, high end 3D workplaces which fit into an office environment, are connected via Grid technology to each other and also to remote, parallel file servers and post-processing servers. Such an infrastructure will allow for an intuitive and collaborative exploration of even very complex phenomena between researchers in Aachen and Jülich.

In a lot of smaller cooperations with RWTH institutes and industry, we provided methodical support, helping our partners to visualize their data by means of state-of-the-art methods and beyond. For this purpose, we have been developing the software framework ViSTA (Virtual Reality for Scientific and Technical Applications) for more than ten years now. ViSTA is based on Open Source standards and is freely available to our research partners.

Torsten Kuhlen is the speaker of the Virtual Reality Center Aachen (see www.vrca.rwth-aachen.de) and in addition the co-speaker of the “Fachgruppe Virtual & Augmented Reality” within the “Gesellschaft für Informatik”. He is a member in the program committees of several national and international conferences like the IEEE VR. This year, he organized the 2011 Eurographics Symposium on Parallel Graphics and Visualization.

Bernd Hentschel co-organized a tutorial on large vector field visualization methods given at IEEE VisWeek 2010, together with Xavier Tricoche (Purdue University), Christoph Garth (UC Davis), Hank Childs (Lawrence Berkeley National Laboratory), and Markus Rütten (DLR). He spoke on the topic of flow visualization in biomedicine, where he particularly stressed the importance of shared-memory, parallel particle tracing methods.
Talks and Publications

Talks

B. Hentschel: *Flow Visualization in Biomedicine*. IEEE VisWeek Tutorial on Large Vector-Field Visualization, Salt Lake City, USA, October 2010.


S. Ullrich: *Bimanual Interaction for Medical Virtual Environments*. Poster presentation, Virtual Reality Interaction and Physical Simulation (VriPhys), Copenhagen, Denmark, November 2010.

S. Ullrich: *Dissecting in Silico: Towards a Taxonomy for Medical Simulators*. Poster presentation, Medicine Meets Virtual Reality (MMVR), Newport Beach, CA USA, February 2011.


**Publications**


**Demonstrations and Exhibitions**

*Visualization of an Extrusion Process*, RWTH Transparent, Aachen, Germany, January 2011

*Bimanual Haptic Interaction with Palpation and Needle Intervention*. Medicine Meets Virtual Reality (MMVR), Newport Beach, CA USA, February 2011.

*Interactive Visualization of a Biomedical Laboratory*, in cooperation with: Formitas GmbH and AutoDesk, ISH Messe, Frankfurt, Germany, March 2011.

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Interactive Visualization of Uncertainty in Probabilistic Tractography, JARA Forum, Berlin, Germany, March 2011.

Interactive Data Visualization in 3D Electromagnetics, Interactive Visualization of Uncertainty in Probabilistic Tractography, Hannover Messe, Hannover, Germany, April 2011.

Interactive Visualization of Uncertainty in Probabilistic Tractography, International Supercomputing Conference (ISC), Hamburg, Germany, June 2011.

Interactive Visualization of Uncertainty in Probabilistic Tractography, 25th Umbrella Symposium, Aachen, Germany, June 2011.

Visualization of an Artificial Blood Pump, 25th Umbrella Symposium, Aachen, Germany, June 2011.

Visualization of an Extrusion Process, Wissenschaftsdialog Rheinland, Aachen, Germany, July 2011

IT-Security

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  Jiang Wang
  Georg Wicherski

• Guests
  Dr.-Ing. Andriy Panchenko
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”. In 2011 the Research Group grew from three research assistants to seven research assistants. In the reporting period twelve student researchers worked on the various projects of the group. 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 management solutions for wireless mesh networks. These solutions include authentication, authorization, and accounting support, as well as efficient key handling and re-authentication.

In the area of privacy, we work on privacy-preserving distributed multi-party applications for desktops as well as mobile platforms. This field of research is based on secure multi-party computation, a highly active research direction in cryptography. Our focus is on designing and implementing practical applications.

Another main field of our research is the detection, collection, and analysis of (mobile) malware and in particular botnet protection. Here, we develop client and server honeypots, design behavior based malware detection for mobile devices and analyze the protection mechanisms of current mobile platforms. Some of this work is conducted as part of the BMBF-funded research project ASMONIA on which we work together with our partners Nokia Siemens Networks, Fraunhofer Institut für sichere Kommunikationstechnologie, EADS Deutschland GmbH, ERNW GmbH, and Augsburg University of Applied Science. In addition, we maintain strong connections to both industry and law enforcement in this area of research and work on several industry-funded projects.

With respect to teaching, the group offers a one-year cycle of four lectures, a seminar, and a laboratory course. This cycle was developed from scratch in 2008/2009. During winter terms we typically offer the lectures IT-Security 1 and Security in Mobile Communications. IT-Security 1 provides an introduction to cryptography and focuses on network security, while Security in Mobile Communications covers the security architectures of attacks against already standardized wireless technologies such as mobile phone networks, wireless local area networks, or Bluetooth. In addition, we offer a seminar on selected topics in mobile security during winter terms. In the summer we offer the lectures IT-Security 2, which focuses on system security and a lecture on Security and Cooperation in Wireless Networks, which covers new developments in wireless technologies such as sensor networks or vehicular networks. Also, in summer terms we offer a security lab in which students learn how to deal with practical attacks against wireless as well as wired networks and systems.
Research Projects

ASMONIA
Andre Egners and Marian Kuehnel
Nokia Siemens Networks, Fraunhofer Institut für sichere Kommunikationstechnologie, Cassidian Systems, ERNW GmbH, and Augsburg University of Applied Science.
Funded by BMBF.

ASMONIA stands for *Attack analysis and Security concepts for MOBILE Network infrastructures, supported by collaborative Information exchange* and is a projected funded by the German Federal Ministry of Education and Research. ASMONIA aims to improve the resilience and reliability of current and future mobile networks and their backbone infrastructure.

PreFairAppl [preferable] - Private and Fair Applications
Georg Neugebauer, Florian Weingarten
Prof. Dr. Susanne Wetzel, Daniel Maier
Funded by DFG and NSF.

PreFairAppl (Private and Fair Applications) is a joint project with the research group of Prof. Susanne Wetzel at the Stevens Institute of Technology, Hoboken, New Jersey. The main focus of the project is the development of fair applications which preserve the privacy of the users. In this context, privacy-preserving refers to the fact that the users' inputs remain private while using the application. The concept of fairness ensures that the computations are performed in a way that recognizes the users' individual preferences on their inputs.

Bootstrapping Security Associations for the Internet of Things
Johannes Gilger
Funded by Siemens AG.

On the Internet of Things more and more devices without the usual human interfaces like keyboard and monitor are going to be connected to the Internet. Examples of such devices are video cameras, sensors or small sensor networks, or metering devices. These devices have in
common that they collect information by sensing their environment. This (potentially private) information needs to be securely provided over the Internet to authorized entities. In the simplest case, these entities are a priori known to the devices and operated by the same operator. However, in many scenarios such as surveillance in public places, remote health care, traffic monitoring, or disaster recovery, different entities may have to be granted access to the collected data or data may have to be shared on a tit-for-tat basis between different operators.

**Botnet Detection and Mitigation in Mobile Networks**

*Mark Schlösser*

Funded by Nokia Siemens Networks.

The threat that malware imposes on computer networks has grown in the past years and is on the move to mobile networks as well. A big portion of malware samples includes "botnet" functionality and can thus be controlled by its author. Within our research we try to improve current and develop new methods of acquiring and analysing malware. From the malware samples we extract command and control information and are thus able to monitor the botnet's activity.

**Accountable WLAN Roaming**

*Johannes Barnickel*

Runded by UMIC Research Centre.

In this project we develop a novel protocol suite for roaming WLAN devices. It supports authentication, key agreement, and secure payment between roaming devices and network operators. This is achieved with the help of an integrated tick payment scheme. Our protocol suite allows operators to quickly change tariffs depending on current demand and allows users to choose between different operators and select from different tariff options on a per-connection basis. In addition, our protocol suite offers a very high degree of privacy protection by revealing only strictly required information to the participating parties.
In contrast to infrastructure wireless networking, wireless mesh networks employ multi-hop communication. This fact and the different use cases of multi and single provider setup impose new security challenges. Keeping the dynamic nature of these networks in mind, bootstrapping security associations onto the nodes, as well as detection and mitigating malicious behavior is the current focus of our study.
Other Activities

On September 30th the research group IT Security organized the rwthCTF, a capture-the-flag-style tournament for participants from all around the world. CTFs realistically mirror the demands and tasks faced by IT security professionals every day. In the rwthCTF over 50 participating teams were supplied with a Linux virtual computer image and network connectivity through a virtual private network (VPN), so they could directly reach other teams. The Linux image given to the teams contained five services, implemented in a variety of programming languages. The common ground for these services was the central gameserver, which would connect to each service, store a piece of unique information (the flag) and retrieve it at a later time. Defending these services and the flags stored within them while at the same time attacking other teams was only part of the challenge though. The money earned for offensive and defensive maneuvers would not matter for the final ranking, but could be used to buy access to a challenge network which would culminate in physical control over a small robot which had to be steered through amaze and crashed into a self-destruct button. The challenge network consisted of multiple stages which required either advanced binary exploitation skills or a solid understanding of cryptography. 

http://ctf.itsec.rwth-aachen.de/

Courses

Winter semester 2010/11

• IT-Security 1 – Network Security
• Data Communications and Internet Technology
• Seminar – Selected Topics in (Mobile) Security

Summer semester 2011

• IT-Security 2 – System Security (held by Dr. Andriy Panchenko during the maternity leave of Prof. Meyer
• Security Lab – The practical hacking lab held every summer term.

Ulrike Meyer’s scientific activities

Prof. Meyer served as member of the program committee for the following conferences

• IEEE LCN 2011 IEEE Conference on Local Computer Networks (LCN)
• iNetSec 2011 Open Problems in Network Security, Workshop colocated with IFIP SEC 2011
• IEEE SICK 2010 LCN Workshop on Security in Communication Networks
• ACM SAC 2010 ACM Symposium on Applied Computing, Track on Information Security Research and Applications
• ISSE 2010 Sicherheit Schutz und Zuverlässigkeit, held in conjunction with SICHERHEIT 2010
• CAT2010 Context Awareness and Trust 2010, held in conjunction with CENTRIC 2010
Talks and Publications

Talks

All of the publications listed below were presented in form of a talk at the respective conference or workshop.

Publications

A. Panchenko, O. Spaniol, A. Egners, T. Engel: Lightweight Hidden Services, 10th IEEE Conference on Trust, Security and Privacy in Computing and Communications (TrustCom), Changsha, November 2011


UMIC Mobile Network Performance Group

Staff

• Faculty
  Prof. Dr. James Gross

• Research Assistants
  Dipl.-Ing. Christian Dombrowski
  Yulin Hu M.Sc.
  Dipl.-Inform. Georg Kunz
  Di Li M.Sc.
  Donald Parruca, M.Sc.
  Dipl.-Ing. Oscar Puñal
  Dipl.-Inform. Marco Weyres
Overview

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

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

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

Our team consists currently of seven PhD students (Oscar Puñal, Christian Dombrowski, Donald Parruca, Di Li, Georg Kunz, Yulin Hu, Marco Weyres), 5 student research assistants and four diploma/master thesis candidates.

Highlights of this year comprise:

- A newly established DFG project presented below.
- Two more PhD students which joined our group.
- The establishment of a lab with FPGA-based prototyping systems for experimental wireless networking research.
- Simon Tenbusch, a student researcher of our group, was awarded the prestigious Schöneborn-Price of RWTH Aachen University for his exceptional bachelor degree.
- A two week trip to China of Prof. Gross following an invitation to Nanjing University and Hefei University of Technology.
Research Projects

Schedulability of Cognitive OFDMA Networks
Funded by DFG

Cognitive radio is a technical concept that enables the reuse of spectrum. In its most flexible flavor called opportunistic spectrum access, so called secondary systems determine autonomously to reuse the spectrum of primary systems based on sensing. However, the sensing process is subject to detection errors which can lead to interference between primary and secondary systems. This project aims at investigating the impact of this interference on the schedulability of primary and secondary OFDMA systems. Schedulability of these systems will be evaluated by the so called effective capacity which accounts for the quality-of-service(QoS)-constrained flow capacity of communication systems. The major difficulty with obtaining the effective capacity is related to mathematically accounting for channel dependent OFDMA resource allocation under the impact of imperfect sensing. For primary systems imperfect sensing leads to a fraction of the spectrum being interfered by secondary systems. It is not known today how to account under these circumstances for the effective capacity. Furthermore, for the secondary system even under perfect sensing we do not have mathematical models that yield the effective capacity. Once obtained, these models can be used for example for pricing spectrum reuse.

Ultra-robust Wireless Transmission

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

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

That is why we follow an integrated cross-layer approach. Our intention is, on the one hand, to gain insights into theoretical boundaries of reliability over wireless channels, and on the other hand, to develop algorithms which base on these theoretical boundaries and their implications. The next - and most important - step is to realize these algorithms in a practical system, and see how the reliability can be improved under real world conditions.
The Wireless-OpenAccess-Research Platform developed at Rice University, Houston - TX/USA, serves as the basis for our implementations. We have already developed a medium access protocol using a token passing scheme to achieve a decentralized deterministic medium access. This protocol supports differentiated traffic classes, and is flexible and failure tolerant.

UMIC Simulation Framework

In cooperation with Georg Kunz and Klaus Wehrle

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

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

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

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

Talks


J. Gross, “Hard Real-Time Communications over Wireless Networks?”, Nanjing University, Nanjing, China, April 2011. (Eingeladener Vortrag)

J. Gross, “Hard Real-Time Communications over Wireless Networks?”, Hefei University of Technology, Hefei, China, April 2011. (Eingeladener Vortrag)


Publications


O. Puñal und J. Gross, " Combined Subcarrier Switch Off and Power Loading for 80 MHz Bandwidth WLANs", In Proc. of the 18th IEEE International Workshop on Local and Metropolitan Area Networks, Chapel Hill, USA (akzeptierte Publikation).


Parallel Programming

Staff

• Faculty
   Prof. Dr. Felix Wolf

• Team Assistant
   Sabine Blumensath

• Scientific Staff
   David Böhme
   Alexandru Calotoiu
   Marc-André Hermanns
   Zhen Li
   Monika Lücke
   Suraj Prabhakaran
   Sebastian Rinke
   Aamer Shah
   Christian Siebert
   Zoltán Szebenyi

• Student Assistants / Researchers
   Max Görtz
   Youssef Hatem
   Mohsin Iqbal
   Yordan Madzhunkov
   Marius Poke
   Christopher Schleiden
   Felix Voigtländer

• Staff of the Associated Young Investigators Group in Jülich
   Dominic Eschweiler
   Dr. Markus Geimer
   Dr. Daniel Lorenz
   Christian Rössel
   Dr. Pavel Saviankou
   Dr. Alexandre Strube
   Dr. Brian Wylie
Overview

Anchored at the German Research School for Simulation Sciences in Aachen and with part of the staff located at the Jülich Supercomputing Centre as members of a Helmholtz young investigators group, the objective of the Laboratory for Parallel Programming is to develop tools that support simulation scientists in exploiting parallelism at massive scales.

Driven by the increasing demand for computing power and accelerated by current trends in microprocessor design, the number of processor cores on modern supercomputers is growing from generation to generation, posing scalability challenges not only for applications but also for the software environment needed for their development. Our group therefore creates solutions that support simulation scientists in exploiting parallelism at massive scales. We specialize in scalable programming tools, parallel I/O libraries, algorithms for load balancing, and middleware for heterogeneous clusters. One of our key projects is Scalasca, a performance analysis tool for large-scale parallel applications, which we jointly develop with the Jülich Supercomputing Centre. Moreover, as a complement to our research activities, we teach the skills required to write correct and efficient parallel programs in science and engineering. Students are introduced to this domain with the goal of subsequently applying their knowledge in a variety of simulation projects or even of contributing to the software tools we develop ourselves.
Research Activities

Scalable Performance Analysis of Large-Scale Parallel Applications (Scalasca)

In cooperation with the Jülich Supercomputing Centre.

Scalasca is a free software tool that supports the performance optimization of parallel programs by measuring and analyzing their runtime behavior. The tool has been specifically designed for use on large-scale systems including IBM Blue Gene and Cray XT, but is also well suited for small- and medium-scale HPC platforms. The analysis identifies potential performance bottlenecks – in particular those concerning communication and synchronization – and offers guidance in exploring their causes. Scalasca mainly targets scientific and engineering applications based on the programming interfaces MPI and OpenMP, including hybrid applications based on a combination of the two. The user of Scalasca can choose between two different analysis modes: (i) performance overview on the call-path level via profiling and (ii) in-depth study of application behavior via event tracing. A distinctive feature of Scalasca is its ability to identify wait states that occur, for example, as a result of load imbalance – even at very large scales. 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. The software has been installed at numerous sites in the world and has been successfully used to optimize academic and industrial simulation codes.

During the reporting period, the scalability of Scalasca was further increased after introducing a new scheme for recording MPI communicators. Moreover, we completed the design of a more scalable file format for the representation of analysis results. Optimized GUI response times will support the analysis of larger data sets. Furthermore, we developed a configurable binary instrumenter that minimizes instrumentation overhead through prior static analysis. A measurement control API allows tracing to be restricted to selected execution intervals only, a feature that is especially useful for long-running applications, where tracing the full execution would produce prohibitively large trace files. Finally, we demonstrated how to detect wait states due to lack of remote progress in programs that use the ARMCI one-sided communication library. Further Scalasca-related research is described along with specific projects. Besides purely technical advancements, Scalasca was also presented to supercomputer users during local and external hands-on workshops/tutorials.
The time-dependent behavior of parallel simulation codes – in particular when adaptive algorithms are employed – is often irregular, making the understanding of performance dynamics an essential prerequisite for program optimization. While existing performance analysis tools typically provide detailed information along spatial dimensions like processes and nodes, performance dynamics has so far been a neglected aspect. To better support developers in optimizing their parallel simulation codes, the LMAC project therefore aims to extend the established performance analysis tools Vampir, Scalasca, and Periscope with new functionality to automatically examine performance dynamics. In addition, the University of Oregon, associated partner, complements the project with corresponding extensions to the performance tool TAU.

The objective of the G8 ECS project is to investigate how to run climate simulations efficiently on future Exascale systems. It focuses on three main topics: (i) how to complete simulations with correct results despite frequent system failures, (ii) how to exploit heterogeneous computers with hardware accelerators close to their peak performance and (iii) how to run efficient simulations with 1 billion threads. This project also aims at educating new generations of climate and computer scientists about techniques for high-performance computing at extreme scale.
Holistic Performance System Analysis (HOPSA)

In cooperation with Forschungszentrum Jülich, Barcelona Supercomputing Center (Spain), Rogue Wave Software AB (Sweden), TU Dresden, Moscow State University (Russia), T-Platforms (Russia), Russian Academy of Sciences (Russia), and Southern Federal University (Russia).

Funded by the EU and the Ministry of Education and Research of the Russian Federation.

The EU project HOPSA in the framework of the EU-Russia Coordinated Call sets out to create an integrated diagnostic infrastructure for combined application and system tuning – with the former being under EU and the latter being under Russian responsibility. Starting from system-wide basic performance screening of individual jobs, an automated workflow will route findings on potential bottlenecks either to application developers or system administrators with recommendations on how to identify their root cause using more powerful diagnostic tools.

Scalable Data Exchange Interface for Fast Parallel I/O (SCIPIO)

In cooperation with the Jülich Supercomputing Centre.

Funded by the Jülich-Aachen Research Alliance.

The EFDA Task Force ITM (Integrated Tokamak Modelling) aims at creating a global modelling framework for the International Thermonuclear Experimental Reactor (ITER) currently under construction in Cadarache (France). For this purpose, various codes used to model key physical processes within the core plasma and its interaction with the vessel walls will be coupled together via the KEPLER workflow system. Although many of these codes are already parallelized, the data exchange mechanism between them works only in a serial way, such that the participating processes of one code first have to gather their simulation data and transfer it serially to the next code. This can lead to serious performance bottlenecks at the interface between the codes. To optimize the data transfer between the models, we developed a parallel I/O interface which is expected to significantly improve the performance between interacting codes and eliminate the bottlenecks caused by serial I/O.
Performance Refactoring of Instrumentation, Measurement, and Analysis Technologies for Petascale Computing (PRIMA)

In cooperation with the University of Oregon (USA).
Funded by the US Department of Energy.

This project pursues the goal of reengineering core components of the two performance-analysis systems TAU, developed by the University of Oregon, and Scalasca, developed locally, for evolution to petascale and beyond. Building on a long history of interaction between the two projects, the two key activities are 1) refactoring certain TAU and Scalasca components for core code sharing, and 2) integrating their functionality more effectively through data interfaces, formats, and utilities. The project is carried out in close cooperation with the SILC project described below.

Scalable Infrastructure for the Automated Performance Analysis of Parallel Codes (SILC)

In cooperation with the Gesellschaft für numerische Simulation mbH, RWTH Aachen University (Center for Computing and Communication), TU Dresden, TU Munich, GWT-TUD GmbH, and University of Oregon (USA).
Funded by the BMBF.

Emerged from the Virtual Institute – High Productivity Supercomputing, the goal of the SILC project is the design and implementation of a scalable and easy-to-use performance measurement and monitoring infrastructure for supercomputing applications. The infrastructure will serve as a common basis for the performance-analysis tools Scalasca, Periscope, Vampir, and TAU. The latter three are developed by research groups in Munich, Dresden, and Eugene (OR, USA), respectively. In addition to increasing their scalability, making the four tools rest on this joint basis will allow them to interoperate more easily and simplify their installation. The enhanced tool suite will be used to tune the performance of academic and industrial simulation programs especially from the Gauss Alliance, preparing them for the new exa-scale era. A beta release of the software was recently published and presented during a Birds of a Feather (BoF) session at the ACM/IEEE Conference on Supercomputing (SC11) in Seattle, USA.
Aachen Institute for Advanced Study in Computational Engineering Science (AICES)

Funded by the 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 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, an algorithm for the semantic compression of time-series call-path profiles was modified to work also with a recently developed statistical measurement technique that usually causes lower runtime overhead. The other project investigates load and communication imbalance in parallel codes. Combining knowledge of the critical path with traditional parallel profiles, a set of compact performance indicators was defined that help answer a variety of important performance-analysis questions, such as identifying load imbalance, quantifying the impact of imbalance on runtime, and characterizing resource consumption. By replaying event traces in parallel, it is possible to calculate these performance indicators in a highly scalable way, making them a suitable analysis instrument for massively parallel programs with tens of thousands of processes.

Virtual Institute – High Productivity Supercomputing (VI-HPS)

In cooperation with Forschungszentrum Jülich, RWTH Aachen University (Center for Computing and Communication), TU Dresden, TU Munich, University of Oregon (USA), University of Stuttgart, and University of Tennessee (USA).

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. 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 Stuttgart and Aachen. In addition, tutorials with and without hands-on exercises were held at various spring and summer schools and at the ACM/IEEE Conference on Supercomputing (SC11) in Seattle, USA. Finally, the virtual institute organized the 4th Workshop on Productivity and Performance (PROPER) in conjunction with the Euro-Par Conference 2011, which was held in Bordeaux, France.
Other Activities

University Courses

• Parallel Programming II (SS 2011)
• Parallel Programming I (WS 2011/2012)
• SiSc Lab (WS 2011/2012)
• Software Engineering for Computational Engineering Science (WS 2011/2012)
• Seminar Parallel Programming (WS 2011/2012)

Workshop (Co)-organization

4th Workshop on Productivity and Performance (PROPER 2011) held in conjunction with the EuroPar 2011 Conference, Bordeaux, France, August 2011.

Workshop on Large-Scale Computer Simulation (jointly organized with Oak Ridge National Laboratory and the University of Tennessee), Aachen, March, 2011.

Tutorials and Short Courses


B. Wylie: Performance analysis tools for massively parallel applications. PRACE Summer School on Taking the most out of supercomputers, CSC, Espoo, Finland, Sept 1, 2011.


M. Geimer: Various HPC programming tools including hands-on exercises presented as part of LinkSCEEM-2 Training Workshop, CaStoRC, The Cyprus Institute, Nicosia, Cyprus, January 27, 2011.

Talks and Publications

Talks


C. Rössel, A. Knüpfer: Score-P - A Joint Performance Measurement Run-time Infrastructure for Periscope, Scalasca, TAU, and Vampir, 5th Parallel Tools Workshop, Dresden, Germany, September 26, 2011


J. Mußler, D. Lorenz, F. Wolf: Reducing the overhead of direct application instrumentation using prior static analysis, Exascale Computing Research Center at the University of Versailles, France, September 6, 2011.


F. Wolf: Recent Scalasca Research, DoE CScADS Workshop, Tahoe City, California, August 2, 2011.


D. Böhme: Supercomputers today and tomorrow, Alumni Cluster Workshop, University of Potsdam, Potsdam, Germany, July 11, 2011.

F. Wolf: Time – An Often Neglected Scalability Dimension of Parallel Performance Analysis, Exascale Computing Research Center at the University of Versailles, France, July 1, 2011.


D. Böhme: Identifying the root causes of wait states in massively parallel applications, 1st AICS International Symposium, RIKEN AICS, Kobe, Japan, March 11, 2011.


D. Böhme: Performance Analysis of Parallel Programs - An Introduction to the Scalasca Toolset, University of Potsdam, Potsdam, Germany, January 13, 2011.

Publications


Advanced Studies in Computational Engineering Science

Staff

- **Faculty**
  Prof. Paolo Bientinesi, PhD

- **Postdoctoral associate**
  Edoardo Di Napoli, Ph.D.

- **Team**
  Matthias Petschow
  Roman Iakymchuk
  Diego Fabregat
  Elmar Peise
Overview

Paolo Bientinesi was appointed as Junior Professor in ‘Algorithm & Code Generation for High-Performance Architectures’ in 2008. Within the Aachen Institute for Advanced Studies in Computational Engineering Science (AICES), Bientinesi is Young Research Leader—leading the group on ‘High-Performance and Automatic Computations’ (HPAC) – member of the steering committee, as well as deputy scientific director.

In November 2010, Bientinesi received funding from the Deutscher Akademischer Austauschdiesnt (DAAD, German Academic Exchange Service) for the research project ‘Wave-packet Representation in Seismic Data Processing and Imaging’, in collaboration with Dr. Anton Duchkov from the Russian Academy of Science. In the summer 2011, Bientinesi successfully underwent the three-year evaluation and his W1 position was confirmed.

Ongoing collaborations

• Prof. Enrique Quintana-Ortí, Universidad Jaume I.
  Eigensolvers for Multi-core and Many-core Architectures.

• Jack Poulson, University of Texas.
  Generalized Eigensolvers for Distributed and Hybrid Architectures.

• Prof. Stefan Blügel, Forschungszentrum Jülich.
  High-Performance Density Functional Theory.

• Prof. Yuriii Aulchenko, University Medical Center Rotterdam.
  Fast Computation of Mixed Models.

• Dr. Victor Eijkhout, Texas Advanced Computing Center.
  Automatic Generation of Krylov Solvers.

• Dr. Anton Duchkov, Russian Academy of Science.
  Parallel Strategies for Wave-packet Representation.

• Prof. Bruno Lang, Bergische Universität Wuppertal.
  The FEAST Eigensolver.

• Prof. Gregorio Quintana-Ortí, Universidad Jaume I.
  High-performance Tensor Operations.

• Martin Bücker, RWTH Aachen.
  Generation of Algorithms for Automatic Differentiation.
Research

Automation

In a sequence of papers, we set the ground for the development of a symbolic system that, from the sole description of a target linear algebra operation, generates algorithms automatically. The core of our methodology stands in the concept of Partitioned Matrix Expression (PME). A PME encapsulates the information about the target operation in a way that facilitates the subsequent identification of loop invariants. The loop invariants then lead to the final algorithms through a technique based on program correctness. We introduced a symbolic system, Cl1ck, that automates the generation of PMEs and loop invariants. In order to generate PMEs, Cl1ck first identifies how the operands in the operation may be partitioned. Instead of a brute force approach of exponential complexity, Cl1ck utilizes a tree-based algorithm that yields only the viable sets of partitioning rules. Through a process of pattern matching, each such set leads to a distinct PME. The key in the PME generation is Cl1ck's ability to identify known patterns. Initially, Cl1ck only recognizes elementary structures, but its knowledge expands by automatically learning the patterns associated with the operations it tackles. Thanks to this augmenting internal knowledge, the system may generate PMEs for increasingly complex operations. In order to obtain loop-invariants, Cl1ck first breaks down the operations specified in the PME into a list of basic computational tasks. To this end, Cl1ck analyzes the structure of the expressions that appear in the PMEs; this step involves an extensive use of pattern matching. In a second step, the resulting tasks are then inspected and a graph of dependencies is built. Both these steps heavily rely on the pattern matching capabilities of Mathematica. Finally, the system traverses the dependency graph, selecting the feasible loop-invariants. For a large set of linear algebra operations, our automatic system discovers all the known algorithms, unifying them under a common root; besides, it discovers previously unknown algorithms.

Performance Modelling

We aim at modelling the performance of a linear algebra algorithm without executing either the algorithm or any parts of it. In general, the performance of an algorithm can be expressed in terms of the time spent on CPU execution and on the time spent on memory-stalls. Our main concern is to build analytical models to accurately predict memory-stalls. As a first step, we considered the scenario in which the input data resides in the L2 cache and proposed an analytical model solely based on detailed knowledge of the target algorithm, the CPU, and the memory hierarchy. As test beds, we considered fundamental linear algebra operations like those included in the BLAS library, and verified the model on different architectures, tailored the basic formula for different processor types and memory systems. In all cases, our model resulted extremely accurate, with deviations normally lower than 2%.

Parallel Eigensolvers

Concluding a 2-year project, we released two libraries for the solution of tridiagonal eigenproblems on shared memory and distributed architectures. We introduced MR3-SMP – an eigensolver specifically designed for multi-core and many-core architectures – and PMRRR – which fully supports pure message-passing, pure multithreaded, and hybrid executions. MR3-SMP breaks the computation into tasks to be executed in parallel by multiple threads. The tasks are both created and scheduled dynamically. While a static division of work would introduce smaller overheads, the dynamic approach is flexible and produces remarkable work load balancing. For small and medium size matrices, MR3-SMP
matches or outperforms ParEig, the fastest existing parallel eigensolver; compared with all the eigensolvers in LAPACK, MR3-SMP is the fastest and most scalable. For large-scale eigenproblems, we designed PMRRR, an MPI-based version of the MRRR algorithm for computing all or a subset of eigenpairs of tridiagonal matrices. Our experiments provide evidence that PMRRR is fast and the most scalable tridiagonal solver available. We then combined PMRRR with the Elemental parallel environment, building a set of routines labelled EleMRRR, to also solve generalized and standard problems. In general, EleMRRR attains the best performance and obtains the best scalability of all solvers.
Other Activities

Teaching

Winter semester 2010/11
• 10ws-14775: Introduction to Scientific Computing Languages

Summer semester 2011
• 11ss-24886: High-Performance Matrix Computations
• 11ss-07034: Introduction to High-Performance Computing

Services

Throughout the year, in addition to serving as member of the AICES steering committee and as AICES deputy scientific director, Bientinesi organized a number of events.
• Minisymposium on ‘High-Performance Linear Algebra on GPUs’, GAMM Annual Meeting 2012, Darmstadt.
• Workshop on ‘GPU Computing’, within the International Conference on Parallel Processing and Applied Mathematics. September 2011, Torun, Poland.
• Short courses at the AICES graduate school:
  − The Eigenproblem on Shared Memory Architectures, Vömel;
  − GPU Programming, Quintana-Ortí;
  − Writing from the Reader's Perspective, Gopen;
Talks and Publications

Talks & Lectures


Paolo Bientinesi: Automation in Computational Biology. 9th International Conference on Parallel Processing and Applied Mathematics (PPAM 2011). September 2011. Torun, Poland.


Publications


Technical Reports


Dissertations
Definability and Model Checking: The Role of Orders and Compositionality

Tobias Ganzow

Finite model theory and descriptive complexity theory are concerned with assessing the expressive power of logics over finite models and with relating the descriptive expressiveness needed for defining a class of structures to the computational complexity of the corresponding decision problem. In recent years, also the model theoretic investigation and computational handling (e.g. of the model checking problem) of infinite structures that are finitely representable has gained much interest.

The first part of this thesis studies how the expressive power of logics over finite structures is affected by the presence of orders. We will first review the concept of order-invariant definability where we allow formulae to use an additional order-relation that is not present in a given structure in such a way that the truth of the formula in the structure does not depend on the actual interpretation of the order relation, and show that order-invariant monadic second-order logic (MSO) is more expressive than counting MSO, an extension of MSO by modulo-counting quantifiers.

Second, we investigate locally ordered undirected graphs, in which only the neighbourhoods of the vertices are linearly ordered, and show that the transitive closure of the edge relation is definable by a formula of deterministic transitive closure logic (DTC) that has access to an auxiliary linearly ordered number sort by encoding Reingold's LOGSPACE reachability algorithm. We further show that DTC with counting terms captures LOGSPACE on this class of graphs.

The second part of the thesis is concerned with techniques for model checking weak monadic second-order logic (WMSO) on a class of inductive structures that allow for a finite representation via systems of equations, and which includes structures relevant for verification purposes such as the infinite binary tree, infinite lists, etc. Our new approach presents an algorithmic alternative to automata-theoretic methods, which exhibit certain drawbacks, and is based on a purely logical decomposition technique using the defining equations. Further, the deployed techniques can be extended to obtain a model checking algorithm for the extension of WMSO by an unbounding quantifier, and thus establish the decidability of its model checking problem on the class of inductive structures.

Evaluators:  Prof. Dr. Erich Grädel  
Dr. Luc Segoufin

Date of oral exam: 22 February 2011
Security for Pervasive Healthcare
Oscar Garcia-Morchon

Ubiquitous 24/7 health monitoring systems based on wireless medical sensors are going to play a key role for pervasive e-health applications. These systems allow care givers to early detect and act on signs of patients’ clinical deterioration improving quality of care in a reliable unobtrusive and cost effective way. Ensuring the privacy and security of the exchanged information is challenging in pervasive e-health environments due to the resource constraints of tiny wireless medical sensors and operational requirements such as user mobility, strict latency needs, or the multitude of parties involved in the system.

We describe a comprehensive and practical security framework for these pervasive health monitoring systems. We distinguish three layers addressing the specific security needs at the patient area network, medical sensor network, and backend levels. Thereby our architecture accommodates the healthcare institution-centric approach predominant today while making provisions for the more patient-centric vision of pervasive e-health environments. The tailored security mechanisms for each individual layer as well as their interworking are presented and evaluated in detail. The analysis shows that our proposed security framework allows the deployment of wire-less medical sensor networks in a very efficient way.

Evaluators: Prof. Dr Klaus Wehrle
Prof. Dr. Matthias Hollick (TU Darmstadt)

Date of oral exam: 9 March 2011
Controlling Development Processes

Thomas Heer

The development of an innovative product is a complex and highly dynamic process which has to be performed in a controlled way. Several dependencies exist between the defined tasks, the assigned resources, and the artifacts to be produced. In a development project, which is planned and executed according to a process definition, the time, budget, and available resources are limited. Controlling a development process involves monitoring the actual performance and analyzing whether it conforms to the plan. Poor performance, changing requirements, the detection of errors, and the creation or modification of key artifacts may require plan changes at process runtime. As a consequence of the inherent complexity of the task, software tool support is essential for controlling development processes.

Different insufficient solutions are nowadays applied in practice for this purpose. Project management systems support project planning and to some degree project controlling, but they do not support the execution of predefined processes. Workflow management systems on the other hand are commonly applied for process execution. However, they do not support the scheduling of tasks in a project, and they are not flexible enough for the management of development processes. As a consequence, both types of systems are insufficient when it comes to controlling development processes. Attempts for their integration fell short with respect to representing execution states in project plans and scheduling workflow instances.

This thesis describes a new concept for a process management system, which combines the strengths of the aforementioned tools and eliminates their deficiencies by substantial extensions. Starting point of the research were results of the collaborative research center (SFB) 476 IMPROVE. An integrated approach for the management of development processes has been extended with respect to task scheduling, progress measurement, and change management in development projects. In particular, an algorithm for the automatic generation of a project schedule has been developed which takes the execution states of the tasks into account. Subprocesses of a development process can be executed by a workflow engine, which interprets predefined workflow definitions. With respect to monitoring, specific progress measures for the degree of completion of tasks have been defined which rely on elements of the process model. In the case of plan changes at process runtime, the consistency of the plan with the execution state of the process is ensured.

The concepts have been implemented in the extension module PROCEED of the commercial life cycle asset information management system Comos of Siemens Industry Software. Comos is widely used in the plant engineering industries. Therefore, this thesis combines fundamental research results with a proof of concept implementation in an industrial context. The realization of PROCEED based on an industrial platform offers great opportunities for further evaluation of the provided functionalities in plant design projects in the plant engineering industries.

Evaluators: Prof. Dr.-Ing. Dr.h.c. Manfred Nagl
Prof. Dr rer.pol. Matthias Jarke

Date of oral exam: 19 July 2011
The task of an automatic speech recognition (ASR) system is to convert an acoustic signal, which contains speech, to written text. The error of an ASR system is measured in the number of words in which the recognized and the spoken sentence differ. This work investigates and develops decoding and system combination approaches within the Bayes risk decoding framework with the objective of reducing the number of word errors.

The Bayes risk decoding framework yields the hypothesis with the least expected number of errors w.r.t. a specified loss function and given the true sentence posterior probabilities. In ASR the loss function of choice is the Levenshtein distance. However, in practice neither the true probabilities are known nor is the computation of the Bayes risk hypothesis with the Levenshtein distance as loss function computationally feasible. Consequently, this work addresses two problems: first, how to compute an estimate for the sentence posterior probabilities given one or several ASR systems; second, how to approximate the computation of the Bayes risk hypothesis with the Levenshtein distance as loss function.

A common approach to reduce the complexity of the Bayes risk decoding is to replace the Levenshtein distance by a benign distance function. In this work the meaning of benign is formalized and a generic, efficient decoder for benign distance functions is developed. In a second step, the decoder is extended to a generic system combination technique. The class of Bayes risk decoders with benign distance functions include the common approaches of confusion network (CN) and minimum frame error (FE) decoding. The properties of existing CN and min. FE decoders are discussed and variants of both approaches are motivated and developed.

For confusion networks an alternative system combination algorithm, called CNC, is known. I will show that the original CNC is a special case of the generic Bayes risk system combination technique. Finally, an extension of the CNC approach is introduced, which aims at overcoming the limitations of the original algorithm. In particular, the extended CNC can deal with unreliable system-dependent probability estimates.

**Evaluators:** Prof. Dr. Hermann Ney  
Dr. Jean-Luc Gauvain HDR.

**Date of oral exam:** 18 July 2011
Infinite two-player games constitute a powerful and flexible framework for the design and verification of reactive systems. It is well-known that, for example, the construction of a controller acting indefinitely within its environment can be reduced to the computation of a winning strategy in an infinite game (Pnueli and Rosner, 1989). For the class of regular games, Büchi and Landweber (1969) showed that one of the players has a winning strategy which can be realized by a finite-state automaton. Based on this fundamental result, many efforts have been made by the research community to improve the solution methods for infinite games. This is meant with respect to both the time needed to compute winning strategies and the amount of space required to implement them. In the present work we are mainly concerned with the second aspect. We study two problems related to the construction of small controller programs.

In the first part of the thesis, we address the classical problem of computing finite-state winning strategies which can be realized by automata with as little memory, i.e., number of states, as possible. Even though it follows from a result of Dziembowski et al. (1997) that there exist exotic regular games for which the size of automata implementing winning strategies is at least exponential in the size of the game arena, most practical cases require far less space. We propose an efficient algorithm which reduces the memory used for the implementation of winning strategies, for several classes of regular conditions, and we show that our technique can effect an exponential gain in the size of the memory.

In the second part of this thesis, we introduce a generalized notion of strategies. One of the players is allowed to delay each of his moves for a finite number of steps, or, in other words, exploit in his strategy some lookahead on the moves of the opponent. This setting captures situations in distributed systems, for example, when buffers are present in communication between remote components. Our concept of strategies corresponds to the class of continuous operators, thereby extending the work of Hosch and Landweber (1972) and, in particular, that of Büchi and Landweber (1969). We show that the problem whether a given regular specification is solvable by a continuous operator is decidable and that each continuous solution can be reduced to one of bounded lookahead. From our results, we derive a generalized determinacy of regular conditions.

**Evaluators:** Prof. Dr. Dr.h.c. Wolfgang Thomas
Prof. Dr. Erich Grädel

**Date of oral exam:** 9 May 2011
Anytime Algorithms for Stream Data Mining. Dissertation
Philipp Kranen

Data is collected and stored everywhere, be it images or audio files on private computers, customer data in traditional or electronic businesses, performance or control data in production sites, web traffic and click streams at internet providers, statistical data at government agencies, sensor measurements in scientific experimentation, surveillance data, etc. There are countless examples, and the amount of data is tremendous. Data mining is the process of finding useful and previously unknown patterns in data. In the examples listed above, data mining can be used for automated recommendation of audio files, business analysis and target marketing, or performance optimization and hazard warnings. While early mining algorithms only considered static data sets, research and practice in data mining must nowadays deal with continuous, possible infinite streams of data, which are prevalent in most real world applications and scenarios.

Anytime algorithms constitute a special type of algorithm that is well suited to work on data streams. They inherit their name from their ability to provide a result after any amount of processing time. The amount of time available is not known to the algorithm in advance: anytime algorithms quickly compute an initial result and strive to improve it as long as time remains. When interrupted they deliver the best result obtained until that point in time.

In this thesis anytime classification is studied in depth for the Bayesian approach. New algorithmic solutions for anytime classification are developed and evaluated in extensive experimentation. The first anytime stream clustering algorithm is proposed and an application to anytime outlier detection is presented. In addition to the algorithmic contributions, new meta-approaches are described that significantly widen the area of applications for anytime algorithms. The solutions and results of this thesis contribute to the state of the art in anytime algorithms and stream data mining research.

Evaluators: Prof. Dr. rer. nat. Thomas Seidl
Prof. Michael E. Houle, PhD, National Institute of Informatics, Tokyo, Japan

Date of oral exam: 14.09.2011
Verification of Continuous-Space Stochastic Systems

Alexandru Mereacre

The dissertation deals with verification algorithms for inhomogeneous continuous time Markov chains (ICTMC), discrete time stochastic hybrid systems (DTSHS) and Markovian timed automata (MTA). For all of these three models we define the notions of time-bounded and time-unbounded reachability. We use time-bounded and time-unbounded reachability in order to compute the satisfiability probability of an $\omega$-regular property.

For ICTMCs we introduce the notions of time-bounded and time-unbounded reachability as a solution of a system of integral equations. We show that for the time-bounded case the reachability probability can be computed by solving a system of ordinary differential equations. For the time-unbounded case we consider two special classes of ICTMCs: periodic and uniform. For both classes we develop efficient techniques based on discrete time Markov chains (DTMCs) in order to compute the time-unbounded reachability. Using the time-unbounded measure we can compute the satisfiability probability for an $\omega$-regular property against an ICTMC.

We introduce the notions of time-bounded and time-unbounded reachability for DTSHS. We develop a discretization algorithm, where the DTSHS is discretized into a DTMC and the resulting reachability probabilities are computed as a solution of a system of linear equations. We compute also an error bound for the time-bounded reachability case. Using the notions of time-bounded and time-unbounded reachability we are able to verify whether a DTSHS satisfies a given $\omega$-regular property. All obtained results are applied to a two-room heating example.

We introduce MTA as an extension of timed automata with exponential distributions. We define the maximum time-bounded and time-unbounded reachability probabilities as a solution of a system of integral equations. We develop a discretization algorithm for the time-bounded reachability case. We discretize the MTA into a Markov decision process and we compute an error bound. For MTAs with a single clock we introduce a system of linear equations which solves the time-unbounded reachability case.

Evaluators: Prof. Dr. Ir. Joost-Pieter Katoen
            Prof. Dr. John Lygeros (ETH Zürich, CH).

Date of oral exam: 2 May 2011
Managing Dynamic Requirements Knowledge – An Agent-Based Approach
Dominik Schmitz

Agent- and goal-based requirements engineering can be considered established in research for many years now. Also first successful applications to industrial practice have been reported. Agent- and goal-based approaches explicate the functional and non-functional goals as well as various kinds of dependencies of possibly conflicting stakeholders. Thereby, they provide enhanced means to support elicitation, analysis, documentation, as well as many other operations on requirements. The thesis strives to add to these advanced support facilities by addressing dynamic issues that are not yet considered in existing approaches.

Several dynamic aspects of the requirements field have been targeted by various research groups. For example, use cases and scenarios have been introduced to capture the interactive features of a system to be developed. From an entirely different perspective, the dynamics of the requirements engineering process itself has been investigated, for example to learn how the volatility of requirements can be addressed.

Inspired by two very different case studies – support for flexible inter-organisational networks of enterprises and the elicitation and analysis of control software requirements in small- and medium-sized enterprises (SMEs) – we address several new dynamic issues in a number of extensions to the i* requirements modelling framework proposed by Yu.

• First, the requirements modelling language is extended to capture the dynamic instantiation of roles by stakeholders in a concrete project. Furthermore, these roles can be related to each other in regard to evolutionary aspects. This allows to capture that the characteristics of a stakeholder can change over time.
• Secondly, the capture, processing, and analysis of individual project requirements is enhanced. The explicit representation of domain knowledge accelerates the capturing procedure. Model-based transformations improve the integration with later development stages. In addition, they are used as a bridge toward agent-based simulations. Simulation experiments and advanced analysis on top of these complement well existing formal model checking approaches.
• Thirdly, we consider the inter-project management of dynamic requirements knowledge. A requirements-based similarity search helps to identify related historic projects and thus to disclose potentially reusable solutions. We have also developed measures to keep up with the fast and project-driven evolution of domain knowledge at SMEs. A partially automated feedback loop integrates repeated, consolidated project experiences of an SME into the earlier mentioned domain knowledge based approach.

In sum, a tailorable method with accompanying tool support is established that addresses the raised dynamic issues. The validations within the two case studies have shown that in particular the work within very innovative, flexible, and customer-oriented settings benefits from the proposed extensions and thus brings forward industrial acceptance of agent- and goal-based approaches in these fields.

Evaluators: Prof. Dr. rer. pol. Matthias Jarke
Professor Eric Yu, Ph.D.

Date of oral exam: 20 December 2010
A Language of Tactile Motion Instructions for Physical Activities

Daniel Spelmezan

Athletes benefit from immediate and frequent feedback on their performance during training. Therefore, coaches try to provide instructions and feedback over multiple sensory channels before, during, and immediately after an exercise: they explain and demonstrate how to move the body, and they move the athletes’ bodies into correct position. In many situations, however, athletes only receive feedback after performing an exercise because they are spatially separated from their coaches. Also, they do not experience tactile feedback through the coaches’ hands.

To overcome these limitations, this work proposes and investigates artificial tactile stimuli for providing instructions and feedback on performance in real time. These tactile signals are called tactile motion instructions. They stimulate specific body locations to communicate how to move and how to adjust the posture. Empirical studies conducted in static and in active situations informed the iterative design and the evaluation of a general set of tactile motion instructions that can represent body movements in an intuitive way. These tactile instructions can be perceived and recognized with high accuracy in situations that are cognitively and physically demanding. In particular, they can lead to faster response times to move the body than spoken instructions that are conveyed over earplugs.

Tactile motion instructions constitute a simple language where sequentially triggered instructions can guide athletes during sequences of body movements. Using snowboarding as an example, a field study conducted with snowboarders who experienced tactile motion instructions while practicing a new riding technique demonstrated that this tactile language can help athletes to learn motor skills.

This work is the first investigation into the intuitive interpretation of full-body tactile stimuli that can instruct how to move the body during physical activities. The insights into the perception and recognition of these stimuli in stationary and in active situations lead to guidelines for designing tactile motion instructions. Besides sports training, the findings from this research can be applied to various domains where immediate feedback on incorrect posture is typically missing or impracticable, such as to prevent injuries in unsupervised situations during daily physical activities, or to enhance rehabilitative exercises for regaining lost motor skills.

This dissertation also presents a custom-built wearable and wireless sensor and actuator system. This system enabled the design of tactile motion instructions and their evaluation in real-world conditions, and demonstrated that sensing and classifying posture and body movements while snowboarding is possible in real time. This system resulted in the first wearable assistant for snowboard training that automatically provided tactile motion instructions during descents.

Evaluators: Prof. Dr. Jan Borchers
Prof. Dr. Martina Ziefle

Date of oral exam: 28 June 2011
The use of domain specific languages (DSLs) for the construction of complex software systems allows for an efficient development, a higher degree of reuse, and reduces recurring and thus error-prone labor. Additionally, DSLs permit to directly involve domain experts in a development process. The drawback is the necessary effort for the creation of the languages including concrete and abstract syntax, symbol tables, context conditions, and supporting language-specific tools. In addition, the specific purpose of DSLs often makes it necessary to combine different languages or even code, starting from sequential tool chains up to the embedment of (parts of) languages into others. The involved languages, the form of combination, and the domain specific adaption however depends on the context of the project, the aim, and the involved users.

In order to address these challenges, this thesis introduces an approach to the compositional development of textual domain specific languages. In a first step, languages are developed independently and without anticipation of future combinations. In a second step, these languages can be combined in different ways and under minimum effort. As technical basis the modularity mechanisms of the MontiCore-framework are used and extended.

The main results of this thesis can be summarized as follows:

• A transfer of the mechanisms of component-based software engineering to the domain of language construction and an investigation which techniques and architectures support a compositional development of languages and software.

• A categorization of language combinations into scenarios and the development and improvement of modularity mechanisms in MontiCore.

• An investigation how the identified scenarios can be realized on the levels of the concrete and abstract syntaxes using the modularity mechanisms.

• The development of a framework for the creation of compositional symbol tables and context conditions and a discussion how the scenarios can be realized for these aspects.

• An extension of the underlying grammar format for the specification of language-specific tools. This specification is used to generate deployable Eclipse-plugins which respect the aspect of compositionality.

Altogether, an integrated and coherent approach for the compositional development of languages on the levels concrete syntax, abstract syntax, symbol tables, context condition checks, and language-specific tools is presented.

**Evaluator:** Prof. Dr. rer. nat. Ursula Goltz

**Evaluator:** Prof. Dr. rer. nat. Bernhard Rumpe

**Date of oral Exam:** 15 July 2011
Central Services
System Administration Group

Staff

- Faculty
  Prof. Dr.-Ing. Hermann Ney

- Research Assistants
  Dipl.-Inform. Willi Geffers

- Technical Staff
  Marion Brandt-Röhrig, M.A.
  Viktor Keil
  Stefanie Scholten
  Karl-Heinz Thevis

- Trainees
  Christian Königs

- Student Workers
  René Birekoven
  Sebastian Kaufmann
  Kevin Möllering
  Behnam Nikzad
  Heiner Oßwald
  Sascha Walther
Overview

Since 1985 the System Administration Group (Rechnerbetrieb Informatik, RBI) operates several computer labs and provides technical support for the Department of Computer Science at RWTH Aachen University. The principal task of the RBI is to install, maintain, and evolve the local network and several central services, including fileservers, 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 team work 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 Gigabit Ethernet 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 fibre. New chairs realize their local network completely based on optical fibre.

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 - 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 database server and software of the computer science library and the workstations for the library users. The database contains the entire stock of books and journals of the library. The RBI develops and supports dedicated software for cataloguing and querying the database.
The library is open to everyone. Students use it as a reference library, but they may take books home overnight. Professors and scientific staff may borrow books and use them in their offices.

Opening hours: Mo-Fr: 8.30 a.m. – 7.30 p.m.

Address: Bibliothek der FG Informatik, RWTH Aachen,
Ahornstr. 55, D-52056 Aachen, Germany
http://www-bib.informatik.rwth-aachen.de

Phone: +49/241/ 80-21025
What you can find in our library

- More than 36,500 monographs and conference proceedings recorded in an online public access catalogue (OPAC).
- “Handapparate”: Required readings for the courses, compiled by professors for their students, accessible on special shelves.
- All diploma theses of our department recorded in a separate database.
- Complete stock of the Springer “Lecture Notes in Computer Science” up to Volume 3000 as well as “Informatik-Fachberichte / Informatik Aktuell” until 2005; only selected titles after that. Additionally we have complete digital access to all LNCS-Volumes since 1997.
- More than 300 journals.
- Always up to date: Magazines like Aachener Nachrichten, PC Magazin, National Geographic, Die ZEIT, ...
- Annual reports from domestic and foreign universities.
- Service for department staff: Books and articles not available on site are procured from the central university library or from international library supplies.
- Literature search training in online databases and catalogues for computer science students in connection with their proseminars and seminars; individually prepared exercises for each participant and his/her topic.
- Website containing plenty of information on our stock and interesting computer science links.
- 3 internet workstations and more than 70 comfortable work places; also separate rooms for student group work.
- Room for students and members with children; provides a place for breastfeeding, a playing area and a changing table.
- Large Open-Air-Reading-Room with another 50 work places.
- Scanner and copier.
- Guided tours through the library for new students and members of our department providing information on our services; in German and English.
- Friendly and qualified consulting and assistance for our visitors.
- Up-to-date press reviews on computer science, student life and the RWTH Aachen.

Highlights

In the past twelve months, several events took place that marked important developments for our library:

1. Magazine: We already shifted more than 5000 books (all volumes of „Informatik-Fachberichte“ and „Lecture Notes in Computer Science“) into our new magazine, made available to us in the cellar rooms. One room of the library is already emptied and we are going to create there an innovative and exciting learning area for about 15 persons. During this process we were already able to establish 12 further working places for our students.

2. New books: At our „Tag der Informatik“, which takes place every first Friday in December, we were happy to present again many new books from five publishers at the
library’s stand. All books were given to us as presents and are now available in our library.

3. New equipment: The constantly increasing number of visitors to our library made an enlargement of the number of our lockers necessary: Now 32 more lockers are available.

4. Our „Waffelfest“: For the second time we took the occasion of the „German Library Week“ in November 2010 to open our book flea market with a reception, where waffles and hot wine punch were offered. Also a big attraction was our „tombola“, in which each third lot was winning. Many students, assistants and professors came by and had an enjoyable afternoon. The money enabled us to provide free mineral water and other goodies („Gummibärchen“) for our visitors over the year.
5. „Lesegarten“: In spring time we were happy to be supported again in our gardening work by a volunteer gardener. Unfortunately since summer a reconstruction of the roof of our building started, and since then we cannot use our Open-Air-Reading-Garden any more.

6. New books and journals: A large institute of computer science in our region decided to close down its library and offers us to choose many mathematical and computer science books, as well as journals. The process of selection is under way.

7. The support for running our staff computers is now provided by the group „Theoretische Informatik“, Prof. Rossmanith and his staff.
Students’ Council
(Fachschaft I/1)

Overview

All students of mathematics, physics and computer science at RWTH Aachen form the Fachschaft Mathematik/Physik/Informatik (student union for maths, physics and computer science). Its active members work hard to represent the students' interests at the university. We do so in the examination boards, the teaching committee and other academic bodies with student representation.

To a big part the past year's work consisted of the development and implementation of a mentoring programme for all computer science Bachelor freshers. Thereby we want to actively help our new students in gaining ground within the academic environment. As the transition from school to university comes with many known problems, the freshers will be supervised by senior students that have already experienced and overcome such difficulties. The mentoring programme, which is a joint project of the Fachschaft I/1 and the department of computer science of RWTH Aachen university, is aimed at reducing student drop-outs. We also collaborate constructively with the department in other areas, of course.

Aside from committee work, there are numerous offers directed explicitly at the assistance of our students. More precisely, we offer daily office hours in our premises at Kármánstr., as well as office hours in the computer science building at least once a week. There, students can seek advice regarding various issues concerning their studies. Furthermore, we provide material for exam preparation, which is used extensively.

Because we pay special attention to the needs of first year students, the Fachschaft possesses a separate consortium that organizes numerous activities to familiarize new students with the daily routine at university. Furthermore we take special care of international students, for instance in the international Master programmes.
Moreover, we support our students by videotaping several lectures in agreement with the respective lecturer, organize social events (for example a Linux install fest), and inform the students through several publications.

In addition to our explicit work for the student body, we stand up for several university-wide improvements. In collaboration with other student unions, we enable students to use the rooms in the Mogam building for study. We also try to create new working spaces for students in the computer science building. Together with the department for computer science, we encouraged the renovation of the lecture halls in the computer science building.

Another domain that we are concerned with is public relations. Hence we once took part in arranging the „Studifest“, an event serving to present the RWTH Aachen to the public, and provided an information stand to introduce our fields of study to interested passers-by. And, of course, we supported the computer science department's open day.

All these activities are only made possible by the numerous students who work voluntarily for the Fachschaft. We want to thank all the active members of the past year, namely:

- André Goliath
- Annalena Wernz
- Björn Guth
- David Dursthoff
- Elmar Borchard
- Gereon Kremer
- Gesche Gierse
- Heiner Oßwald
- Holger Weber
- Inga Herber
- Jakob Breier
- Jan Bergner
- Julian Meichsner
- Marlin Frickenschmidt
- Martin Bellgardt
- Martin Lang
- Matthias Heinrichs
- Mauricio Cattaneo
- Patrick Hallen
- Patrick Lömker
- Sebastian Arnold
- Svenja Schalthöfer
- Tobias Schäfer
- Veronika Flatten

We are looking forward to another year of fruitful collaboration with the computer science department.
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.

UMIC is funding three Endowed Professorships that belong to the Computer Science Department. These include the post of Prof. Ulrike Meyer, and those of the two junior professors James Gross and Bastian Leibe.

The focus of UMIC research is on mobile information and communication systems of the next decade. The service quality as perceived by the users must be at least an order of magnitude over that of today’s systems with lower cost. This goal can only be achieved by joint interdisciplinary research, taking all aspects into account from mobile applications to ultra-highly integrated implementation. Key pillars of the cluster research include

• Mobile Application and Services,
• Wireless Transport Platform,
• RF Subsystems and SoC (System on a Chip) Design.

The close interdisciplinary cooperation of the participating teams is essential for the success of the cluster (see figure below).

Research targets of “Wireless Transport Platform” are smart, mobile, broadband and low-cost systems, which provide adaptive configuration and seamless connectivity, balancing between
conflicting targets like data-rate, radio range and power consumption by continuous joint optimization.

Matching requirements and features of applications and services on the one hand and of the wireless transport platform on the other hand is a key approach of the research area “Mobile Applications and Services”.

Design methodology and implementation are addressed by “RF Subsystems and SoC Design”. Major challenges to be addressed are the nanometre-CMOS integration of flexible radio frequency subsystems required for cognitive terminals and “Multi-Processor-System-on-Chip” (MPSoC) platforms, designed for maximum performance and energy efficiency, taking into account the features and issues of future silicon technology generations.

Research topics like performance and reliability of complex systems, privacy and security, energy efficiency, and software architecture affecting all pillars of the UMIC research are grouped within the research “Interdisciplinary Methods and Tools”.

Nucleus of the cluster research is the UMIC centre, hosting the interdisciplinary research teams headed by Junior Professors and UMIC Distinguished Researchers, the prototyping labs and a demonstrator space. More than 20 chairs and institutes from the Electrical Engineering and Information Technology Faculty and the Computer Science Department of RWTH Aachen are active members of the UMIC research cluster.

**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

**RWTH Team 0ldEur0pe won RuCTF 2010**

The RuCTF is the ‘Russian version’ of the well-known International Capture The Flag (also known as the iCTF) competition. It is a distributed, wide-area security exercise, whose goal is to test the security skills of the participants. In 2010, RuCTF was held on 18 December
UMIC Distinguished Lecture

This year’s Distinguished Lecture was given by Prof. Anthony Ephremides, of the University of Maryland. It was entitled ‘Stable Throughput, Rate Control, and Delay in Multi-Access Channels’. The Lecture took place at RWTH’s SuperC building, on 23 May.

Prof. Anthony Ephremides talked a framework for the study of multi-access channels that combines traditional ‘networking’ approaches with physical layer aspects. He limited the detailed analysis to a simple 2-user channel but was able to demonstrate the connection between stability and reliable communication. In addition, the related problem of ‘emptying’ a set of queues over such a channel in minimum time was also addressed. At least conceptually, his approach can be applied to more general environments.

UMIC Open Day

The UMIC cluster of excellence (Ultra High-Speed Mobile Information and Communication) held its Open Day on 13 July. The Open Day aims at giving the UMIC partners from industry and research, as well as the interested public the opportunity to become acquainted with our house and its research areas and to gain an insight into current projects.

There a multitude of applications and demonstrations, ranging from exploring the physical layer of wireless transmission to the direct handling and operation of new devices. Exhibits were shown all over the building attracting a large number of visitors from different areas. The UMIC open day formed another well recognized opportunity to popularize recent research progress.

UMIC Day

The 2010 UMIC Day was held on 18 October, at RWTH’s SuperC building. The scientific programme comprised Keynote Speeches by Adam Wolisz on ‘Do we have a Vision of the Future Wireless Networks?’ and by Stephan ten Brink on ‘Trends in Wireless Communications’. Dr. Wolisz is Professor for Telecommunication Networks at the TU Berlin; Dr ten Brink is with Alcatel Lucent Deutschland AG. Additional presentations were given by UMIC’s very own Profs. Rudolf Mathar and Berthold Vöcking on ‘Coding on a Façade’ and ‘Algorithmic Aspects of Spectrum Allocation in the Physical Model’, respectively. The usual informal get together with a buffet rounded off the event.
Aachen Institute for Advanced Study in Computational Engineering Science (AICES)

AICES is a doctoral program established in November 2006 under the auspices of the Excellence Initiative of the German state and federal governments in the funding line graduate schools. The program sets out to advance the computational engineering in three critical areas of synthesis: model identification and discovery supported by model-based experimentation, understanding scale interaction and scale integration, and optimal design and operation of engineered systems.

Since 2002, RWTH Aachen University has been establishing educational structures to meet the future research challenges in computational engineering science (CES). In 2004, the Center for CES has been established. Bachelor and Master programs in CES are operating, and were joined by the AICES doctoral program in the summer semester of 2007.

AICES is spearheaded by 15 RWTH institutes from four departments including Computer Science and enjoys participation from Forschungszentrum Jülich and the Max Planck Institute for Iron Research in Düsseldorf. Today, approximately 28 doctoral fellows pursue their doctoral degrees funded through AICES scholarships and recruitment of additional fellows is still ongoing. Currently, five of the 28 dissertation projects are carried out in computer science under the supervision of Prof. Bientinesi and Prof. Wolf.

More information

www.aices.rwth-aachen.de

Contact

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Virtual Institute – High Productivity Supercomputing (VI-HPS)

The Virtual Institute - High Productivity Supercomputing is a joint initiative of Forschungszentrum Jülich, German Research School for Simulation Sciences, RWTH Aachen University, TU Dresden, TU Munich, University of Stuttgart, University of Oregon, University of Versailles Saint-Quentin, and University of Tennessee. Funded by the Helmholtz Association, the mission of this virtual institute is to improve the quality and accelerate the development process of complex simulation programs in science and engineering that are being designed for the most advanced parallel computer systems such as the IBM Blue Gene/P in Jülich. For this purpose, the partners develop and integrate state-of-the-art programming tools for high-performance computing that assist domain scientists in diagnosing programming errors and optimizing the performance of their applications. Besides the purely technical development of such tools, the virtual institute also offers training workshops with practical exercises to make more users aware of the benefits they can achieve by using the tools. During the past year, two tuning workshops with hands-on sessions were organized in Stuttgart and Aachen. In addition, tutorials with and without hands-on exercises were held at various spring and summer schools and at the ACM/IEEE Conference on Supercomputing (SC11) in Seattle, USA. Finally, the virtual institute organized the 4th Workshop on Productivity and Performance (PROPER) in conjunction with the Euro-Par Conference 2011, which was held in Bordeaux, France.

More information
www.vi-hps.org

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German Research School for Simulation Sciences

The German Research School for Simulation Sciences is a joint venture of Forschungszentrum Jülich and RWTH Aachen University, combining the specific strengths of the two founders in the fields of science, engineering, and high-performance computing in a unique synergistic way. Located in dedicated modern facilities on the Aachen and Jülich campuses and equipped with privileged access to world-class computing and visualization resources, the school is committed to research and education in the applications and methods of HPC-based computer simulation in science and engineering. As an essential element of its mission, the school provides a Master's and a doctoral program designed to train the next generation of computational scientists and engineers.

The Laboratory for Parallel Programming in Aachen led by Prof. Wolf, one of the school's four research divisions, is affiliated with the computer science department of RWTH Aachen University and specializes in tools that support simulation scientists in exploiting parallelism at massive scales.

More information
www.parallel.grs-sim.de

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The Bonn-Aachen International Center for Information Technology (B-IT) is a pioneering activity of the German Federal government and the state of North Rhine-Westphalia in their effort to establish excellence clusters across universities and research institutes in Germany. B-IT is a joint institute of RWTH Aachen University and Bonn University in cooperation with the Fraunhofer Institute Center Birlinghoven Castle and the FH Bonn-Rhein-Sieg. B-IT aims at the internationalization of elite study programs in Applied Informatics. Prof. Matthias Jarke serves as Founding Director together with Prof. A.B. Cremers, Bonn, and Prof. K. Witt, FH Bonn-Rhein-Sieg. Prof. Jan Borchers is Study Coordinator of the Media Informatics program, Dr. Jürgen Rapp its study advisor.

The three master programs Media Informatics, Software Systems Engineering, and Life Science Informatics were the first such programs in Europe to be awarded the EuroInf European accreditation label in Informatics, in parallel to its re-accreditation by the German ASIIN agency.

English-Language International Master Programs
Supported by the €57 mio. B-IT Foundation and supplementary NRW-state and federal funds, BIT offers highly selective English-language master programs in Media Informatics, Life Science Informatics, and Autonomous Systems. B-IT master programs include a significant
share of research lab courses in the participating Fraunhofer institutes of Applied Information Technology FIT, Intelligent Analysis and Information Systems IAIS, and Scientific Computing and Algorithms SCAI. A second goal of B-IT is a kind of honor class support for the undergraduate computer science curricula at Bonn and RWTH Aachen University.

The B-IT Master program in Media Informatics continued to be one of the most successful programs at RWTH Aachen University in terms of success rate and study time. Several MI alumni have already completed their doctoral theses; as an example, Fahad Aijaz (MI graduate of 2006) finished his Ph.D. thesis on a Mobile Web Server Platform with distinction, supervised within the Excellence Cluster UMIC by Professors Walke (Communication Networks) and Jarke (Information Systems). One of his demo applications, "Social Network in your Pocket (SNiP)", achieved fourth place in a worldwide Ericsson mobile application competition after tests with over 1000 users from US, China, Europe, and Australia, against 128 competing proposals.

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. The 180 B-IT students come from over 40 countries.

All study programs are operating at full capacity. The Media Informatics program managed by RWTH Aachen accepts about 30-35 students annually after a strict pre-selection which leads to a success rate of student close to 90%. The placement record of B-IT remains excellent. Master graduates have been accepted as doctoral candidates in many leading universities and research institutes worldwide, including places such as the ETH Zürich, the Universities of Cambridge and Oxford as well as Stanford. Meanwhile some of the early B-IT graduates have already finished their doctoral degrees.

B-IT Research School

Since late 2008, the B-IT Research School offers doctoral training in eight areas of applied information technology and its formal fundamentals. Key training concepts include:

- the teambuilding within research areas across the organizational boundaries of the B-IT partners, to achieve a critical mass similar to the large top universities worldwide;
• a system of compact specialized courses for each area enabling not just holders of doctoral scholarships but also “normal” research assistants with heavy teaching and project duties to participate;

• 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.

Welcome party for the new B-IT students
The “DFG-Graduiertenkolleg 1298 AlgoSyn” (Algorithmic Synthesis of Reactive and Discrete-Continuous Systems”) is a highly interdisciplinary research training group funded by the Deutsche Forschungsgemeinschaft. Its mission is to develop algorithmic methods for automatic synthesis – in an interdisciplinary cooperation that encompasses theoretical computer science, areas of practical computer science, and engineering.

The year 2010 marked the ending of the first funding phase (of 4½ years), and in July 2010 the DFG evaluation committee visited us in Aachen to set up a recommendation about continuation for the second funding phase. In November 2010 we received the very good news that the prolongation of AlgoSyn was granted. However, the official letters about this only arrived in Aachen after the critical date of 31st December 2010. Anyway, the work continued, now with 12 full scientific research positions rather than “stipendia”.

In “AlgoSyn 2”, starting on New Year’s Day of 2011 for another period of 4½ years, eleven professors/docents are the scientific advisors: Dirk Abel, Erika Ábrahám, Ulrich Epple, Erich Grädel, Joost-Pieter Katoen, Stefan Kowalewski, Christof Löding, Bernhard Rumpe, Wolfgang Thomas (speaker), Berthold Vöcking, Ekkehard Wendler.

The 12 PhD students funded at the time of the publication of this report (November 2011) are: Namit Chaturvedi, Diana Fischer, Marcus Gelderie, Friedrich Gretz, Sten Grüner, Paul Hänsch, Ulrich Loup, Jan Oliver Ringert, Stefan Schulz, Thomas Ströder, Sabrina von Styp, Melanie Winkler. During the period of this report (October 2010 – September 2011), the AlgoSyn scholarship holders Alexandru Mereacre (group of J.-P. Katoen) and Michael Holtmann (group of W. Thomas) finished their PhD; and Michaela Slaats (group of W. Thomas) and Dominique Gückel (group of S. Kowalewski) are about to finish around the end of 2011.

The organisation of the AlgoSyn seminar and the AlgoSyn workshops was in the hands of the speaker of AlgoSyn (W. Thomas) and the PhD students steering committee consisting of Nils Jansen, Ulrich Loup (speaker), Jan-Oliver Ringert, and Sabrina von Styp. As always we could rely on the help from our administrative staff, Helen Bolke-Hermanns, supported by Silke Cormann, secretary of the Chair of Informatik 7.

Special congratulations go to our AlgoSyn PhD student Thomas Ströder, who received the “Friedrich-Wilhelm-Preis 2011” for his diploma thesis (group of J. Giesl). This prize is conferred after a very strict competition within RWTH Aachen, in which the Faculty of Mathematics, Computer Science, and Natural Sciences only can nominate two diploma theses altogether.

Several special events are to be noted:

- On 11-12 November 2010 we had an intensive workshop in Rolduc; guest speakers were Sven Schewe (Liverpool) and Olga Tveretina (Karlsruhe).
- In March 2011, we had an internal AlgoSyn workshop in Schloss Dagstuhl. The picture shows the participants in the typical setting - on the stairs of the chapel of Schloss Dagstuhl.
In June 2011, we participated (as in every year) in the Dagstuhl Meeting of all German research training groups in computer science; this year it was the first time that the meeting had to be split into two halves of 2½ days each, in order to cope with the large number of research training groups.

Finally, many AlgoSyn members participated in the organization of the largest Aachen scientific event of computer science in 2011, the “Concurrency and Dependability Week”, with the conferences CONCUR 2011, QEST 2001, and TGC 2011, as well as many affiliated workshops. A reward for all these efforts of help with the organization was the possibility to take part in a very rich scientific program.

For more information please visit: www.algosyn.rwth-aachen.de.
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. 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 2010-2011, the AIT department doubled its number of professors from three to six, hiring Prof. Rudolf Fleischer (formerly Max-Planck Institute Informatics Saarbrücken and Fudan University, China) in Theoretical Computer Science, Prof. Basel Dayyani in Software
Technology (formerly Motorola Research and Professor in Dubai), and Dr. Sven Packmohr (Paderborn) in Business Informatics.

The initial IT student population in 2008 comprised only four students, but has been growing since; 17 students joined in 2011, the foundation year for a Bachelor’s program. Omani companies have been impressed by the quality of the early students who performed their first internships.

The quality management support offered by RWTH Aachen University, and the exchange visits, are funded by a major grant of the German international exchange service DAAD. In 2009, an external review of this project characterized it as outstanding within the set of currently forty similar programs DAAD is supporting worldwide.
Forum Information Technology  
at RWTH Aachen University

At RWTH Aachen University the Interdisciplinary Forums are a medium and a platform for the development of interdisciplinary research and education. On the one hand they serve as a communication network and constitute a marketplace for creative ideas and on the other hand they are launching activities to be a catalyst for highly interdisciplinary topics which can only be deduced in an interdisciplinary cooperation and with a transdisciplinary perspective.

The main focus of the Forum Information Technology is to be a RWTH wide 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 (German: Forum Informatik, short: FI) not only connects research and education in the fields of Information Science/Information Technology/Computational Engineering at RWTH Aachen University but also pursues the goal of initiating interdisciplinary projects.

In addition to that it serves as a partner- and project marketplace for its members, supports the exchange of information and ideas, initiates cooperations and joint projects and establishes an appropriate public image.

Promoting the collaboration of its members with external research and development institutions, government agencies, organizations, politics and economy (especially REGINA e.V.) the forum has become quite important in political consulting, in the development of research programs of the European Union and in the advancement of the university education.

One major task the forum is dealing with is to bring researchers from different professional backgrounds together, to establish a dialogue and therewith foster impulses for interdisciplinary cooperation. In order to truly overcome discipline and communication boundaries and to work together effectively these networks have to grow and expand over a long period. This networking progress is supported by the following formats of the forums:

- Workshops (singular meeting of exchange for scientists)
- Task Forces (continuous meetings and activities)
- Lecture (singular top-class lecture of a topical theme)
- Scientific Speed Dating (introduction and presentation in a very quick modus, especially meant for postgraduates)
- Kaminabend (exchange of research and industry in relaxed and nice atmosphere)
- Lecture course (focus on one theme of different perspectives)

Excellence Initiative and Current Situation

Fostered through the currently ongoing second phase of the Excellence Initiative, the whole university and with it the FI is moving towards new frontiers. The FI and in particular its members are actively involved in these discussions, e.g. through participating in several proposals:
The continuation proposal for UMIC has been issued. This proposal was jointly developed by electrical engineers and computer scientists, most of them organized in the FI,

“Mobile Multimedia” has been issued as new proposal, also very much driven by members of the FI, and

“Sustainable Buildings of the Future - Meeting Energy and Demographic Challenges” has some principal investigators also organized in the FI.

The continuation proposal for graduate school "Aachen Institute for Advanced Study in Computational Engineering Science" (AICES) with nearly all PIs being members of the FI.

With currently roughly 85 members the FI is the largest and also one of the oldest forums. While informatics was a relatively small new discipline when starting the forum, informatics has meanwhile become a major driving force for industrial innovation and productivity. In this respect informatics has become very successful: it permeates nearly any other discipline that builds on parts of information technology concepts and tools. Thus informatics has become intrinsically interdisciplinary, but also to some extent a commodity:

Information technology is not only a research field, but also a provider of now existing manifold solutions that typically need to be adapted and implemented in the according domain. This is often a great challenge on its own.

To address the future challenges of information technologies as well as the new political requirements that have changed a lot through the Excellence Initiative the FI is currently rethinking its future role at the RWTH. From its ~85 members and their research fields it is quite clear that some are interested in pushing informatics frontiers further, but many are interested in interdisciplinary adaptation and use of information technologies in their domains. It is currently an important issue to address the transformation of the current FI to become a flexible platform to help users of information technologies to address their needs and bring them together with the appropriate enablers, while also adapting the FI to meet the global challenges that RWTH has identified.

Organization

Board

• Prof. Dr.rer.nat. Bernhard Rumpe (Chairman of the board since Juli 3rd 2010)
• Prof. Dr.-Ing. Gerd Ascheid
• Prof. Marek Behr PhD
• Prof. Dr.rer.nat. Sabina Jeschke
• Prof. Dr.rer.nat Torsten Kuhlen
• Prof. Dr.-Ing. Jens-Rainer Ohm
• Prof. Dr. rer. oec. Kai Reimers
• Prof. Dr.phil. Martina Ziefle
• Prof. Dr.-Ing. Dipl.-Wirt.Ing. Thomas Gries, University Representative of the Interdisciplinary Forums
• Prof. Dr.med. Rolf Rossaint, Vice Rector for Structural Development and Research

Management

• Navina von Felbert, M. A. (Manager Interdisciplinary Forums)
• Dr. Regina Oertel (Coordinator Interdisciplinary Forums)
The periodic lecture series of the Forum FI addresses current topics of high interest in the RWTH community and attracts highly reputed scientists to come to Aachen to give a lecture which regularly takes place in the SuperC Building of RWTH Aachen University. The theme of the current lecture is robotics. More information on the lectures can be found on the web site of the Forum www.fi.rwth-aachen.de (→”Interdisziplinäre Lehre”).

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<th>Winter Semester 2011/2012</th>
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<tr>
<td><strong>Imagination- Innovation- Intervention</strong></td>
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<td>Human-robotic interaction in the field of technical science</td>
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<td><strong>From Hand to Head-</strong> About what connects hands, brains and robotics</td>
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<td><strong>Morphogenetic Robotics</strong></td>
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The robotic scientist: Distilling Natural Laws from Experimental Data, from cognitive robotics to computational biology
Prof. Hod Lipson
Cornell University
23.01.2012

### Winter Semester 2010/2011

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<tr>
<th>Event Title</th>
<th>Speaker &amp; Institution</th>
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<tr>
<td>About global, national and regional eHealth approaches and strategies</td>
<td>Prof. Dr. Reinhold Haux</td>
<td>21.10.2010</td>
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<tr>
<td>Modular model-based specifications and Development of distributed interactive systems</td>
<td>Prof. Dr. Dr. h.c. Manfred Broy</td>
<td>19.12.2011</td>
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<tr>
<td>Humanoid Robotics- a Challenge for the AI-Research and Robotics</td>
<td>Prof. Dr. Sven Behnke</td>
<td>13.01.2011</td>
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<tr>
<td>Learning and cooperating multimodal Robots</td>
<td>Prof. Dr. -Ing. Rüdiger Dillmann</td>
<td>23.01.2012</td>
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**Cooperation with the Gesellschaft für Informatik e.V. (GI)**

The exchange of information technology experts is organized by more than thirty regional groups of the Gesellschaft für Informatik e. V. The integration of the Forum Information Technology to the Germany-wide network of the GI Regional Groups improves the visibility of the forum and also attracts more people to the forum’s events. In the course of the cooperation the members of the GI Regional Group Aachen will be invited to public activities of the forum (e.g. Lecture Series).

**Virtual Reality Center Aachen**

This year, the Virtual Reality Center Aachen could celebrate its tenth birthday. Currently, more than 40 RWTH institutes as well as 19 companies and external research institutions are organized in the VRCA. Not only the large number of VRCA members, but in particular the numerous projects conducted under the roof of the VRCA emphasize the research vitality and demonstrate the strategic importance of Virtual and Augmented Reality in sciences. Joint projects that cross disciplinary boundaries create an atmosphere where complementary skills supplement each other in an ideal fashion. In fact, Virtual and Augmented Reality are not just topics located in a single faculty. Instead, with Computer Science, Architecture, Civil Engineering, Mechanical Engineering, Georesources and Materials Engineering, Electrical Engineering and Information Technology, Arts and Humanities, and finally Medicine, eight out of the nine RWTH faculties contribute significantly with research or teaching activities to this fascinating field. This broad interdisciplinary character was instrumental in making the VRCA successful, both at a local and international scale. As such, the success story of the VRCA is also an achievement of the Forum Informatik, which promoted and supported the VRCA activities from the very beginning.
In the context of the excellence initiative of the German federal and state governments, Virtual Reality plays a vital role in two RWTH Clusters of Excellence, the RWTH Graduate School “Aachen Institute for Advanced Study in Computational Engineering Science” (AICES), where a high-resolution PowerWall has been installed to empower young researchers, as well as the Jülich Aachen Research Alliance (JARA), where an immersive visualization network (ivNET) aims to create a new quality of collaboration between researchers at RWTH and the Forschungszentrum Jülich.

The recently published, fourth progress report of the VRCA can be downloaded from the Forum Informatik Homepage and impressively demonstrates the importance of advanced visualization, Virtual and Augmented Reality for a Technical University like the RWTH - both as a research area as well as a tool in science and engineering.

Prof. Torsten Kuhlen (Speaker VRCA)

**Special Interest Group Robotics**

The Forum Information Technology started a Special Interest Group (SIG) of 35 scientists on the highly interdisciplinary topic Robotics in September 2010. Since then a core group mechanics, rehabilitation, and software engineering has started an effort to launch a DFG International Research Training Group (IRTG) in collaboration with the Canadian Universities École de technologie supérieure, McGill University, Université Laval, and the Natural Sciences and Engineering Research Council of Canada (NSERC). Close cooperation between the participating researches from both countries, several meetings on the German side, and a first official visit to Quebec and Montreal have resulted in a draft proposal present at DFG defining the research objective of this IRTG as: to develop fundamental concepts, approaches and basic principles for modular assistive robotic systems (MARS) that establish a safe physical interaction with physically disabled persons while increasing their independence and thus, the quality of everyday life.

The participating German researchers are from nine different institutes ranging from mechanical engineering (IRT, IGM, IKT), over electrical engineering (ISEA), rehabilitation (RPE), sociology (IfS), and information management (ZLW-IMA), to software engineering (SWC, SE). The nine participating Canadian researchers augment and complement the above research fields. While the DFG IRTG program focuses on research aspects of the collaboration, the NSERC Collaborative Research and Training Experience Program (CREATE) also highlights the training aspects of researchers in assistive robotics. These combinations of research fields and IRTG perspectives will provide new insights into assistive robotics for physically disabled persons as well as new training opportunities for researchers.

**Graduate School AICES**

The graduate school Aachen Institute for Advanced Study in Computational Engineering Science (AICES) continued to support the activities of five hosted and eight associated Junior Research Groups in diverse areas of computational engineering, including over 35 graduate students in those research groups. One of the Junior Research Group leaders, Prof. Karen Veroy-Grepl, was inducted into the Junges Kolleg of the NRW Academy of Sciences. In July 2011, the third meeting of the Advisory Board has taken place, and served to solidify the concept for continuation funding in 2012–2017. The continuation proposal was finalized and delivered to the DFG in August 2011. The same summer, AICES organized two international conferences: the Aachen Conference in Computational Engineering Science AC.CES 2011 in Aachen featuring 17 distinguished invited speakers, and, jointly with graduate schools at TU
Munich and TU Darmstadt, the International Conference on Computational Engineering ICCE 2011 for young scientists in Darmstadt. As opening events in the CES seminar series organized each semester, the Charlemagne lectures were delivered by Peter Lax (Courant Institute) and Endre Süli (Oxford).
REGINA e.V. – Competence Network
Information Technology Aachen

Members
• over 100 companies based in the Aachen region
• 22 chairs and institutes of RWTH Aachen University
• Aachen University of Applied Sciences
• Research Centre Jülich
• Aachen chamber of industry and commerce

The Aachen IT Competence Network REGINA e.V. covers the whole spectrum of business, research and education in the region. REGINA e.V. provides a focus for the activities of the member institutions, and strengthens their collaborations on a commercial, scientific and educational level.

REGINA brings together companies of all sizes, from small start-ups to large international enterprises, drawing the majority of its members from the SME sector. Specialist fields include:
• Communication
• Hardware
• Domain-specific software
• Technical applications/automation
• Controlling/Optimization
• Infrastructure, Internet, e-commerce
• IT consulting
• IT personnel management
• Technology transfer
• Research and training
REGINA companies include world market leaders in specialized sectors, such as AIXTRON (semiconductor technology), DSA (quality assurance for the automobile industry) and CSB (application domain-specific software for the food industry).

**Board**

- Dr. H. Röllinger, SOPTIM AG (chairman)
- Dipl.-Math. R. Geisen Alabon GmbH (chairman)
- Dipl.-Ing. M. Wallrath, Ascom Deutschland GmbH (chairman)
- Dr. R. Oertel, Head of Department 4.0., Technology Transfer & Research Funding, RWTH Aachen
- Dipl.-Ing. M. Bayer, Chamber of Industry and Commerce Aachen
- Dr.-Ing. J. Mansfeld, DSA GmbH (former chairman)
- Prof. Dr. St. Kowalewski, Chair of Computer Science 11, Software for embedded systems, RWTH Aachen

**Activities in 2010 – 2011**

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 2010/2011:

- **Management Get-togethers**: Worths in Corporate Sales, Intercultural Communication, Competitive Intelligence vs. Industrial Espionage, Social Media Marketing
- **Round-table Discussion**: Free Space Internet
- **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 Dutch partner organization REGITEL and the Belgian DSP Valley contributes to this process.

REGINA is a partner of the Interreg IV-Project TTC (Top Technology Cluster). TTC is a joint cross-border initiative to support technology-oriented companies, especially SMEs, to find the right partners and to establish sustainable business cooperation within the triangle Southern-Netherlands – Western-Germany – Eastern-Belgium.

Career

REGINA is engaged in developing strong links between research and industry. The aim is to educate highly qualified young talents as future employees in regional IT companies, so that expertise is rooted in the Aachen region in the long term. This effort is supported by REGINA's own Internet-based job-placement exchange, which not only advertises jobs for graduates but also training, work-experience opportunities, and postgraduate internships. Finally, grants for graduate students have been donated by REGINA companies.

REGINA - Career Portal:
Karriere.ac is an internet-based job placement exchange for high tech jobs in the Aachen region. REGINA member companies run a chance to offer their vacancies for free.

Career by Click! → 1 Application – 100 Recipients
Applicants send their applications to REGINA and we forward them to our member companies. The job candidate can reach in this way more than 100 recipients with only one click.

Night of the Companies
If you have finished university and are looking for a new job then catch the bus and visit your prospect employers. Once a year, in November, we organize for students and graduates the so called Night of the Companies. There are 5 bus lines which carry the participants to companies in the region of Aachen and give them the opportunity to get to know interesting job offers. Further information: www.nachtderunternehmen.de

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The mission of the Fraunhofer Institute for Applied Information Technology FIT, located in Birlinghoven Castle, Sankt Augustin, and at RWTH Aachen University, is to support human-centered computing in the context of organizational processes. Researchers in FIT study lifecycle-wide methods for the design and evolution of adaptive, user-oriented information and cooperation systems in the interplay of human work practice with organizational processes. About 130 researchers, technical and administrative personal, and student assistants work in the institute.

FIT Executive Director Prof. Dr. Matthias Jarke also serves as Chairman of the ICT Group and Member of the Presidency of the Fraunhofer Society. With ca. 4.100 employees and a budget of over €210 mio. across its 17 member institutes (about 70% externally funded), the Fraunhofer ICT Group is the largest European research organization in the field of Information and Communication Technologies. In addition to Prof. Jarke, three of the four department leaders in Fraunhofer FIT also hold faculty positions at RWTH Aachen University: Thomas Berlage, Wolfgang Prinz, and Thomas Rose.

FIT pursues its mission in four major research areas which are complemented by special business fields and competence centers (see www.fit.fraunhofer.de for details).

FIT.CSCW (Prof. Wolfgang Prinz, PhD) investigates the field of Cooperation Support Systems.

The BMBF Project ‘SurgeryNet’ offers an innovative Web 2.0 training platform surgeons, with a key focus on minimally invasive surgery. The central idea is the combination of daily work processes and the collection of learning content, through a time- and location-independent provision of the latest know-how. Users can comment and discuss the existing content to ask questions and bring in their knowledge. During the project, a new interface and new functions will be developed and integrated in the BSCW to create the SurgeryNet platform. SurgeryNet will provide functions of a social community, like a profile and communication features and also picture and video sharing functions.

Social media, smart-phones and surface computing strongly influence today’s use and development of cooperation systems. While social network services have many millions of private users, companies hesitate to use the technology. Several of our projects deal with this discrepancy. Based on a study of the salient characteristics of prominent Web 2.0 applications we developed recommendations on how to adapt these cooperation platforms to the use within organizations. Companies could thus integrate the characteristic features of social platforms into their application systems and processes, thus providing their staff with better tools for communication and cooperation. A methodology to study cooperativity, which measures the cooperation in an organization, indicates the room – and need – for
improvements. Our initial experience indicates that these tools improve the way people communicate and help to reduce the flood of emails bogging down many organizations.

IdeaPitch is a novel application brings together desktop computers, iPhones and the multi-touch table Microsoft Surface for communicating, generating and structuring ideas. IdeaPitch lets its users exchange short notes with a simple gesture. It provides a novel, intuitive form of interaction for brainstorming sessions and documents the results for future use. Another Microsoft Surface application, NETme, supports social networking among visitors to events like conferences that requires advance registration. With the registration visitors can enter – besides the usual information like name, address and affiliation – their user names in social networks (XING, Facebook, Twitter, buzz etc.), upload a photo and add information on their professional interests. At the conference the visitors receive badges with a 2D barcode that identifies them to the NETme system. They can use the Microsoft Surface with NETme, explore the social networks, and contact other visitors that are of interest to them.

Last but not least it should also be mentioned that Georg Hackenberg, a student in Software Systems Engineering at RWTH Aachen University won the first prize in the Hugo-Geiger competition for best master/diploma thesis 2010 within the whole Fraunhofer Society, which has over 5.000 student assistants. Hackenberg, also a former Hiwi of UMIC, did his thesis at FIT under supervision of Prof. Wolfgang Prinz on a novel method for marker-free gesture recognition. He is currently a Ph.D. candidate in the group of Prof. Manfred Broy at Technical University of Munich.

FIT.LIFE (Prof. Dr. Thomas Berlage) investigates the field of Life Science Informatics, addressing navigational support for micro-surgery, system environments for large-scale bioinformatics research, and assistive devices for users with special needs.

The BMBF project ‘ExPrimage’ mainly focussed on the unsupervised regional and structural analysis of breast cancer tissue samples using a number of different functional and structural labels scanned under an automated microscope. The set of tools that has been developed in
the project include image registration, supervised and unsupervised classification, and a database and user interface for metadata annotation and visualization of results. These tools will be very useful for the future analysis of pathology images. The project was carried out in collaboration with the University Hospital Hamburg Eppendorf, Carl Zeiss MicroImaging and Qiagen.

The project ‘Toponomics in Cholestatic Liver Diseases’ is part of the Clinical Research Group 217 ‘Hepatobiliary Transport and Liver Diseases’ (Speaker: Prof. Dr. D. Häussinger, University Düsseldorf) developed a workflow for an automatic data analysis. This included the evaluation of canalicular transport and also complete the workflow for basolateral transport. Moreover, a fully automated imaging method was established for nuclear translocation. The project also analysed the properties of confocal vs. non-confocal imaging and the resulting information in the z-axis. The results are now going to be integrated into routine high-throughput workflows for clinical research.

**FIT.ICON** (Prof. Dr. Reinhard Oppermann, Univ. Koblenz-Landau) develops context-adaptive and mobile systems for eLearning and mobile work.

Jointly with Informatik 5, they are main partners in the ROLE EU project in Personalized Technology-Enhanced Learning; other large eLearning projects include the AILB project which develops novel tools to enhance the basic professional competencies for hearing-impaired young workers; the latter is a joint project with the DESIRE research team at RWTH Aachen University led by Prof. Dr. Ludwig Jäger. FIT is coordinator of a new 12 m€ EU integrated project called ebbits which extends HYDRA results to Enable Business-Based Internet of Things and Services in cooperation with SAP AG and eight other business and science partners, and a large partner in the 19 m€ BRIDGE project which investigate the suitability of multi-agent systems for coordination tasks in large-scale emergency management.

Prof. Reinhard Oppermann, who had for ten years been the leader of FIT's largest department ‘Information in Context’ (ICON), celebrated his retirement party in June 2011. Dr. Markus Eisenhauer, group leader on ubiquitous computing in ICON, has been chosen as his successor, starting end of 2011. Eisenhauer’s group had an unusual success in new project acquisition by getting almost all their large-scale EU proposals accepted, most notably the BRIDGES Integrated Project on initial emergency response using ubiquitous computing technologies, where FIT.ICON is overall coordinator as well as biggest partner. ICON’s successful continuing training program for Certified Usability Engineers continued with further growth into its third year.

**FIT.PRO** (Prof. Dr. Thomas Rose) develops process management solutions for domains that can be characterized by the complexity of their decision processes, especially emergency management. Methods and tools for process capture and business models for operating services, including related data integration and data warehousing questions, are a major topic. Mobile data integration applications such as car-to-car information management settings (see report on CoCar project in report by Informatik 5) are also pursued.

In the new BMBF project InfoStrom (www.infostrom.org) we cooperate with companies such as RWE, PSI and SAP to develop tools for the informal capture of knowhow about processes that help to deal with the break-down of the electric power supply network. Since private and public organizations have to cooperate, transparency of processes is decisive.

EU Project Profitex (www.project-profitex.eu) develops advanced navigation and communication support systems for fire services. For engineering these systems we pursue a simulation-based design methodology developed within the precursor wearIT@work project.
to study the use of partially simulated prototypes under realistic operational conditions. Requirements elicitation and field trials will be conducted with several fire services across Europe. In EU project Socionical (www.socionical.eu) we are analysing complex socio-technical systems by means of complexity science and various simulation methods. In particular we are exploring the impact of ambient intelligence technologies on rescue forces in case of large-scale emergencies, e.g. how can mobile phones be used to gather information on a crisis. In EU project Vicon (www.vicon-project.eu) we study the use of virtual simulations to support product design, and develop tools that provide users with age-related impairments to operate virtual prototypes of household appliances such as laundry machines and phones.

Complementing the four research areas, three FIT competence centers support the German government with microeconomic simulations for the impact analysis of proposed new laws, and the industry and public sector with advanced usability studies as well as methods and tools for enabling web compliance checking and inclusive accessibility to the internet.
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