

Annual Report 2012

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

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Preface

It is a great pleasure to welcome you as a reader of the annual report of the Computer Science Department at RWTH Aachen University. This report provides a summary of the research and teaching activities of our department in the period from November 2011 to October 2012. 2012 has been an extremely active year. Several important scientific achievements, various changes in our team of professors, and the celebration of 40 years Computer Science at our university. The major highlights are mentioned below, but the report provides much more information about our scientific successes, details about our teaching activities, and important recent developments in the department.

We had the pleasure to welcome many new students this year, both for the Bachelor program, as well as the Master program. Also in our international Master study programs such as Systems Software Engineering and Media Informatics several students from all around the world joined. During the summer semester, several diploma students took the last opportunity to do exams, and started working on their diploma theses. In the course of 2013, the last diploma students will finish their studies.

What did all happen this year at our department? Too much to all be mentioned here, but let me focus on a couple of highlights. In May, we celebrated 40 years of Computer Science with a well-attended symposium. An overview over this period by our emiriti Walter Oberschelp and Manfred Nagl can be found in this report. A must to read for those of you that are interested in the history of the department. During the symposium, John Mylopoulos (Univ. of Trento, Italy, and Univ. of Toronto, Canada) received a honorary doctorate, the third one in CS@Aachen. Less than a month later, we celebrated the 60th birthday of Matthias Jarke, an occasion at which he received the Fraunhofer medal. In the summer semester, a series of talks were organized to celebrate the Alan Turing year.

In October, we welcomed Martin Grohe in our department as professor in Logic and Theory of Discrete Systems. From the upcoming summer semester on, he will lead the Chair of Informatik 7. He will present his research area at this year's Computer Science Day. Three colleagues left the department. Martin Hoefler accepted a W2-Professur at the MPI in Saarbrücken, James Gross started as associate professor at the KTH Stockholm, Sweden, and apl.-Prof. Martin Bucker took up his duties as W3-Professor at the University of Jena. We thank these colleagues for their contributions and engagement during their years in Aachen, and wish them a lot of success at their new positions.

After a long preparation phase, the construction of the new E3 Building started in September, and is planned to be completed before WS 13/14. In the mean while, the construction of new rooms for the B-IT research school in Aachen were completed. We also welcomed the new aixCAVE, with a surface of 25 square meters the largest CAVE in the world.

Various department members were invited as keynote speakers at highly ranked conferences, and several papers and theses were awarded. Too many to be mentioned here. Important distinctions and awards have been received. I'd like to mention a few highlights. Matthias Jarke has become a fellow of the GI, became a member of Acatech (the German Academy of Technical Sciences), and was re-elected as chairman of the Fraunhofer Verbund IuK Technologien. Berthold Vöcking became a member of the DFG review board for CS, whereas Bernhard Rumpe joined the board of the GI and Nagl joined the board of Informatics Europe. Last, but not least, Stefan Kowalewski was elected as Dean of the Faculty of Mathematics, Computer Science and Natural Sciences.

Finally, many national and international projects have been successfully acquired. Two highlights I want to mention. Bastian Leibe received an ERC Starting Grant for his project on "Computer Vision for Scene Understanding from a First-Person Perspective", and later this year received the Intel Young Faculty Research Award. Gerhard Lakemeyer was successful in acquiring a DFG Research Group on "Hybrid Reasoning for Intelligent Systems".

Many more achievements can be found in this report, and I invite all of you to start reading. We are looking forward to 2013 in which we expect to open our new E3 building, and in which several international conferences will be organized by the CS department, such as Software Engineering 2013, Euro Par, and the Kaspersky-Konferenz on Cybersecurity.

I'd like to thank Kai Jakobs for compiling this annual report.

Aachen, November 2012

Joost-Pieter Katoen
Head of Department

Berthold Vöcking
Former Head of Department

Faculty Life

40 Jahre Informatik an der RWTH Aachen: Die ersten 20 Jahre

Walter Oberschelp

Vortrag, gehalten am 11.5.2012 bei einer akademischen Feier aus Anlass der Ehrenpromotion von J.Mylopoulos

40 Jahre – eine solche Zahl scheint selbst für eingefleischte Zahlenmystiker kein besonderer Anlass zum Jubilieren. Aber ein kurzer Rückblick sei mir heute gestattet.

Im Juni 1972 beschloss die damalige Mathematisch-Naturwissenschaftliche Fakultät der RWTH, zum Wintersemester 1972/73 einen neuen Diplom-Studiengang Informatik einzurichten.

Wir müssen uns dabei eines Mannes erinnern, dessen Initiative wir die Informatik hier verdanken: Prof. Dr. Fritz Reutter, der damalige Leiter des Instituts für Geometrie, Numerik und Praktische Mathematik und Leiter eines Rechenzentrums, das weit und breit, d.h. im nieder- und mittelhheinischen Bereich, eine der wenigen Möglichkeiten bot, ein „Elektronengehirn“ zu benutzen. Reutter hatte durch umsichtige Planung und durch zähes Verhandeln gegen viele Widerstände den Weg für die Informatik frei gemacht. Die Vorgeschichte hat er in der „Alma Mater Aquensis“ 1971 dargelegt.

Prognosen können irren! Vor genau 40 Jahren, im Mai 1972, prophezeite der Club of Rome im schweizerischen St. Gallen sein Zukunfts-Szenario „Grenzen des Wachstums“. Obwohl man schon damals mit World3 ein auf Großrechnern lauffähiges Weltmodell verwendete, kam die Informatik als Wachstumsfaktor noch nicht explizit vor. Heute sind wir klüger! Man ahnte zwar, dass die Informatik eine große Zukunft haben würde, aber die Entwicklung war kein Selbstläufer. Schon gar nicht in Aachen! Seinerzeit gab es in der Bundesrepublik nur sehr wenige Studiengänge für Informatik – wichtig waren vor allem Karlsruhe und die TU München. Die Initiative, Informatik an weiteren Hochschulen einzurichten, ging – etwas vereinfacht gesagt – vom Bund aus. Er hatte seine Hilfe für 1971, allerspätestens für 1972 zugesagt. Aber in Aachen war man keineswegs bedingungslos bereit, diesen Schritt zu tun. Die Elektrotechnik war sicher, die sich abzeichnenden Neuerungen in ihrer eigenen Fakultät als „Technische Informatik“ verkraften zu können und hatte im Mai 1972 beschlossen, ein eignes Diplom-Fach Informatik in ihrer Fakultät nicht zu eröffnen. Die Mathematisch-Naturwissenschaftliche Fakultät (Fakultät 1) hatte – nolens volens – 1971 zwei Lehrstühle für „Angewandte Mathematik, insbesondere Informatik“ ausgeschrieben und damit schon als klare Struktur-Vorgabe „Unterordnung unter die Mathematik“ formuliert.

Auf den ersten dieser Lehrstühle wurde ich 1971 von der TU Hannover aus berufen, zunächst mit der Aufgabe, ab WS 1971/72 für den Diplom-Studiengang Mathematik das Nebenfach Informatik zu etablieren, was auch tatsächlich geschah.

Der Erfolg meiner Bewerbung beruhte offensichtlich auch auf meiner Herkunft aus der Mathematischen Logik in Münster mit H. Hermes, H. Scholz, W. Ackermann und G. Hasenjaeger, in der die Turing-Maschine bereits Standard-Lehrstoff gewesen war. Und mit der Turing-Maschine (wir sind heuer im Turing-Jahr!) und mit dem Begriff der Berechenbarkeit begann deshalb auch die Einführung in die Informatik. Programmieren war noch ein wunder Punkt! Fortran-Kurse gab es im Rechenzentrum. Für Algol hatten wir keinen

Compiler. Niklaus Wirth hatte zwar schon 1972 an der ETH in Zürich seine Programmiersprache Pascal in die Lehre eingeführt, aber das hatte sich noch nicht bis zu uns herumgesprochen. Die theoretische Programmiersprache MIX aus dem Standardwerk von Donald Knuth war schön und gut, aber sehr kompliziert. Ich habe dieserhalb immer noch ein schlechtes Gewissen, wenn ich an die damalige Zeit zurück denke.

Der Ruf auf den zweiten Lehrstuhl erging 1972 an Jürgen Merkwitz (†) vom Kernforschungszentrum Karlsruhe. Reutter schaffte es, die erforderlichen vier Lehrstühle mit einschlägigem Informatik-Know-How zusammen zu kratzen: Sein eigener Lehrstuhl, derjenige von W.Ameling in der Elektrotechnik und ein neuer Lehrstuhl für Betriebssysteme in der Elektrotechnik (D.Haupt) konnten vorgewiesen werden; sie standen aber kaum für die „Kern-Informatik“, wie man sie damals verstand, zur Verfügung. Hier kamen nur die beiden neuen Lehrstühle in der Fakultät 1 in Betracht, die aber jeweils nur zur Hälfte der Informatik zugerechnet wurden.

Und dann kamen im November 1972 tatsächlich die ersten 80 Studierenden der Informatik, dazu noch viele weitere Mathematik-Studenten mit Nebenfach Informatik. Es gab einen Studienplan für das erste Semester mit meiner Einführungs-Vorlesung in die Informatik. Dazu viel Mathematik und eine vorläufige Diplomprüfungsordnung. Ich war anfangs der einzige Dozent in der Informatik. Unverantwortlich aus heutiger Sicht, damit einen Studiengang zu eröffnen!

Jürgen Merkwitz konnte erst zum SS 73 zusagen nach hartnäckigen Verhandlungen mit dem Land, die oft auf des Messers Schneide standen: Es ging um seine Ausstattung mit gemieteten Räumen am Büchel und um die Umbenennung und Umwidmung seines Lehrstuhls als „Informatik I“. Mein eigener Lehrstuhl konnte Räume beziehen in der sog. „Baubaracke“ – heute steht dort das Super C. Der Lehrstuhl teilte sich mit dem ebenfalls dort untergebrachten Lehrstuhl Mathematik, insbesondere Operations Research (Rolf Kaerkes) den für 200 000 DM angeschafften Rechner SPC 16, der 4KB „Kernspeicher“ besaß und mit einer Lochstreifen-Peripherie ausgestattet war.

Die personelle Entwicklung der Informatik in den ersten 10 Jahren war leicht überschaubar: 1975 besetzte Klaus Indermark – aus Bonn kommend – den Lehrstuhl Informatik II, 1978 kam H.Noltemeier (auf Informatik III), der sich aber sehr bald (1981) nach Würzburg absetzte. Hinzu kam 1976 ein Lehrgebiet für Theoretische Informatik I mit Klaus Weihrauch. Dieser ging dann aber an die Fern-Uni Hagen, es folgte Britta Schinzel (1981-91 in Aachen, dann in Freiburg). Schließlich wurde 1982 ein weiteres Lehrgebiet Theoretische Informatik II eingerichtet, in dem Wolfgang Thomas (1989 Ruf nach Kiel) schon einmal Maß nahm für sein späteres Wirken an der RWTH (mein Nachfolger ab 1998).

Das war's zunächst! Ein Studien- und Forschungsfach mit sehr starken mathematischen Anteilen! Wir wenigen Informatiker versammelten uns in regelmäßigen Besprechungen im HKI, dem „Harten Kern Informatik“, um den Schreibtisch eines Kollegen herum, um immer wieder an Studienplan und DPO (Diplom-Prüfungsordnung) herumzubasteln und anstehende Entscheidungen vorzubereiten. Eine vom Ministerium immer wieder eingeforderte Studienordnung haben wir in dieser Zeit nie zustande gebracht – es ging auch ohne!

Materielle Unterstützung erhielt die Informatik vor allem vom Bund mit dessen „Überregionalen Forschungsprogramm Informatik“ ÜRF, das offiziell allein der Forschungs-Unterstützung dienen musste, aber notgedrungen und stillschweigend geduldet vorwiegend in der Lehre verbraten wurde. Aber es gab Forschung und viel qualifizierten wissenschaftlichen Nachwuchs. Ich nenne nur die Habilitationen der ersten 20 Jahre: Biskup, Damm, Klaeren, Loogen, Martini, Sonnenschein, Vogler und Vossen. Alle diese Kolleginnen und Kollegen sind heute Hochschul-Professoren!

Ein Kuriosum aus der damaligen Zeit: Die erste Habilitation (Joachim Biskup) stieß auf heftige Bedenken der vorwiegend aus Mathematikern bestehenden Kommission, weil der Kandidat in seinem Probe-Vortrag Overhead-Folien verwendete, wo doch der Habilitand gefälligst mit Kreide an der Tafel zu agieren hätte! Power Point gab es noch nicht, geschweige denn das Internet!

In den ersten 10 Jahren war unsere Informatik klar theorie-lastig. Man konnte sich damals einfach keinen Informatik-Professor vorstellen, der nicht auch alle Qualifikations-Stufen für einen Mathe-Prof. durchlaufen hatte. Ich selbst hatte ja als geprüfter Gymnasial-Lehrer dann meine mathematischen Weihen in Hannover durch Habilitation bei dem Behnke-Schüler Horst Tietz empfangen – meine Zusammenarbeit mit Wolfgang Händler und Bodo Schlender dort, die beide schon damals wirkliche Allround-Informatiker waren, zählte da nicht viel.

Eine stärker praxisorientierte Ausrichtung erhielt die Informatik erst 1984, als (durch Umwidmung eines OR-Lehrstuhls) Otto Spaniol auf I4 berufen werden konnte. Ein rasanter Aufschwung begann. Zwei Jahre später übernahm dann Manfred Nagl den seit 5 Jahren verwaisten Lehrstuhl Informatik III (ehemals Noltemeier), der auf Grund vieler administrativer Hemmnisse bis dato nicht hatte besetzt werden können. Nun endlich hatte die Informatik das erforderliche Angebots-Spektrum annähernd erreicht und die öffentliche Akzeptanz der Informatik war so gestiegen, dass sie sich 1992 – nach 20 Jahren, für volljährig erklären konnte.

Es gab natürlich Höhen und Tiefen: Der Jahresbericht 1990 beklagt, dass 5 von 11 Professuren vakant seien. Das schwerfällige Berufungsverfahren, Uneinigkeit über die künftigen Schwerpunkte der Informatik, der leergefegte Markt geeigneter Professoren trugen dazu bei. Die Konturen des Faches formten sich nur langsam: 1986 erschien der erste Jahresbericht der Fachgruppe; aus ihnen konnte man die weitere Entwicklung nunmehr besser verfolgen. Seit 1987 wird die Tradition des Tages der Informatik am ersten Freitag im Dezember kontinuierlich gepflegt. Das sind immerhin auch schon 25 Jahre! Die Dynamik der Weiter-Entwicklung verstärkte sich, besonders dank den neu berufenen Professoren. 1986 bis 1988 konnte etappenweise der Umzug in die ehemalige Pädagogische Hochschule an der Ahornstraße erfolgen – die Arbeitsräume am Büchel und im Fakultätsgebäude am Templergraben konnten aufgegeben werden. Der Ausbau einer facheigenen Bibliothek machte große Fortschritte: 1991 konnte mit Renate Eschenbach erstmals eine etatmäßige Leiterin eingestellt werden. Die Umstellung vom Zentralrechner zum PC und zum lokalen Rechnernetz fällt in diese Zeit; ebenso für Aachen neue Einrichtungen und Institutionen wie ein Graduiertenkolleg, der Industrieverbund REGINA und die Forschergruppe SUKITS.

Und mit neuen Kollegen begann die dritte Dezennie unserer Informatik: 1991 ergab sich mit der Berufung von Matthias Jarke auf den Lehrstuhl Informatik V eine ganz wichtige weitere Ausbaustufe. Im Bereich der nicht als Lehrstühle dotierten Lehrgebiete ergab sich eine gewaltige Fluktuation, denn die dorthin berufenen Kollegen wurden schnell wieder in höhere Positionen nach auswärts fortberufen und konnten nicht bei uns gehalten werden – sie gingen weg wie warme Semmeln! Bernd Walter (ab 86), Bernhard Steffen (ab 90), Alfons Kemper (ab 91) und Wolfgang Nejdil (ab 92), sie alle blieben nur kurze Zeit in Aachen.

Eine Statistik aus dem Jahresbericht zum WS 92/93 gibt einen rohen Überblick über den Studien-Erfolg der ersten 20 Jahre: Insgesamt 2800 Studierende wurden bei uns eingeschleust. 1200 studierten zu dieser Zeit. 800 hatten uns mit dem Abschluss-Diplom verlassen. In dem Verlust von 800 Studierenden verbergen sich Karteileichen wie auch viele oft tragische Einzelschicksale des Scheiterns.

Über diesen ersten 20 Jahren wollen wir nicht den Dunst der Selbst-Beweihräucherung aufsteigen lassen. Stattdessen müssen wir den Dank nach vielen Richtungen hin aussprechen, und ich möchte dies als der älteste „Überlebende“ stellvertretend tun:

Ohne die engagierte Hilfe der Fachkollegen aus der Mathematik wäre die Informatik hier nicht zustande gekommen. In gemeinsamer Arbeit mit dem DPA Mathematik (Vorsitz B.Rauhut) wurden immer wieder fächerübergreifend Prüfungsergebnisse verglichen und Vorurteile, nach denen die Informatiker die „Fußkranken der Mathematik“ seien, abgebaut. Da viele Studierende in beiden Fächern (und oft auch in der Physik) Prüfungen ablegten, konnte eine Gleichwertigkeit des Anforderungs-Niveaus dieser Fächer nachgewiesen werden. Und auch das Vorurteil, dass die (wenigen) Frauen die schlechteren Informatiker seien, wurde klar widerlegt. Einige Kollegen mit besonderer Nähe zur Informatik müssen namentlich genannt werden: Rolf Kaerkes(†), Rolf Möhring, F.Josef Radermacher und H.Jürgen Zimmermann, aus meiner persönlichen räumlichen Nähe Michael Richter (1975-86) und Erich Grädel (ab 1992). Aber auch dem Bereich Elektrotechnik ist die Informatik zu Dank verpflichtet. Es gab eine konstruktive Konkurrenz! Zu nennen sind vor allem Walter Ameling (†). Dieter Haupt, Friedel Hoßfeld und Otto Lange. Viele gemeinsame Diplomarbeiten und auch Dissertationen sind mit der Medizin, besonders im Bereich der Bild-Diagnostik entstanden (Rudolf Reppes). Und in den großen Ingenieurwissenschaftlichen Instituten WZL, IKV, IBF usw., gab es von Anfang an viele gemeinsame Arbeiten, die der Informatik viel Praxisnähe bescherten.

Die Informatik in Aachen verdankt ihren Aufstieg aber nicht nur Professoren! Zahllose wissenschaftliche Mitarbeiter und Hilfskräfte haben am Aufbau mitgearbeitet. Sie sind in Übungen und Seminaren und beim Aufbau der Rechner-Strukturen oftmals über Gebühr beansprucht worden. Dies gilt auch in hohem Maße für unsere Sekretärinnen und für das gesamte technische Fachpersonal. Niemand konnte sich auf die bequeme Infrastruktur eines etablierten Faches zurückziehen – es musste improvisiert und oft mutig und kreativ gearbeitet werden. Die Jahres-Schluss-Endspurts in einer rigiden Haushalts-Bürokratie sind uns allen noch in guter Erinnerung.

Und angesichts der vielen Skandale in heutiger Zeit ist nun doch erwähnenswert: Es hat in dieser ganzen Zeit nicht einen einzigen Fall von unerlaubter Vorteilsnahme, Prüfungs-Begünstigung oder ähnlichem Missbrauch gegeben. Nicht einmal „Übergriffe“ wie in der Mathematik, wo ein erboster Professor eine Studentin, die während seiner Vorlesung strickte, mit Kreide beworfen haben soll. Auch Guttenplag dürfte bei uns nicht fündig werden. Die Qualität unserer vielen Promotionen steht außer Frage – dies muss besonders einmal gesagt werden aus Anlass einer Ehrenpromotion wie heute.

Ich erinnere mich an einen einzigen (ausländischen) Studierenden, der unsere Gebräuche noch nicht kannte und mir nach seiner Abreise einige Flaschen Cognac hinterließ mit dem Versprechen, mir künftig einen guten Job in seiner neu aufzubauenden Firma zu geben. Irgendwann ist diesen Flaschen bei einem Institutsfest der Garaus gemacht worden – eine offizielle Meldung an meinen Dienst-Vorgesetzten habe ich aber aus Zeitgründen nicht abgeben können.

Und noch ein Schlaglicht: Zur üblichen Wanderung der Erstsemester in den Aachener Stadtwald stellte ich bei der Verwaltung den Antrag auf Rückerstattung der von mir verauslagten 20 DM Miete für die Grillhütte. Als ich die Frage, ob dort Bier geflossen sei, bejahen musste, wurde ich abschlägig beschieden, da die Kriterien einer Dienst-Veranstaltung nicht gegeben seien. Und dabei blieb es. Und doch kann ich auch ein Loblied auf unsere Verwaltung, die selber oft unter ihren Vorschriften litt, anstimmen: Ich danke für viel Verständnis, besonders beim hektischen Jahresabschluss. Da hat dann ein Angestellter schon

einmal ein Auge zuge drückt, wenn ihm treuherzig versichert wurde, dass viele große Geräte fristgemäß in den allerletzten Dezembertagen wirklich geliefert worden seien oder dass manche Hilfskräfte in den letzten Jahreswochen mehrmals zwischen Lehrstühlen hin und her rotiert seien...

Zuletzt noch das entscheidende Wort zu unseren Studierenden. Sie waren engagiert und haben großes Verständnis für unsere Situation aufgebracht. Es gab (außer den zeitüblichen allgemeinen Protestaktionen) meiner Erinnerung nach keine größeren gezielten Proteste gegen unsere Arbeit. Immer wieder werde ich von unseren Alumni auf die Qualität der Ausbildung in dieser Gründerzeit angesprochen. Die ersten seinerzeit veröffentlichten Rankings haben dies bestätigt. Es war eine spannende Zeit! Und es blieb spannend, wie der Folgebericht von Manfred Nagl über die folgenden 20 Jahre zeigen wird.

40 Jahre Informatik an der RWTH: Die zweite Hälfte 1992 – 2012

Manfred Nagl

Eine halbe Stunde für vierzig Jahre, das entspricht einer Darstellung von sieben Kilometern auf einem Zentimeter. Von diesem Zentimeter hat mein Vorredner, Herr Oberschelp, die ihm zustehende Hälfte bereits verbraucht. Für die zweiten *zwanzig Jahre* verbleibt also ein *halber Zentimeter*. Erwarten Sie, verehrte Damen und Herren, deshalb keine Vollständigkeit, insbesondere nicht bei der Nennung von Namen und Verdiensten. Meine Ansprache ist somit eher eine Aufzählung von Merkpunkten als eine ausformulierte Rede.

In *vier kurzen Abschnitten* will ich (1) zunächst einige Fakten und Zahlen präsentieren, um den Rahmen unseres Außenauftritts abzustecken, (2) auf die inhaltlich wichtigsten Ereignisse und Entwicklungen in den zwanzig Jahren eingehen, (3) durch einige Vergleiche die Veränderungen über diese Zeit herausarbeiten und schließlich (4) zusammenfassen, den Blick nach vorne richten, aber auch einige kritische Dinge anmerken.

1. Rückblick mit Stolz

Wissenschaftliche *Leistung* präzise zu erfassen, ist nicht einfach. Diese hat ja eine stark inhaltliche Komponente. Man behilft sich daher meist mit *Parametern*, die diese Leistung charakterisieren und der Angabe der entsprechenden *Parameterwerte*.

Unsere großen Felder sind Forschung und Lehre, vgl. Abb. 1. Für diese großen Felder gibt es *Parameter*. Leistung heißt dabei immer, Erfolge in Relation zu den eingesetzten Ressourcen zu setzen. Schließlich müssen Erfolge auch kommuniziert werden, um Außenwirkung und Beachtung zu erzielen. Für diese vier Felder *Forschung, Lehre, Ressourcen* und *Außenwirkung / Beachtung* sind in Abb. 1 einige Parameter angegeben.

Zu den mit einem Pfeil gekennzeichneten Parametern werde ich in meinen Ausführungen später kurz eingehen. Die mit einem Haken versehenen Parameter sollen gleich jetzt aufgegriffen werden, um eine *erste Charakterisierung* des derzeitigen *Stands* der *Fachgruppe* Informatik zu liefern. Sie sehen also, dass ich nicht auf alle Parameter von Abb. 1 eingehe. Und die dort aufgeführten Parameter sind bei weitem nicht alle, die betrachtet werden können.

Beginnen wir also mit der *Charakterisierung* der *Parameter*, die mit einem Haken in Abb. 1 gekennzeichnet sind. Die *Forschung* der Fachgruppe überdeckt die meisten der großen Forschungsgebiete der derzeitigen Informatik. Gleichwohl werden bestimmte Schwerpunkte gebildet. Die Forschung ist anwendungsbezogen, mit starken Verbindungen zu verschiedenen Anwendungsfeldern, hauptsächlich zu den ingenieurwissenschaftlichen. Die Forschung hat dennoch eine starke theoretische Breite und Fundierung. In der *Lehre* hatten wir im letzten Jahr folgende Kennzahlen: Auf Diplom- und Masterniveau wurden 2011 bei uns 220 Absolventen ausgebildet, zusätzlich zu den 107 Bachelors. Bezüglich der Anzahl der Bachelorabsolventen sind wir nach dem Wechsel zum Bachelor-/Master-System immer noch nicht in einem eingeschwungenen Zustand angekommen, der bei 200 Bachelors pro Jahr liegen dürfte. Auf die *Ressourcen* gehen wir später genauer ein. Einige seien vorab erwähnt, auch weil sie bei Erfolgskennzahlen üblicherweise selten genannt werden, nämlich unsere eigenständigen Organisationen Informatik-Bibliothek, -Rechnerbetrieb sowie auch das Rechen- und Kommunikationszentrum der RWTH, das allgemeine Dienste auch für die Fachgruppe leistet.

Zwei Details zur *Außenwirkung*: Die Professorenbilanz (Einwerbung von außen; Ausbildung junger Wissenschaftler, die nach außen berufen werden; Abwehr von Angeboten von außen) war in den letzten 20 Jahren überaus positiv. Auch in den außeruniversitären und bundesweit sichtbaren Ämtern war die Fachgruppe außerordentlich präsent: In den letzten 10 Jahren kam ein Mitglied des Wissenschaftsrats, der Informatik-Hauptgutachter der DFG, der Präsident der GI und der Fakultätentagsvorsitzende aus Aachen.

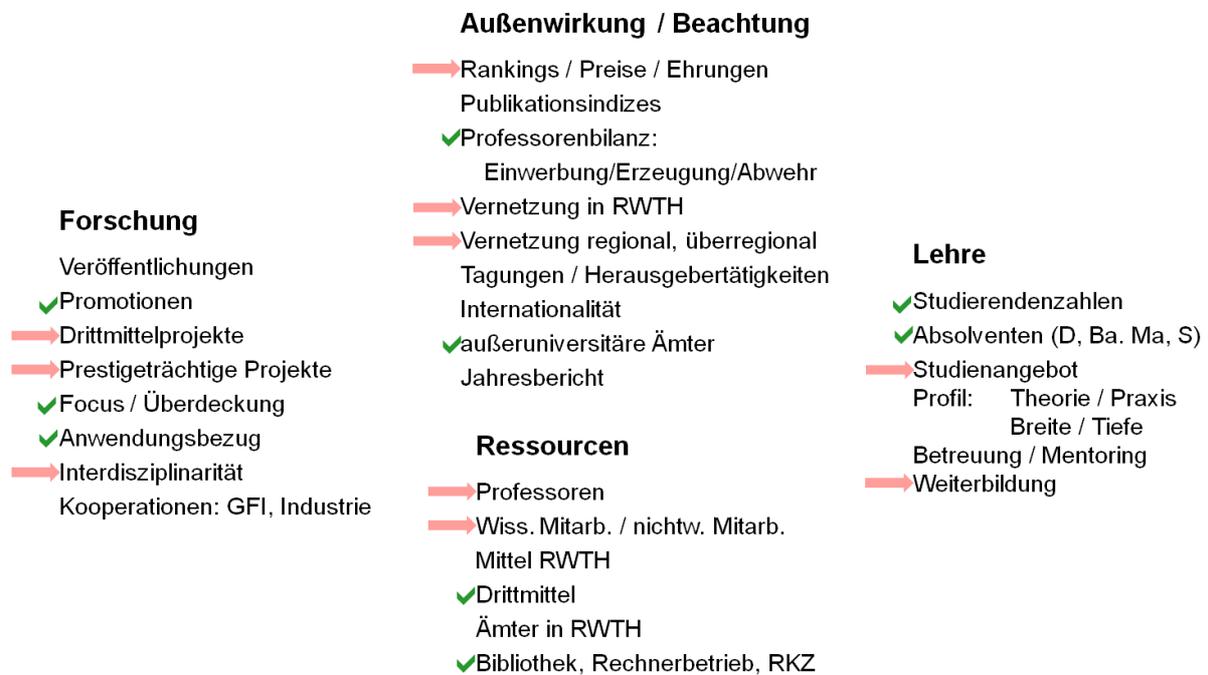


Abbildung 1: Parameter wissenschaftlicher Leistung

Nun noch einige *Zahlen und Details zu einigen Parametern* der vier Felder: Im Mittel hatten wir in den letzten Jahren 27 *Promotionen* pro Jahr. Z.Zt. gibt es 2290 *Studierende* mit der Haupttrichtung Informatik und 2650, die Informatik als ein Studienfach gewählt haben. Die Studierenden befinden sich in folgenden *Studiengängen*: im Bachelor-Studiengang Informatik, in den Master-Studiengängen Informatik, Software Systems Engineering, Media Informatics, im Diplom-Studiengang (keine Aufnahme mehr seit dem WS 2006/2007), im Lehramts-Studiengang Sekundarstufe II, in den Studiengängen Technik-Kommunikation und Computational Engineering Science, an denen die Informatik beteiligt ist, sowie auch in einigen Nebenfachangeboten der Informatik. Derzeit hat die Fachgruppe 31 *Professorinnen und Professoren* (incl. der Juniorprofessoren und Nachwuchsgruppenleiter), 189 *wissenschaftliche Mitarbeiter* und ein *Drittmittelaufkommen* von 14,7 Mio. € pro Jahr. In den *Rankings* der Wirtschaftswoche, von CHE oder im DFG-Mittelranking belegt die Fachgruppe immer vorderste Plätze.

2. Zeitlich wichtige Ereignisse

In diesem Abschnitt beschreiben wir die *Meilensteine* der Entwicklung der Fachgruppe, festgehalten in zwei Abbildungen. Abb. 2 führt die *Professorenbilanz* auf, auf einem Zeitstrahl von 1992 bis 2012. Der horizontale Balken enthält die Namen der Sprecher der Fachgruppe in der jeweiligen Zeitperiode.

Oberhalb des Zeitstrahls finden sich die *Namen* der neuen *Professorinnen und Professoren* an ihrem jeweiligen Zugangsjahr. Wir erkennen, dass die *Zugänge in Wellen* erfolgten. Die Na-

men bis 1993 entsprechen dem Ausbau durch Hochschulsonderprogramm-Mittel, von 1995 bis 2005 dem Ausbau durch Mitteln der RWTH, der Fakultät, der Fachgruppe und des Bonn-Aachen International Center for Information Technology, in der Zeit ab 2006 ergeben sich die Zuwächse hauptsächlich durch Gelder im Rahmen der Exzellenzinitiative. In allen drei aufgeführten Phasen sind auch Namen aufgeführt, die ausscheidende Professoren ersetzt haben.

Oberhalb des Zeitstrahls finden sich auch die Namen der Professoren – durch einen Kreis gekennzeichnet – deren Wegberufungen an andere Orte erfolgreich abgewendet werden konnten. Die *Bleibebilanz* der Fachgruppe Informatik ist also überaus erfolgreich.

Unterhalb des Zeitstrahls finden sich – durch auf den Kopf gestellte Dreiecke kenntlich gemacht – die Habilitationen, d.h. die *Vorbereitung jüngerer Wissenschaftler für eine erfolgreiche Karriere andernorts*. Natürlich gab es auch Wegberufungen ohne vorausgehende Habilitationen.

Unterhalb des Zeitstrahls sind auch die *Abgänge* angegeben. Im Jahre 1995 verstarb Kollege Merkwitz. Vier Emeritierungen – gekennzeichnet durch Dreiecke – fanden danach statt. Alle Emeriti sind nach wie vor aktiv für die Fachgruppe tätig.

Unterhalb des horizontalen Balkens finden sind die Namen der Professoren aufgeführt, die an andere Universitäten wegberufen wurden. Bis auf zwei Ausnahmen handelt es sich um erste Rufe auf Professorenstellen für junge Wissenschaftler oder um Rufe auf höherwertige Professorenstellen. Somit zeigen diese *Wegberufungen* unsere *erfolgreiche Nachwuchsarbeit* bzw. die *fruchtbare Arbeit* von Kollegen, die sie *für Stellen* mit besserer Ausstattung an anderen Universitäten qualifiziert haben.

Nicht verhehlen will ich *zwei kritische Phasen*, die die Fachgruppe durchlaufen hat und die in Abb. 2 durch zwei dicke Ausrufezeichen gekennzeichnet sind. In der Zeit 1994/95 gab es eine große Zahl offener Professorenstellen, sodass ein großes Ungleichgewicht zwischen Studierenden und Professoren entstand. In der Zeit um 2001/02 gab es nach den Hypes DotCom, den Umstellungen aufgrund des Jahres 2000 und der Einführung des Euro einen so großen Sog von Seiten der Industrie, dass zu wenige Diplomiertere/ Master für die Promotion an der Universität zurückblieben. Dies führte dazu, dass viel zu wenige Mitarbeiter für die Betreuung der Vielzahl der Studierenden vorhanden waren. Die Situation löste sich für uns glücklicherweise durch das Platzen der Blasen. Beide Phasen waren kritisch in dem Sinne, dass der langfristige Erfolg der Fachgruppe ernsthaft gefährdet war.

Abb. 3 gibt *wichtige Projekte* und Ereignisse der hier *betrachteten 20 Jahre* wieder. Wir konzentrieren uns dabei auf die Projekte mit *Finanzierung* durch die *Deutsche Forschungsgemeinschaft*, da diese mit einer größeren Reputation und Außenwahrnehmung verbunden sind.

Hier ist die *Forschergruppe* SUKITS von 90 bis 87, der *Sonderforschungsbereich* IMPROVE von 1997 bis 2006 und der *Transferbereich* 61 am Ende des SFB bis 2009 zu nennen. Ende 2011 kam die neue Forschergruppe Hybris hinzu. Weitere Beteiligungen an Sonderforschungsbereichen betreffen die SFBs 401, 427, 540 und 686. Auch bezüglich der Einwerbung von *Graduiertenkollegs* war die Fachgruppe überaus erfolgreich. Das begann mit dem GK „Informatik und Technik“ von 1991 bis 2000, dem nachfolgende GK „Software für Kommunikationssysteme“ von 2000 bis 2010. Im Jahre 2005 kam noch das neue Graduiertenkolleg AlgoSyn hinzu.

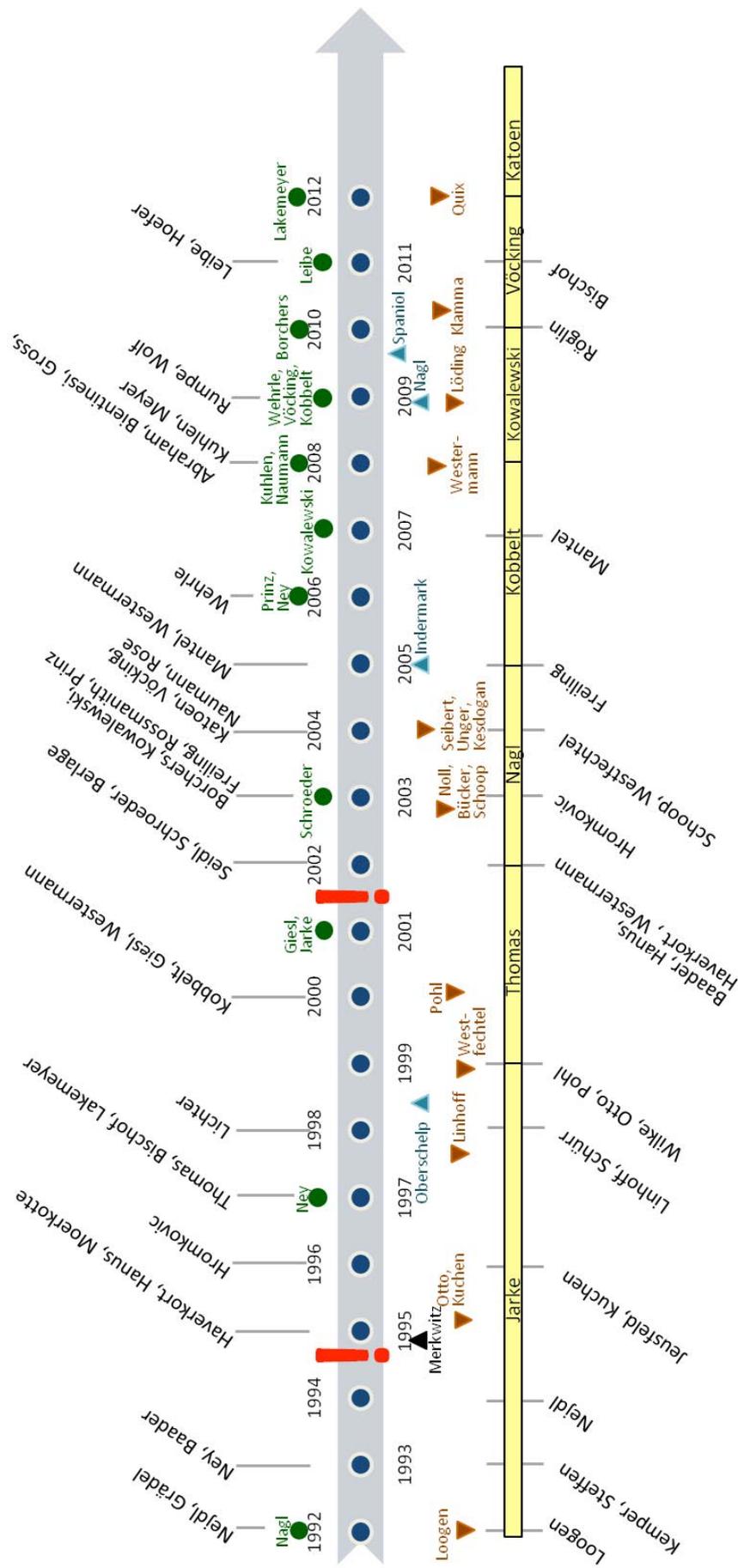


Abbildung 2: Meilensteine der Entwicklung: Professorenbilanz

Schließlich gaben die erfolgreichen Beteiligungen an diversen Maßnahmen der *Exzellenzinitiative* der Fachgruppe großen Auftrieb und auch einen erheblichen finanziellen Zuwachs. Hier ist in erster Linie das *Exzellenzcluster* UMIC – Fachgruppe Informatik zusammen mit der Fakultät für Elektrotechnik und Informationstechnik – zu nennen. Auch an dem Exzellenzcluster der Produktionstechnik ist die Fachgruppe beteiligt. Eine merkbare Beteiligung der Fachgruppe gibt es ferner bei der *Graduiertenschule* AICES.

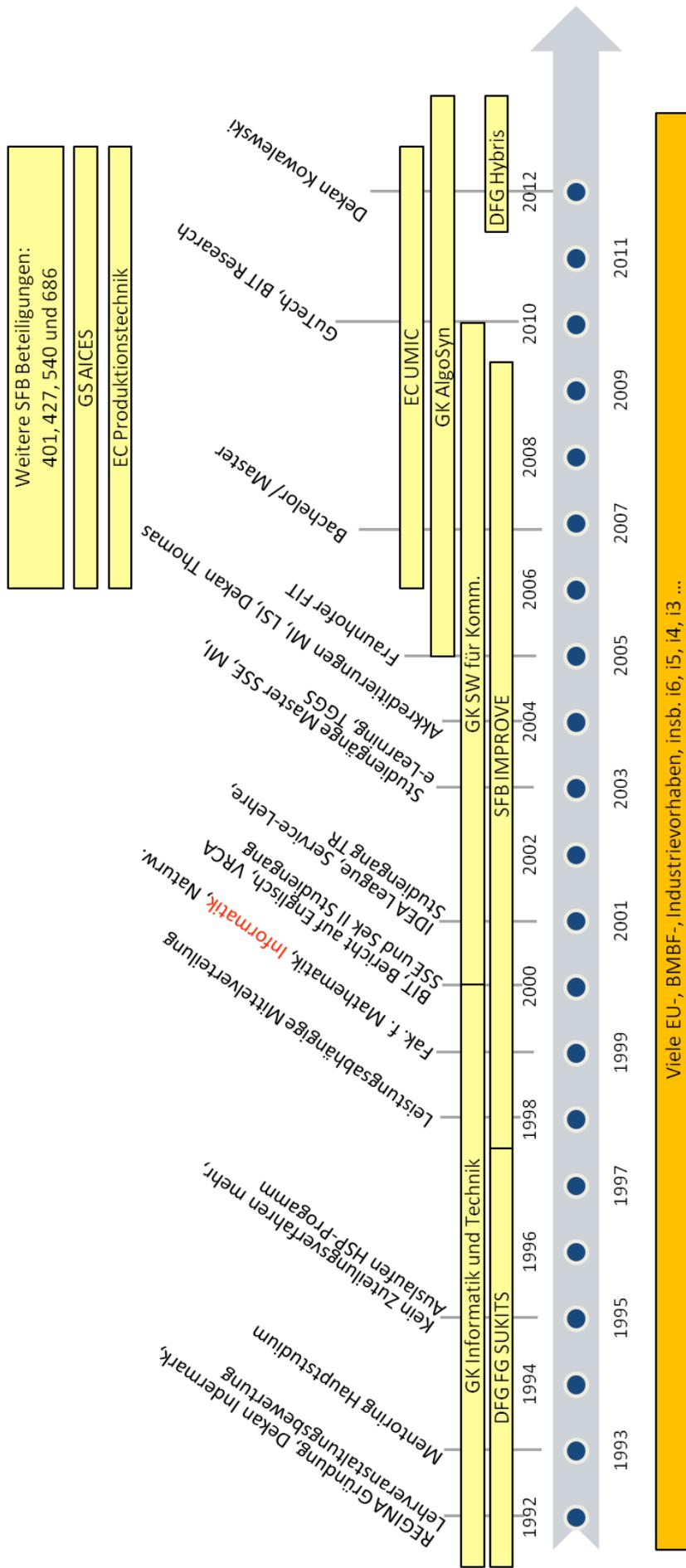
Wenn nicht ausgeführt, so doch erwähnt werden sollen die *zahlreichen weiteren Projekteinwerbungen* bei *EU-, BMBF-, Industrie-, NRW-Landesprojekten* und diversen *Stiftungen* mit einem erheblichen Finanzvolumen, an dem in erster Linie und in absteigender Reihenfolge die Lehrstühle Informatik 6, 5, 4 und auch 3 beteiligt waren.

Oberhalb der horizontalen Balken, die die erwähnten Projekte charakterisieren, finden sich noch *wichtige Ereignisse der letzten zwanzig Jahre*. Erlauben Sie, dass ich mich auf wenige beschränke. Im Jahre 1992 fand die Gründung des Regionalen Industrieclubs Aachen (*REGINA*) statt, der mit der Fachgruppe seitdem eng verflochten ist. Im Jahre 1999 wurde die *Fakultät* in Fakultät für Mathematik, Informatik und Naturwissenschaften *umbenannt*. 2000 wurde das bereits erwähnte *BIT* gegründet, 2010 BIT Research. Im Jahre 2000 und 2003 wurde die *neuen Studiengänge* Software Systems Engineering und Media Informatics eingerichtet, im Jahre 2003 und 2010 die auswärtigen „Ableger“ der RWTH Thai-German Graduate School (*TGGS*) in Bangkok und German University of Technology in Oman (*GUTech*) in Muscat. Diese Studiengänge und Ausgründungen haben wesentlich zur *Internationalisierung* der Fachgruppe beigetragen.

Aus Platzgründen nicht erwähnt werden können die zahllosen *Preise, Ehrungen, Ämter, gewonnenen Wettbewerbe, Tagungen, geschriebenen und herausgegebenen Bücher und Artikel mit Auszeichnungen* sowie die Vielzahl durchgeführter *Feste*, die allesamt aufgrund der engagierten Arbeit der Aachener Wissenschaftler errungen, erzielt und gefeiert wurden. Dies alles hat das Ansehen außerhalb Aachens verstärkt.

Lassen Sie mich diesen Abschnitt mit einer *zusammenfassenden Charakterisierung* abschließen: Die Fachgruppe Informatik ist eine Mannschaft überaus engagierter Wissenschaftler. Sie ist forschungsstark und hat ein anwendungsbezogenes Profil, das auf Theorie baut. Sie ist offen für verschiedene Formen der Zusammenarbeit mit anderen Disziplinen in und außerhalb der RWTH, mit der Industrie und mit großen Forschungseinrichtungen. Sie ist international sichtbar durch Veröffentlichungen, internationale Studiengänge und Studierende aus dem Ausland sowie durch Ableger der RWTH in Thailand und Oman und auch viele internationale Kontakte und Zusammenarbeiten. Die Fachgruppe ist verbunden mit der regionalen Industrie über REGINA sowie auch mit der überregionalen Industrie in Deutschland, der EU und darüber hinaus.

Natürlich ist das *nicht nur eine Leistung der Wissenschaftler*, also der Professoren und der wissenschaftlichen Mitarbeiter. Bereits erwähnt wurden die Bibliothek, der Rechnerbetrieb Informatik sowie das RKZ der RWTH. Allgemein aufzuführen sind hier die Leistung der nichtwissenschaftlichen Mitarbeiter und insbesondere auch die der Studierenden, die über ihre Examensarbeiten zur wissenschaftlichen Arbeit merklich beitragen. Zu benennen ist hier auch die Fachschaft, also die Vertretung der Studierenden, die zu der Fachgruppe Informatik ein überaus konstruktives Verhältnis entwickelt hat.



... viele Preise, Ehrungen, Ämter, gewonne Wettbewerbe, Tagungen, Bücher und Feste

Abbildung 3: Meilensteine der Entwicklung: Ereignisse, Projekte

3. Vergleiche zwischen ehemals und jetzt

Im letzten Hauptabschnitt möchte ich anhand einiger Beispiele den Ausbaustand zu Beginn und zu Ende des Berichtszeitraums¹ einander gegenüberstellen. Dies gibt einen plastischen Eindruck von der *rasanten Entwicklung der Fachgruppe Informatik* in den letzten 20 Jahren.

Beginnen wir mit den *Professoren*. Abb. 4 zeigt links die Gruppe der Professoren vor dem Informatik-Gebäude im Jahre 1992 mit 7,5 Professoren, der Lehrstühle 1 bis 5, den beiden Lehrgebieten 2 und 3 und dem Lehrstuhl Angewandte Mathematik insbesondere Informatik, der halb zur Informatik und halb zur Mathematik zählte. Das auf der rechten Seite aufgenommene Bild von 2011, aufgenommen auf Rolduc bei einem Strategietreffen, ist, trotz der beiden einkopierten Damen Abraham und Meyer, mit 27 Personen (von 31) nicht vollständig. Der Vergleich der Bilder zeigt somit das rasante Anwachsen der Fachgruppe.

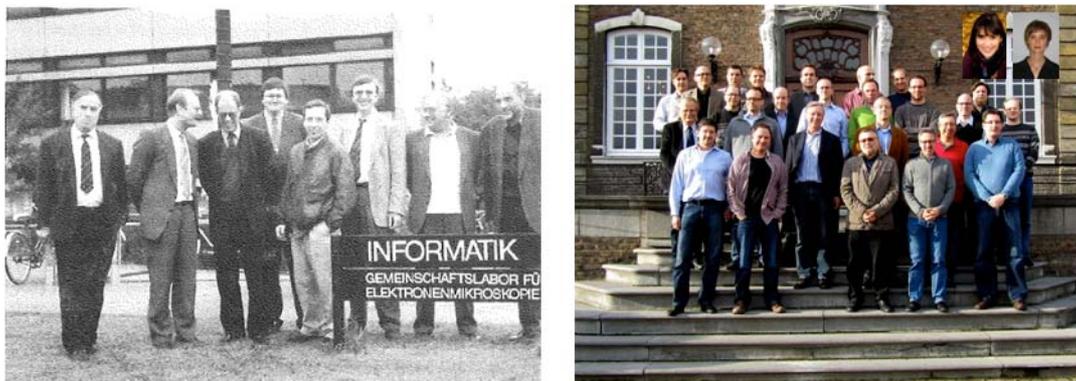


Abbildung 4: Professoren 1992 (links) und 2011 (rechts)

Die nächste Abb. 5 zeigt einen Lageplan des Informatik-Zentrums Hörn. Von den dort erkennbaren *Gebäuden* war 1992 - siehe linken Teil der Abbildung - nur das Gebäude E1 (schraffiert) und ein einziges halbes Stockwerk des Gebäudes E2 der Fachgruppe zugeteilt. Auf der rechten Seite sehen wir den jetzigen Ausbaustand. Das gesamte Informatik-Zentrum Hörn incl. Altbau ist von der Fachgruppe belegt, mit Ausnahme eines Flures im Gebäude E2 (GFE). Inzwischen wurde zusätzlich noch je die Hälfte der Gebäude E1 und E2 aufgestockt, um Räume für die Fachgruppe zu schaffen. Für das Exzellenzcluster UMIC wurde ein weiteres, neues Gebäude errichtet, das teilweise von der Fachgruppe belegt ist. Schließlich befinden sich einige Gruppen auch im inzwischen erweiterten RKZ². Der Rest des Informatik-Zentrums Hörn sind Hörsäle und Seminarräume, die hauptsächlich von der Informatik genutzt werden. Das neue Gebäude E3, das 2013 fertiggestellt sein soll, befindet sich in Planung.

Das nächste Bild (Abb. 6) zeigt links die *Anzahl der wissenschaftlichen Mitarbeiter* wieder in den beiden Vergleichsjahren. Im Jahre 1992 gab es in der Fachgruppe 63,5 wissenschaftliche Mitarbeiter, 35 vom Land NRW bezahlt und 28,5 über eingeworbene Drittmittel, also ein Verhältnis von 1: 0,81. Dem gegenüber finden wir 2012 eine Zahl von 189 wissenschaftlichen Mitarbeitern, davon 44 vom Land und 145 aus Drittmitteln. Die entspricht jetzt einem Verhältnis eines vom Land bezahlten Mitarbeiters zu 3,3 Drittmittel-Mitarbeitern. Der Ausbau des Personals wurde somit fast ausnahmslos durch selbst und von außen eingeworbene Drittmittel erzielt. Das Verhältnis 1: 3,3 spricht zwar für die Qualität und das Engagement der Fachgruppe. Meines Erachtens wurde hier aber bereits eine sinnvolle Schwelle überschritten.

¹ Gegenüberstellung meist mit 2011; das Jahr 2012 war zum Zeitpunkt des Vortrags nicht einmal zur Hälfte abgelaufen.

² Die Gebäude von UMIC und RKZ sind in der Abbildung nur als Verweise zu erkennen.

In der Abb. 7 finden wir die *Drittmittelzahlen* der Fachgruppe, die natürlich hauptsächlich aus der Bezahlung von Drittmittel-Mitarbeitern herrühren. Wir sehen, dass das Volumen von 2,68 im Jahre 1992 auf 14,7 Mio. € im Jahre 2011 angewachsen ist. Das ist ein Vergrößerungsfaktor von 5,5! Selbst wenn man den Betrag von 2,68 aus dem Jahre 1992 mit einer jährlichen Inflationsrate von 3% korrigiert, ergibt sich immer noch ein Zuwachs mit dem Faktor 3. Dabei sind die Drittmittel der Fraunhofer-Gruppe bei den Zuwächsen nicht eingerechnet.



Abbildung 5: Nutzfläche für die Informatik: 1992 (links) und jetzt (rechts)

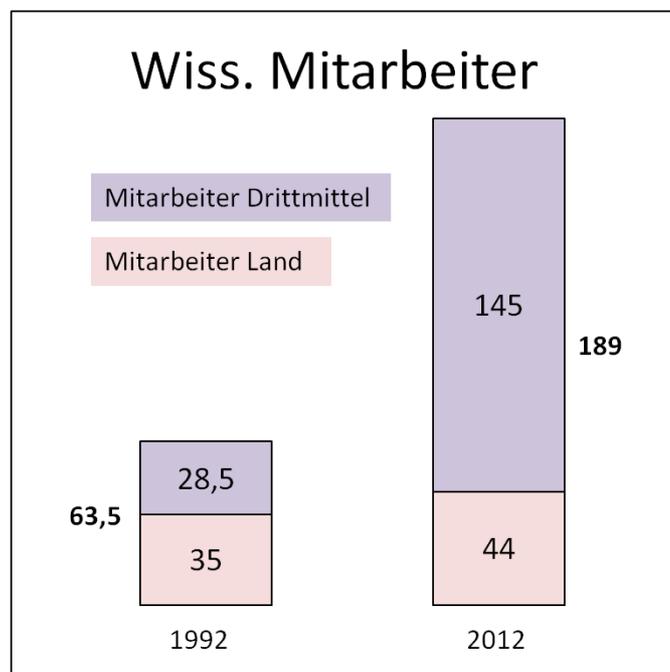


Abbildung 6: Wissenschaftliche Mitarbeiter in der Informatik: 1992 (links) und jetzt (rechts)

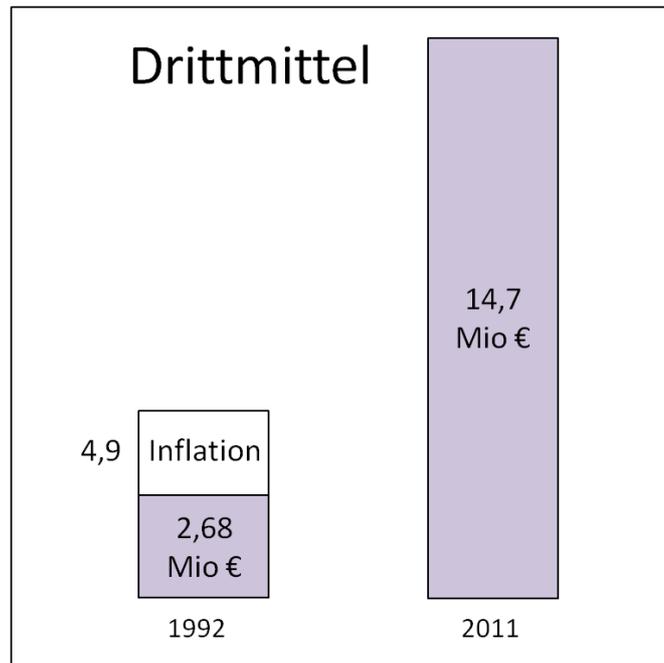


Abbildung 7: Drittmittel in der Informatik: 1992 (links) und 2011 (rechts)

In der Abb. 8 stellen wir einige *Kennzahlen* über *Abschlüsse* und *Arbeiten* für die beiden Vergleichsjahre einander gegenüber. Die *Studierendenzahlen* (alle Studierenden, die mit Informatik zu tun haben) haben sich verdoppelt. Das Gleiche trifft für die Master- bzw. Diplom-*Abschlüsse* zu. In Zukunft kommt aber noch etwa die gleiche Zahl von Bachelor-Arbeiten und -Abschlüssen hinzu. Wir hoffen, dass die überwiegende Zahl der Bachelors für den Master bleibt und noch von außen weitere dazukommen. Die Zahl der *Doktorprüfungen* hat sich versechsfacht. Interessant ist auch, wie viele *Abschlussarbeiten* (Diplom-/Masterarbeiten bzw. Doktorarbeiten) *in englischer Sprache* abgefasst werden. Bei Diplom-/ Masterarbeiten stieg der Anteil von 0 auf 40%, bei Doktorarbeiten hat er sich von 40% auf 80% verdoppelt.

Einige Vergleiche		
Stud.	1325	2650
Abschlüsse	89 D	186 D, Ma + 107 Ba
Dr. + Hab.	5 + 1	36 + 1
Arbeiten in Englisch	0% D 40% Dr.	40% D, Ma 80% Dr.
	1992	2011

Abbildung 8: Vergleichszahlen für die Informatik 1992 und 2011

Wir sehen also fast überall einen allgemeinen *Zuwachsfaktor* von 3 oder mehr. Dies spiegelt sich in auch in der Dicke der Jahresberichte wider. Ich habe Ihnen den von 1992 mit 178 Seiten und den von 2011 mit 504 Seiten mitgebracht; der Bericht für 2012 wird erst gegen Ende des Jahres fertiggestellt sein.

4. Zukunft und Reflexion

Die Fachgruppe Informatik steht – wie die Informatik in Deutschland und auch weltweit – vor *großen Herausforderungen*. *Informatiklösungen* sind *zukünftig* in einem vierfachen Sinne eingebettet: Wir hatten bereits in den letzten 10 Jahren (1) einen dramatischen Zuwachs an Lösungen und benötigten Arbeitskräften für eingebettete Systeme (z.B. Robotersteuerung), also Softwaresystemen, die in technische Systeme eingebettet sind. Diese eingebetteten Systeme sind (2) meist in weitere technische oder organisatorische Systeme eingebettet. Beispiele hierfür sind Produktions- und Lieferketten und allgemein Geschäftsprozesse in Unternehmen. Es ergibt sich also die Notwendigkeit zu einer weiteren Integration. Eine zusätzliche Einbettung erfolgt (3) auch in den örtlichen Kontext, der auch beweglich sein kann, und wiederum aus vielen Einbettungen bestehen kann (z.B. Internet der Dinge). Schließlich ist alles (4) in das globale Netz Web einzubetten, mit zukünftig eher semantischen Ausprägungen (Web 2.0 oder 3.0).

Somit sind zukünftige Lösungen *verteilt*. Sie sind auch oft *mobil*. Sie sind in verschiedenem Sinne eng *integriert*. Sie müssen auch *flexibel* sein, da nicht für jede Änderung ein neuer Entwicklungsprozess begonnen werden kann. Schließlich müssen sie den jeweiligen *Kontext berücksichtigen* und sie müssen auch *personalisierbar* sein, um den Charakteristika der Nutzer zu genügen. Der Bau entsprechender Systeme muss *besser verstanden* sein, um mit vertretbarem Aufwand zu neuen Lösungen zu kommen bzw. Lösungen auf den neuen Stand zu bringen. Will man hier saubere, effiziente Systeme mit umfassender Funktionalität bauen und später warten, so stellen sich viele *neue Forschungsfragen*, von den Gebieten der Theorie bis hin zu allen Gebieten der Praktischen und Angewandten Informatik.

Diese Fragen entsprechen dem Profil der Fachgruppe. Deren *Forschungsprofil*, praxisbezogen mit theoretischer Fundierung, Verbindung zu den Anwendungen, insbesondere aus den Ingenieurwissenschaften, wird auch andernorts angestrebt. Die Fachgruppe ist aufgefordert, ihr Profil und ihre Sichtbarkeit nach außen durch weitere *Anstrengungen* zu erhalten. Andere Fakultäten sind uns auf den Fersen! Insbesondere wollen wir auch das *Profil und die Qualität der Ausbildung* – auch hier die Verbindung von Theorie, Praxis und Anwendungen – bewahren, damit unsere Absolventen den ihnen gestellten Aufgaben genügen und sich weiterhin in der Industrie behaupten.

Natürlich haben wir auch *Schwachpunkte*. So ist der *Frauenanteil* auf der Ebene der Studierenden, Absolventen, Promovenden und insbesondere auch der Professoren zu niedrig. Das Gleiche gilt auch für die *Internationalisierung*, insbesondere für Mitarbeiter und Professoren. Schließlich ist – angesichts der demografischen Entwicklung – ein deutliches Engagement auf dem Gebiet der *Weiterbildung* für Mitarbeiter aus der Industrie nötig, eine Aufgabe, deren Bedeutung und Notwendigkeit bisher weder von den Universitäten noch von der Industrie ernsthaft wahrgenommen wurde.

Für Leistung ist auch Muße nötig. Ich habe oben bereits auf das bereits bedenkliche Maß hingewiesen, in welchem wir uns heute die Mittel selbst beschaffen müssen. Der Leistungsdruck wurde durch die Exzellenzinitiative noch einmal bedenklich verschärft. Die hochschulpolitischen Veränderungen sind nicht unbedingt kreativitätsfördernd: Umstellung auf das Bachelor-/ Master-System; allenthalben Messung jeglicher Leistung, auch wenn man gar nicht weiß, was Leistung überhaupt ist; die Verminderung der Zeit für eigentliche Wissenschaft, weil

mehr Aktivitäten auf den Ebenen Management oder Marketing erforderlich sind; der erhebliche Aufwand, der derzeit in politische Arbeit gesteckt werden muss, damit in Zukunft das Arbeitsumfeld für wissenschaftliches Arbeiten überhaupt noch gegeben ist. Die Liste ließe sich beliebig fortsetzen. Unser Arbeitsumfeld Universität hat einen Weg beschritten, bei dem die Gefahr droht, dass in Zukunft Qualität durch Aktionismus ersetzt wird.

Die Fachgruppe Informatik ist eine gute Mannschaft, mit vielen sichtbaren Erfolgen, die in der RWTH und außerhalb der RWTH, auch international, wahrgenommen werden. Die Herausforderungen sind groß, wenn der Status quo gehalten werden soll oder noch einmal gesteigert werden soll. Es sind also weitere und *vielfältige Anstrengungen* nötig. Hoffentlich verbleibt dabei genügend *Zeit für die eigentliche Arbeit in Forschung und Lehre*. Konzentrieren wir uns also auf das Wesentliche und hoffen wir, dass uns für dieses Wesentliche auch die entsprechende Zeit eingeräumt und der nötige Rahmen mit entsprechenden Ressourcen geboten wird!

Honorary Doctorate for Professor John Mylopoulos

On May 11, 2012, John Mylopoulos Ph.D., Professor Chiara Fama at the University of Trento/ Italy, and Professor emeritus at the University of Toronto / Canada, was awarded the degree of Doctor honoris causa by the Faculty of Mathematics, Informatics, and Natural Sciences, RWTH Aachen University. The citation, handed over by Rector Prof. Dr. Ernst Schmachtenberg, focused on his role as the father of formally based conceptual modeling.

Professors Matthias Jarke (Information Systems, RWTH Aachen, and Chairman, Fraunhofer ICT Group) and Wolfgang Marquardt (Process Engineering, RWTH Aachen, and Chairman, German National Science Council) shared the laudatory speech. In his part, Jarke used a Social Network Analysis to highlight the central role of John Mylopoulos in interlinking the fields of software engineering, artificial intelligence, and databases through conceptual modeling; indeed, John Mylopoulos is the only individual ever who has been program chair of the top conferences in all three fields. His continued research impact has recently been documented by his award of an ERC Advanced Grant. Wolfgang Marquardt gave impressive examples how the conceptual modeling approaches fostered by John Mylopoulos have also transcended other engineering fields, especially the process modeling in chemical engineering.

John Mylopoulos is the third honorary doctoral graduate of the Informatics department whose 40th anniversary had been celebrated by a colloquium earlier in the day. His two predecessors Jan van Leeuwen and Reinhard Wilhelm also participated in the awards ceremony, as did many friends and colleagues from Germany, Europe, and North America, in addition to a large turn-out from within the Informatics department and the rest of RWTH Aachen. The award ceremony was followed by a festive dinner in Aachen's historic City Hall which lasted well into the night.



Rector Ernst Schmachtenberg and Senate President Wolfgang Thomas officially handed over the honorary degree certificate.



The two first honorary doctorate holders Professors Jan van Leeuwen (second from right) and Reinhard Wilhelm (third from left) were among the first to congratulate John Mylopoulos

Matthias Jarke turns 60

This year, Prof. Dr. Matthias Jarke, who holds the Chair Informatik 5 (Information Systems) turned 60. Traditionally, such an occasion is commemorated by a celebratory colloquium. It took place on 1 June and was formally opened by Prof. Joost-Pieter Katoen, the Head of the Computer Science Department. His introductory remarks highlighted Prof. Jarke's many achievements during his 20+ years at RWTH.

Two of Prof. Jarke's long-standing international collaborators, Tung X. Bui (University of Hawaii) and Yannis Vassiliou (National Technical University of Athens) saw to the international flavour of the event. They talked about 'Decision Support Systems and Digital Economies' and 'Information Systems Engineering', respectively.

Tradition has it that some of the honouree's 'academic children' also contribute to the programme of such events. In this case, Manfred Jeusfeld (PhD 1992), now with Tilburg University, gave a talk entitled 'ConceptBase = Meta-Object Facility plus Resource Description Framework'. Subsequently, Klaus Pohl (PhD 1995; University Duisburg-Essen) and Peter Peters (PhD 1996; McKinsey & Company) talked about 'Requirements and Software Engineering'.

Matthias Jarke's other hat is that of the Director of the Fraunhofer Institute for Applied Information Technology (FIT). Accordingly, Wolfgang Prinz, Head of the 'Cooperation Systems' department at FIT also gave a talk entitled 'Human-centered Computing in a Process Context'.

After the coffee break, this was followed by a presentation given by Ulrich Trottenberg (University of Cologne), Matthias' predecessor as Director of FIT. He presented the research centre 'Schloß Birlinghoven', where FIT is based.

The colloquium came to an end with some concluding remarks from Joost-Pieter Katoen.

It should be mentioned that on the occasion of his 60th birthday Matthias was also presented with the Fraunhofer Medal in recognition of his outstanding services to Fraunhofer-Gesellschaft (see below).



24. Open Day - Tag der Informatik

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. Traditionally, the event takes place on the first Friday in December. In 2011, the event was organised by the Chair of Computer Science 6 (Human Language Technology and Pattern Recognition).

Traditionally the event starts after lunch with an informal get together. This time, welcome addresses were given by RWTH's Vice-Rector Prof. Dr. Aloys Krieg, the Dean of the Faculty of Mathematics, Computer Science and Natural Sciences, Prof. Dr. Gerhard Hiß, and by the Head of the Department of Computer Science, Prof. Dr. Berthold Vöcking. This was followed by the introduction of the new Faculty members, Prof. Dr. Martin Hoefer, (Algorithmic Game Theory) and Prof. Dr. Bastian Leibe (Mobile Multimedia Processing) who briefly presented their respective fields of research.

The keynote speech was given by Dr. Jean-Luc Gauvain of the Computer Sciences Laboratory for Mechanics and Engineering Sciences (LIMSI) in Paris. The talk was entitled 'The Quaero project and spoken language processing for multimedia search in unstructured data'.

After the coffee break the ever popular 'One Minute Madness' (OMM) offered a number of junior researchers an opportunity to present their work to a not necessarily expert audience. OMM requires to do this presentation within 100 seconds ('One Hundred Second Madness' doesn't sound nearly as good as the original title) and with one non-animated slide. It's mostly entertaining and good fun.



The subsequent graduation ceremony was introduced by witty talks held by Prof. Dr. Klaus Indermark, Emeritus and the representative of the Alumni Club Dietrich Hunold. As part of the ceremony, several awards and prizes were given to outstanding graduates by different sponsors.

For many, the traditional evening banquet and After TdI party are the day's highlights. Here, the graduates, their families, many current students and alumni, the CS department staff and many visitors from industry and academia gather in a convivial with amply food and drink.

InfoCup 2011 BY SOPTIM

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 1 July. Twelve teams had registered. Accordingly, the group phase comprised three groups with 6 teams each.

The teams and the groups:

Group A	Group B	Group C
UMIC	FS	i8/MMP
i6	i1	i7/mgi
i10	i4	i11
i2	i12	i5/LuFGi9

All team in Group A played on a similar level. At the end of the day, teams UMIC and i10 made the Quarter Finals, as die team i6 as 'lucky loser'. Team i4 clearly dominated Group B; teams i12 and i1 (the second lucky loser) also survived the preliminaries. Not unlike Group A, Group C was a very homogeneous group. While teams i8/MMP and i11 went through to the Quarter Finals, team i7/mgi very narrowly failed. Last year's winner, i5, didn't stand a chance this time. Bet the overall 'red lantern' was won by the Student Council's team.

The Quarter Finals brought some surprises. i4 lost to i6, i11 and i12 were also eliminated despite their respective strong performance in the preliminaries. As a result, all three teams from Group A were in the Semis, together with i8/MMP. Here, UMIC won on penalties against i8/MMP, and i10 repeated their victory in the preliminaries against i6, who also lost the match for third place to i8/MMP.



Similarly, the Finals saw a rematch between UMIC and i10. Yet, this time i10 came of better with a last minute goal; the end result was 2-1. Congratulations.

The final ranking:

1. i10
2. UMIC
3. i8/MMP
4. i6

5. i11

6. i12

7. i4

8. i1

9. i2

10. i5/LuFGi9

11. i7/mgi

12. Students Council

Players and spectators let the day gently fade away with the traditional After-Soccer-Party, enjoying the barbecue and the cold beer.

Computer Science Summer Party – Sommerfest der Informatik

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 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 this year's summer party.

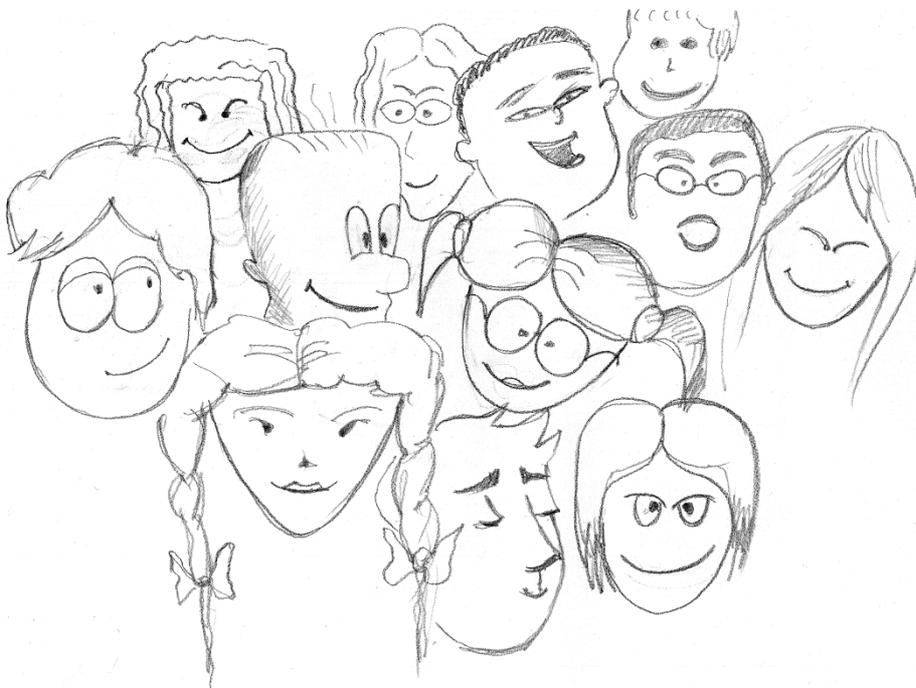
Said official ceremony was followed by the – less formal – party proper. A small(ish) buffet and plenty of drinks were on offer. The typical crowd of about 600 people attended the events, including the graduates and their families, current students, most of the staff of the computer science department, and several guests from other departments.



Bright Brains in Computer Science – Helle Köpfe in der Informatik

Starting seven years ago, the Department of Computer Science joined the support program *Aachener Model* for highly talented pupils from elementary schools in city and county of Aachen, which was continued since then. An external steering committee selected 16 children who attend the new program called *Helle Köpfe in der Informatik – Bright Brains in Computer Science*. During eight course meetings, faculty members of the Department of CS introduced the talented pupils to basic topics of computer science.

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



The seminar set in 2010 had the following topics:

- Computer, Campus, Cleverness: erstes RWTH-Rendezvous (Helen Bolke-Hermanns)
- Warum kann man eine CD zerkratzen? (Peter Rossmannith)
- Suchen und Sortieren (Thomas Seidl)
- Die Nadel im Heuhaufen (Thomas Noll)
- Kara, der programmierbare Marienkäfer (Horst Lichter)
- Bunt ist meine Lieblingsfarbe (Jan Borchers)
- Rechnen mit Nullen und Einsen (Erika Abraham)
- Wie funktioniert das Internet? (Klaus Wehrle)

More Information and photos of all events can be found in the web:

[/www.helle-koepfe.informatik.rwth-aachen.de/](http://www.helle-koepfe.informatik.rwth-aachen.de/)

The experiences made were very positive, and the program will be continued in the next years.



Teaching

Contents and Curricula of the Various Computer Science Programmes

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. RStandard 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!

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 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 a response to the growing importance of computer science in all branches of science and society. A central issue in the school education of computer science is its broad understanding of computer science as a discipline which provides concepts and tools for the analysis and construction of information processing systems - a scope which clearly transcends "programming" and the ability to run software systems.

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

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

An overview of the curriculum

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

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

The essential 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 10 for German language classes. At present, about 80 students from 20 countries are enrolled in the programme.

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

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

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

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

Media Informatics Master Programme

Goals of the Programme

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

Formal Entrance Requirements

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

Special Entrance Requirements

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

General Description of the Programme

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

The programme is characterised by a significant proportion of research lab courses embedded in both basic and applied research of the participating Fraunhofer Institutes of Applied Information Technology (FIT), and Media Communication (IMK). Major topics include: digital interactive media, internet infrastructures, management of information, communication and security, knowledge management, visualisation, and virtual engineering on the basis of augmented reality. Special courses on modelling of spatial and mobile aspects, and on usage,

annotation, and retrieval of spatial data provide for a special focus in the important application domain of Geographical Information Systems. The programme of study also includes methodological aspects of designing media informatics systems from the perspectives of software engineering, usability, media design, and business requirements.

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

Career Opportunities

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

Language of Instruction

The Programme will be taught completely in English

Duration of the Programme

Two years

Beginning of the Programme

October

Deadline for application:

March 1st the same year the programme starts

Further information

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

RWTH Aachen University

Chair Informatik 4

Media Informatics Team

52056 Aachen, Germany

E-Mail: msc-mi@b-it-center.de

Webpage: <http://mi.b-it-center.de/>

Courses Taught in 2012

Summer Term 2012

Diploma

Datenstrukturen und Algorithmen	Katoen, Heinen, von Styp - Rekowski, Dehnert	V (4)
Datenstrukturen und Algorithmen (Übung)	Katoen, Heinen, von Styp - Rekowski, Dehnert	Tut (2)
Datenstrukturen und Algorithmen (Globalübung)	Katoen, Heinen, von Styp - Rekowski, Dehnert, Raumverwaltung (Krüger)	Ü (2)
Klausur Datenstrukturen und Algorithmen	Katoen, Heinen, von Styp - Rekowski, Dehnert,	Kl
Systemprogrammierung	Kowalewski, Dernehl, Schommer, Betreuer	P (3)
Formale Systeme, Automaten, Prozesse	Thomas,	VT (3)
Formale Systeme, Automaten, Prozesse (Hörsaalübung)	Thomas, Olschewski, Otto	Ü (2)
Formale Systeme, Automaten, Prozesse (Gruppenübungen)	Thomas	Tut (2)
Klausur Formale Systeme, Automaten, Prozesse	Thomas,	Kl
Klausureinsicht Formale Systeme, Automaten und Prozesse	Thomas,	F
Lineare Algebra I für Informatiker	Hanke, Hiß,	V (3)
Lineare Algebra I für Informatiker	Hanke, Hiß,	Ü (2)
Klausur Lineare Algebra I für Informatiker	Hiß, Hanke,	KIT
Einführung in die angewandte Stochastik	Kamps	V (3)
Einführung in die angewandte Stochastik (Diskussion)	Kamps, Wang, Schmiedt	F (2)
Einführung in die angewandte Stochastik	Kamps, Wang, Schmiedt	Ü (1)
Prüfungsklausur Einführung in die angewandte Stochastik	Kamps, Cramer, Steland,	Kl
Prüfungsklausur Einführung in die angewandte Stochastik (Wdhl.)	Kamps, Cramer, Steland,	Kl
Klausureinsicht Einführung in die angewandte Stochastik	Kamps,	
Mathematische Logik	Löding, Grädel,	V (3)
Mathematische Logik	Löding, Grädel,	Tut (2)
Mathematische Logik (Diskussion)	Löding, Grädel,	F (1)
Klausur Mathematische Logik	Löding, Grädel,	Kl
Proseminar "Methoden und Werkzeuge"	Seidl, Hassani, Kranen	PS (2)
Datenstrukturen und Algorithmen (Übung)	Katoen, Heinen, von Styp - Rekowski, Dehnert	Tut (2)
Datenstrukturen und Algorithmen (Übung)	Katoen, Heinen, von Styp - Rekowski, Dehnert	Tut (2)
Softwarepraktikum: Implementierung	Katoen, Nguyen, Dehnert	PT (3)

heuristischer Algorithmen für Brettspiele		
Software-Projektpraktikum	Lichter, Hoffmann, Vianden	PT (3)
Software-Projektpraktikum Maschinelle Übersetzung	Ney, Huck, Freitag	VÜPT (4 (V1+Ü3))
Multimodal Media Madness	Borchers, Herkenrath, Völker, Krämer, Bohne,	VP (V1+P3)
Proseminar: Ausgewählte Kapitel der Computergraphik	Kobbelt, Sattler, Menzel	PST (2)
Künstliche Intelligenz	Lakemeyer, Schiffer, Niemüller, Beck, Schwering	PS (2)
Proseminar: Fortgeschrittene Programmierkonzepte in Java, Haskell und Prolog	Giesl, Otto, Emmes, Brockschmidt, Ströder	PS (3)

BSc

Algorithmen auf Graphen	Unger	PS (2)
Algorithmen auf Graphen I	Unger	S (2)
Algorithmen auf Graphen II	Seibert	S (2)
Applied Automata Theory	Thomas,	VT (3)
Applied Automata Theory	Thomas, Lang, Chaturvedi, N.N.,	Ü (2)
Applied Automata Theory (Exam)	Thomas,	KI
Betriebssysteme und Systemsoftware	Leibe, Bitsch Link, Weyand	Ü (2)
Betriebssysteme und Systemsoftware	Leibe, Bitsch Link, Weyand	V (3)
Betriebssysteme und	Leibe, Bitsch Link, Weyand	Ü (2)
Compilerbau	Noll, Naumann,	V (3)
Compilerbau	Noll, Jansen, Gretz	Ü (2)
Current Research Topics in Computer Graphics, Geometry Processing, and Computer Vision	Kobbelt, Leibe, Ebke, Kremer	S (2)
Current Topics in Computer Vision and Machine Learning	Leibe, Horbert	S
Datenbanken und Informationssysteme	Jarke, Klamma, Geisler, Hannemann, Terwelp,	VT (3)
Datenbanken und Informationssysteme	Jarke, Klamma, Geisler, Hannemann, Terwelp	Ü (2)
Datenkommunikation und Sicherheit (vormals: Sichere verteilte Systeme)	Wehrle, Thißen, Viol,	V (3)
Datenkommunikation und Sicherheit (vormals: Sichere verteilte Systeme) - Diskussionsstunde	Wehrle, Thißen, Viol	Ü (2)
Datenkommunikation und Sicherheit (vormals: Sichere verteilte Systeme) - Klausur	Wehrle, Thißen, Viol,	KI
Datenstrukturen und Algorithmen	Katoen, Heinen, von Styp - Rekowski, Dehnert	V (4)
Datenstrukturen und Algorithmen (Globalübung)	Katoen, Heinen, von Styp - Rekowski, Dehnert, Raumverwaltung (Krüger)	Ü (2)

Datenstrukturen und Algorithmen (Übung)	Katoen, Heinen, von Styp - Rekowski, Dehnert	Tut (2)
Die Softwaretechnik-Programmiersprache Ada 95	Nagl, Horst	VT (3)
Effiziente Algorithmen	Unger,	V (3)
Effiziente Algorithmen	Unger, Ochel, Geulen, Ries	Ü (2)
Einführung Anwendungsfächer im Bachelor Informatik	Schlüter,	
Einführung in die angewandte Stochastik	Kamps	V (3)
Einführung in die angewandte Stochastik	Kamps, Wang, Schmiedt	Ü (1)
Einführung in die angewandte Stochastik (Diskussion)	Kamps, Wang, Schmiedt	F (2)
Einführung in die angewandte Stochastik (Fragestunden)	Kamps, Wang, Schmiedt	F
Einführung in eingebettete Systeme	Kowalewski, Kamin	VÜ (3+1)
Einführung in High-Performance Computing	Bücker	VT (3)
Einführung in High-Performance Computing	Bücker	Ü (1)
Entwicklung NXT-gesteuerter LEGO-Fahrzeuge mit Java	Kowalewski, Hänsch, Kalkov	VPT (4)
Formale Systeme, Automaten, Prozesse	Thomas,	VT (3)
Formale Systeme, Automaten, Prozesse (Gruppenübungen)	Thomas	Tut (2)
Formale Systeme, Automaten, Prozesse (Hörsaalübung)	Thomas, Olschewski, Otto	Ü (2)
Foundations of Multi-Core Memory Models	Noll, Katoen, Yue, Wu, Gretz	S (2)
Funktionale Programmierung	Giesl	V (3)
Funktionale Programmierung	Giesl, Brockschmidt, Emmes	Ü (2)
Geschäftsmodelle und IT-Anwendungen in der Elektromobilität	Jarke, Bastian, Krempels, Terwelp	P (5)
Introduction to Knowledge Representation	Lakemeyer, Beck,	VÜT (3)
Klausur Betriebssysteme und Systemsoftware	Leibe, Bitsch Link, Weyand	KI
Klausur Compilerbau	Noll,	KI
Klausur Datenbanken und Informationssysteme	Jarke, Klamma,	KI
Klausur Datenstrukturen und Algorithmen	Katoen, Heinen, von Styp - Rekowski, Dehnert,	KI
Klausur Effiziente Algorithmen	Unger,	KI
Klausur Formale Systeme, Automaten, Prozesse	Thomas,	KI
Klausur Funktionale Programmierung	Giesl,	KI
Klausur Introduction to Knowledge Representation	Lakemeyer,	KIT
Klausur Lineare Algebra I für Informatiker	Hiß, Hanke,	KIT
Klausur Mathematische Logik	Löding, Grädel,	KI

Klausur Software-Qualitätssicherung	Lichter,	KIT
Klausureinsicht Einführung in die angewandte Stochastik	Kamps,	
Klausureinsicht Formale Systeme, Automaten und Prozesse	Thomas,	F
Kompressionsalgorithmen	Rossmann, Langer, Reidl	S (2)
Künstliche Intelligenz	Lakemeyer, Schiffer, Niemüller, Beck, Schwering	PS (2)
Lineare Algebra I für Informatiker	Hanke, Hiß,	V (3)
Lineare Algebra I für Informatiker	Hanke, Hiß	F
Lineare Algebra I für Informatiker	Hanke, Hiß,	Ü (2)
Mathematische Logik	Löding, Grädel,	V (3)
Mathematische Logik	Löding, Grädel,	Tut (2)
Mathematische Logik (Diskussion)	Löding, Grädel,	F (1)
Mentoring Informatik	Fachgruppe Informatik, Akbari, Leonhardt	ÜT
Mentoring Informatik NTW	Nagl, Fachgruppe Informatik, Akbari, Leonhardt	Tut
Mobile & Locations Based Augmented Reality (AR) App/Game Entwicklung	Rumpe, Akbari, Leonhardt	P (4)
Mobile Internet Technology	Wehrle, Thißen	VÜ (3+1)
Modellierung und Analyse hybrider Systeme	Abraham, Chen,	VÜT (3+1)
Modellierung und Analyse hybrider Systeme Prüfung	Abraham,	
Multimodal Media Madness	Borchers, Herkenrath, Völker, Krämer, Bohne,	VP (V1+P3)
Nachholklausur Betriebssysteme und Systemsoftware	Leibe, Bitsch Link, Weyand	KI
Netzwerke und Internet	Wehrle, Thißen,	PS (2)
Numerische Bibliotheken	Naumann	PS (2)
Probabilistic Method	Vöcking, Radke	S (2)
Proseminar: Ausgewählte Kapitel der Computergraphik	Kobbelt, Sattler, Menzel	PST (2)
Proseminar: Fortgeschrittene Programmierkonzepte in Java, Haskell und Prolog	Giesl, Otto, Emmes, Brockschmidt, Ströder	PS (3)
Prüfung Einführung in eingebettete Systeme	Kowalewski, Kamin,	KI
Prüfung Einführung in High-Performance Computing	Bücker,	KI
Prüfung Mobile Internet Technology	Wehrle, Thißen,	KI
Prüfungsklausur Einführung in die angewandte Stochastik	Kamps, Cramer, Steland,	KI
Prüfungsklausur Einführung in die angewandte Stochastik (Wdhl.)	Kamps, Cramer, Steland,	KI

Robuste Software für heterogene Netzwerke	Kowalewski, Schommer	S (2)
Satisfiability Checking	Giesl, Abraham, Otto, Emmes, Loup, Jansen, Brockschmidt, Ströder, Nellen, Corzilius	S (2)
Selected Topics in Human Language Technology and Pattern Recognition	Ney	ST (2)
Selected Topics in IT-Security and Cryptography	Meyer, Weingarten	ST
Seminar "Advanced Data Analysis"	Seidl, Ivanescu	ST (2)
Seminar Dynamische Systeme	Kowalewski, Hänsch	ST (2)
Seminar Robust Reliable Robotics	Lakemeyer, Niemüller, Schiffer, Belle, Beck	S (2)
Seminar über Automatentheorie	Thomas, Löding	S (2)
Seminar: Advanced Internet Technology	Wehrle, Thißen,	S (2)
Seminar: Aktuelle Themen der Virtuellen Realität	Kuhlen,	S (2)
Seminar: Mobile Internet Technology	Wehrle, Thißen,	S (2)
Seminar: Mobile Networks	Gross	S (2)
Software Engineering Seminar: Modellbasierte Softwareentwicklung	Rumpe, Mir Seyed Nazari	ST (2)
Software-Architekturen	Nagl, Horst	V (3)
Software-Architekturen	Nagl, Horst	ÜT (2)
Software-Architekturen	Nagl, Horst	MP
Software-Projektpraktikum	Lichter, Hoffmann, Vianden	PT (3)
Software-Projektpraktikum Maschinelle Übersetzung	Ney, Huck, Freitag	VÜPT (4)
Software-Qualitätssicherung	Lichter	VT (3)
Software-Qualitätssicherung	Lichter, Ganser, Dragomir	ÜT (2)
Softwarepraktikum "Developing a Pinball Game"	Kobbelt, Krecklau, Li,	P (4)
Softwarepraktikum: Implementierung heuristischer Algorithmen für Brettspiele	Katoen, Nguyen, Dehnert	PT (3)
Systemprogrammierung	Kowalewski, Dernehl, Schommer, Betreuer	P (3)
Theoretical Aspects of Distributed Computing in Sensor Networks	Vöcking, Keßelheim,	S (2)
Vorkurs Mathematik für Informatiker	Cramer, Kamps, Katzur	V
Web Science Seminar	Jarke, Klamma, Renzel	ST (2)
Zweite Klausur Effiziente Algorithmen	Unger,	KI

MSc

Accenture Campus Challenge 2011: Enterprise 2.0-Plattformen - Ideen- und Produktentwicklung auf Basis von nutzergenerierten Inhalten	Quix, Jarke	P (4)
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Advanced Data Models	Jarke, Quix, Li, Kastrati	VÜT (V3/Ü1)
Advanced Learning Technologies	Schroeder, Chatti, Thüs,	VÜ (3+2)
Advanced Learning Technologies - Masterexam	Schroeder, Chatti	MPT
Advanced Model Checking	Katoen,	V (3)
Advanced Model Checking	Katoen, Sher Vira, Chakraborty, Yue	Ü (2)
Algorithmen auf Graphen I	Unger	S (2)
Algorithmen auf Graphen II	Seibert	S (2)
Algorithmen und Komplexität	Vöcking	S (2)
Algorithmische Spieltheorie	Hoefler	V (3)
Algorithmische Spieltheorie	Hoefler	Ü (2)
Analyse von Algorithmen	Rossmann	V (4)
Analyse von Algorithmen (Klausur)	Rossmann,	KI
Analyse von Algorithmen (Übungen)	Rossmann, Langer, Reidl, Sikdar	Ü (2)
Applied Automata Theory	Thomas,	VT (3)
Applied Automata Theory	Thomas, Lang, Chaturvedi, N.N.,	Ü (2)
Applied Automata Theory (Exam)	Thomas,	KI
Arbeitsgemeinschaft Informationslogistik	Jarke, Krempels, Terwelp	AG (2)
Arbeitsgemeinschaft Metadata in Community Information Systems	Jarke, Klamma	AGT (2)
Arbeitsgemeinschaft Model Management	Jarke, Quix	AG (2)
Arbeitsgemeinschaft Programmverifikation	Giesl, Brockschmidt, Emmes, Otto, Plücker, Ströder,	Ü (2)
Arbeitsgemeinschaft: Communication Systems Engineering	Wehrle, Thißen	AG (3)
Arbeitsgemeinschaft: Mobile Communications	Wehrle, Thißen	AG (3)
Arbeitsgemeinschaft: Sensornetze	Wehrle, Thißen	AG (3)
Automatic Generation and Analysis of Algorithms	Bientinesi	VP V3/ÜE1
Automatic Generation and Analysis of Algorithms - Final Exam	Bientinesi	MP V3/ÜE1
Compilerbau	Noll, Naumann,	V (3)
Compilerbau	Noll, Jansen, Gretz	Ü (2)
CSCW und Groupware: Konzepte und Systeme zur computergestützten Zusammenarbeit	Prinz	VÜT (V2/Ü1)
Designing Interactive Systems II	Borchers, Wittenhagen, Heller, Lichtschlag,	VÜ (V3/Ü2)
Designing Interactive Systems II (Klausur)	Borchers, Wittenhagen, Heller, Lichtschlag	KI (V3/Ü2)

Die Softwaretechnik-Programmiersprache Ada 95	Nagl, Horst	VT (3)
Einführung in eingebettete Systeme	Kowalewski, Kamin	VÜ (3+1)
Einführung in High-Performance Computing	Bücker	VT (3)
Einführung in High-Performance Computing	Bücker	Ü (1)
Exploring High-dimensional Data: Advanced Mining Techniques	Seidl, Günemann,	VÜ (3+2)
Fortgeschrittene Methoden in der Automatischen Spracherkennung	Schlüter, Ney,	VÜ (3/1)
Foundations of Multi-Core Memory Models	Noll, Katoen, Yue, Wu, Gretz	S (2)
Funktionale Programmierung	Giesl	V (3)
Funktionale Programmierung	Giesl, Brockschmidt, Emmes	Ü (2)
Generative Softwareentwicklung	Rumpe, Schindler, Mir Seyed Nazari	VÜT (3+2)
Generative Softwareentwicklung - Prüfung	Rumpe,	KI
Geometrieverarbeitung	Kobbelt,	V (3)
Geometrieverarbeitung	Kobbelt, Dekkers, Schaefer	Ü (2)
Geometrieverarbeitung (Klausur)	Kobbelt,	KI
Globale Beleuchtung und Image-based Rendering	Kobbelt, Bachelor Informatik	V (3)
Globale Beleuchtung und Image-based Rendering	Kobbelt, Möbius, Frohn	Ü (2)
Globale Beleuchtung und Image-based Rendering (Klausur)	Kobbelt,	KI
Infinite Games	Löding	VT (3)
Infinite Games	Löding, Spelten	Ü (2)
Infinite Games (Exam)	Löding,	MP
Innovationen im Software Engineering	Rumpe, Hermerschmidt,	VT (2)
Innovationen im Software Engineering - Prüfung	Rumpe, Hermerschmidt	BPT (2)
Introduction to Knowledge Representation	Lakemeyer, Beck,	VÜT (3)
Klausur Advanced Data Models	Jarke, Quix,	KI
Klausur Compilerbau	Noll,	KI
Klausur Exploring High-dimensional Data	Seidl	KI
Klausur Funktionale Programmierung	Giesl,	KI
Klausur Introduction to Knowledge Representation	Lakemeyer,	KIT
Klausur Parallele Programmierung II	Wolf,	KI
Klausur Software-Projektmanagement	Lichter,	KI
Klausur Software-Qualitätssicherung	Lichter,	KIT
Klausur zu CSCW und Groupware: Konzepte und Systeme zur computergestützten	Prinz	KI

Zusammenarbeit		
Kombinatorische Probleme im Wissenschaftlichen Rechnen	Naumann	VÜ (2+2)
Kombinatorische Probleme im Wissenschaftlichen Rechnen	Naumann	KI
Kompressionsalgorithmen	Rossmann, Langer, Reidl	S (2)
Lehrstuhlkolloquium	Kowalewski	EK
Lehrstuhlseminar	Katoen, Giesl, Abraham	S (2)
Machine Learning	Leibe, Floros	VÜT (3+1)
Master-Mentorenprogramm: Angewandte Informatik		
Master-Mentorenprogramm: Daten- & Informationsmanagement		
Master-Mentorenprogramm: Software & Kommunikation		
Master-Mentorenprogramm: Theoretische Informatik		
Masterprüfung Fortgeschrittene Methoden in der Automatischen Spracherkennung	Ney, Schlüter,	MP
Mobile & Locations Based Augmented Reality (AR) App/Game Entwicklung	Rumpe, Akbari, Leonhardt	P (4)
Mobile Internet Technology	Wehrle, Thißen	VÜ (3+1)
Modellierung eines Solarturmkraftwerks	Abraham, Richter	P (4)
Modellierung und Analyse hybrider Systeme	Abraham, Chen,	VÜT (3+1)
Modellierung und Analyse hybrider Systeme Prüfung	Abraham,	
Network Simulation	Gross	V (3+1)
Parallele Programmierung II	Wolf,	VT (V3)
Parallele Programmierung II	Wolf,	Ü (Ü2)
Praktikum "Data Mining Algorithmen"	Seidl, Boden, Fries	P (4)
Praktikum Sensor-Netzwerke	Wehrle, Thißen	P (4)
Praktikum Virtuelle Realität	Kuhlen, Beer, Pick	PT (4)
Probabilistic Method	Vöcking, Radke	S (2)
Prozess Management	Rose	VÜ (V2/Ü1)
Prozesse und Methoden beim Testen von Software	Kriebel, Mir Seyed Nazari,	VT (V2)
Prozesse und Methoden beim Testen von Software - Klausur	Rumpe, Kriebel,	KIT
Prozessmanagement (Klausur)	Rose	KIT
Pruefung Sicherheit in der	Meyer	KI

Mobilkommunikation		
Prüfung Advanced Methods of Cryptography	Mathar,	KI
Prüfung Advanced Model Checking	Katoen	KI
Prüfung Algorithmische Spieltheorie	Hoefer,	MP
Prüfung Cryptography I	Mathar,	KIT
Prüfung Einführung in eingebettete Systeme	Kowalewski, Kamin,	KI
Prüfung Einführung in High-Performance Computing	Bücker,	KI
Prüfung Machine Learning	Leibe	MP
Prüfung Mobile Internet Technology	Wehrle, Thißen,	KI
Prüfung Network Simulation	Gross,	MP
Prüfung Sicherheit und Zuverlässigkeit softwaregesteuerter Systeme	Kowalewski,	KI
Prüfung Theorie Verteilter Systeme	Vöcking,	KI
Prüfung: Research Focus Class on Communication Systems	Wehrle,	MP
Research Focus Class on Communication Systems	Wehrle, Thißen	VÜ (V3+Ü2)
Robuste Software für heterogene Netzwerke	Kowalewski, Schommer	S (2)
Satisfiability Checking	Giesl, Abraham, Otto, Emmes, Loup, Jansen, Brockschmidt, Ströder, Nellen, Corzilius	S (2)
SCRUM-Basierte Software Entwicklung im Bereich Internet der Dinge	Jarke, Zimmermann	P (5)
Security Lab	Meyer, Neugebauer, Schloesser	P (4)
Selected Topics in Human Language Technology and Pattern Recognition	Ney	ST (2)
Selected Topics in IT-Security and Cryptography	Meyer, Weingarten	ST
Seminar "Advanced Data Analysis"	Seidl, Ivanescu	ST (2)
Seminar Dynamische Systeme	Kowalewski, Hänsch	ST (2)
Seminar Robust Reliable Robotics	Lakemeyer, Niemüller, Schiffer, Belle, Beck	S (2)
Seminar über Automatentheorie	Thomas, Löding	S (2)
Seminar: Advanced Internet Technology	Wehrle, Thißen,	S (2)
Seminar: Aktuelle Themen der Virtuellen Realität	Kuhlen,	S (2)
Seminar: Mobile Internet Technology	Wehrle, Thißen,	S (2)
Seminar: Mobile Networks	Gross	S (2)
Seminar: Mobile Networks	Gross	S (2)
Sicherheit in der Mobilkommunikation	Meyer, Gilger	VÜT (3+1)
Sicherheit und Zuverlässigkeit softwaregesteuerter Systeme	Kowalewski, Förster	VÜ (V3/Ü1)

Simplex in SMT	Abraham, Loup, Corzilius	P (4)
Software Engineering Praktikum: Smart Feedback Apps	Rumpe, Kurpick, Pinkernell, Look, Lindt	PT (4)
Software Engineering Seminar: Modellbasierte Softwareentwicklung	Rumpe, Mir Seyed Nazari	ST (2)
Software-Architekturen	Nagl, Horst	V (3)
Software-Architekturen	Nagl, Horst	ÜT (2)
Software-Architekturen	Nagl, Horst	MP
Software-Projektmanagement	Pricope, Lichter, Harun	VT (2)
Software-Projektmanagement	Lichter, Pricope, Harun	Ü (1)
Software-Qualitätssicherung	Lichter	VT (3)
Software-Qualitätssicherung	Lichter, Ganser, Dragomir	ÜT (2)
The Geometry Processing Pipeline	Kobbelt, Sibbing, Zimmer, Campen	PT (4)
The Media Computing Project (Praktikum Hauptstudium)	Borchers, Möllers, Wacharamanotham,	P (2)
Theoretical Aspects of Distributed Computing in Sensor Networks	Vöcking, Keßelheim,	S (2)
Theorie verteilter Systeme	Vöcking	V (3)
Theorie verteilter Systeme	Vöcking, Reiffenhäuser, Winkler	Ü (2)
Vorkurs Informatik	Lichter, Ganser, Katoen	VÜ
Web Science Seminar	Jarke, Klamma, Renzel	ST (2)

Winter 2012/13

Diploma

Klausureinsicht Einführung in die angewandte Stochastik (Wdh.)	Kamps	
Mensch-Maschine-Interaktion	Borchers, Wittenhagen, Krämer,	PS (2)
Proseminar "Elementary Data Mining Techniques"	Seidl, Hassani, Boden	PS (2)
Proseminar: Algorithmen und Werkzeuge für die Verifikation	Abraham, Jansen, Loup, Chen, Nellen, Corzilius	PS (2)
Unternehmensgründung und neue Medien	Jarke, Klamma, Renzel, Nicolaescu	PT

BSc

Advanced Internet Technology	Wehrle, Thißen,	V (3)
Analysis für Informatiker	Sander,	V (4)
Analysis für Informatiker	Sander,	Ü (2)
Analysis für Informatiker (Diskussion in Gruppen)	Sander,	Ü (2)

Automatic Speech Recognition	Schlüter, Ney,	V (4)
Automatic Speech Recognition	Schlüter, Ney, Nußbaum	ÜT (2)
Bachelorprüfung Einführung in statistische Klassifikation	Ney,	MP
Basic Techniques in Computer Graphics	Kobbelt,	V (3)
Basic Techniques in Computer Graphics	Kobbelt, Sattler, Menzel, Campen, Kremer	Ü (2)
Basic Techniques in Computer Graphics (Klausur)	Kobbelt,	KI
Berechenbarkeit und Komplexität (Globalübung)	Rossmannith, Langer, Reidl, Sikdar,	Ü (2)
Berechenbarkeit und Komplexität	Rossmannith	V (3)
Berechenbarkeit und Komplexität	Rossmannith	Tut
Current Research Topics in Computer Graphics and Geometry Processing	Kobbelt, Zimmer, Frohn	ST (2)
Data Mining Algorithmen	Seidl	VÜT (3+2)
Data Mining Algorithmen Prüfung	Seidl,	KIT,
Designing Interactive Systems I	Borchers, Völker, Corsten, Wacharamanatham,	VÜT (V3/Ü2)
Designing Interactive Systems I - Klausur	Borchers, Völker, Corsten, Wacharamanatham,	KI (V3/Ü2)
Die Softwaretechnik-Programmiersprache Ada	Nagl, Kurpick,	VT (3)
Die Softwaretechnik-Programmiersprache Ada	Nagl, Kurpick	ÜT (3)
Die Softwaretechnik-Programmiersprache Ada	Nagl, Kurpick	KI (3)
Diskrete Strukturen	Hanke, Hiß,	VÜ (3+1)
Einführung in die Technische Informatik	Kowalewski, Kalkov, Dernehl	V (4)
Einführung in die Technische Informatik	Kowalewski, Kalkov, Dernehl	Ü (2)
Einführung in statistische Klassifikation	Ney, Schlüter,	V (4)
Einführung in statistische Klassifikation	Ney, Wiesler, Lehnen	ÜT (2)
Entwurfs- und Programmierkonzepte mobiler Applikationen	Kowalewski, Franke	PS (4)
Erfüllbarkeitsüberprüfung (Satisfiability Checking)	Abraham, Corzilius, Jansen, Loup	VÜT (V3 Ü1)
Erfüllbarkeitsüberprüfung Prüfung	Abraham,	MP
Explorative Suche mit Lego Mindstorms Robotern	Abraham, Nellen,	P (3)
Formale Grundlagen der UML	Katoen	KI
Game Programming	Kobbelt	VPS (3)
Game Programming	Kobbelt, Sibbing, Möbius, Ebke	MP
Implementierung eines Brettspiels inklusive KI	Rossmannith, Langer, Reidl, Sikdar	VP (4)

Infinite Computations	Thomas,	VT (3)
Infinite Computations	Thomas, Chaturvedi,	Ü (2)
Infinite Computations (Exam)	Thomas,	KI
Introduction to Artificial Intelligence	Lakemeyer, Niemüller, Schwering,	VÜT (V3Ü2)
Introduction to Scientific Computing Languages	Bientinesi	VPT (V3/ÜE1)
Introduction to Scientific Computing Languages - Final Exam	Bientinesi,	MPT (V3/ÜE1)
iPhone Anwendungsprogrammierung	Borchers, Lichtschlag, Heller	VÜ (V3Ü2)
iPhone Anwendungsprogrammierung - Klausur (3 Credits)	Borchers, Lichtschlag, Heller,	KI (V3Ü2)
iPhone Anwendungsprogrammierung - Klausur (6 Credits)	Borchers, Lichtschlag, Heller,	KI (V3Ü2)
Klausur Analysis für Informatiker	Stens	KIT
Klausur Berechenbarkeit u. Komplexität	Rossmannith,	KIT
Klausur Berechenbarkeit und Komplexität (Wdhl.)	Rossmannith,	KI
Klausur Diskrete Strukturen	Hanke, Hiß,	KI
Klausur Diskrete Strukturen (Wdhl.)	Hanke, Hiß,	KI
Klausur Einführung in die Technische Informatik	Kowalewski,	KI
Klausur Implementierung von Datenbanken	Jarke, Quix, Kastrati, Li, Geisler	KI
Klausur Introduction to Artificial Intelligence	Lakemeyer, Niemüller, Schwering	KIT
Klausur Numerisches Rechnen	Grepl,	KIT
Klausur Numerisches Rechnen (Nachholtermin)	Grepl,	T
Klausur Programmierung	Giesl,	KI
Klausur: Advanced Internet Technology	Wehrle, Thißen,	KI (3+1)
Mathematische Logik II	Grädel,	V (3)
Mathematische Logik II	Grädel,	Ü (2)
Mensch-Maschine-Interaktion	Borchers, Wittenhagen, Krämer,	PS (2)
Mentoring Informatik	Fachgruppe Informatik, Akbari, Leonhardt	ÜT
Modellbasierte Softwareentwicklung	Rumpe, Hölldobler, Schindler,	VÜT (2+3)
Modellbasierte Softwareentwicklung	Rumpe, Schindler, Hölldobler	KIT
Numerisches Rechnen	Grepl,	V (3)
Numerisches Rechnen (Beratungstermin)	Grepl, Esser, Zhang, Berger	F (2)
Numerisches Rechnen (Großübung)	Grepl, Esser, Zhang, Berger	Ü (2)
Programmierung	Giesl, Brockschmidt, Emmes, Otto, Ströder,	V (4)
Programmierung (Globalübung)	Giesl, Brockschmidt, Emmes, Otto, Ströder,	Ü (2)
Programmierung (Übung - Tutorium)	Giesl, Brockschmidt, Emmes, Otto, Ströder,	Ü (2)

Proseminar Automatentheorie	Thomas, Löding,	PST (2)
Proseminar Datenkompression	Ney, Schlüter	PST (2)
Proseminar Informationstheorie	Grohe	PS (2)
Proseminar: Algorithmen und Werkzeuge für die Verifikation	Abraham, Jansen, Loup, Chen, Nellen, Corzilius	PS (2)
Prüfung Mathematische Logik II (mündlich)	Grädel,	MP
Rechnergestütztes Differenzieren	Naumann	VÜ (4)
Rechnergestütztes Differenzieren	Naumann	KI
Selected Topics in Human Language Technology and Pattern Recognition	Ney	S (2)
Seminar "Aktuelle Entwicklungen des Multimedia Retrieval"	Seidl,	ST (2)
Seminar Information Management in the Web	Quix, Jarke, Geisler, Kastrati	S (2)
Seminar Learning Analytics & Educational Data Mining	Schroeder, Chatti, Thüs	HS (2)
Seminar Logik und Komplexität	Grohe	S (2)
Seminar Parallele Programmierung	Wolf, Simulation Sciences Dozenten	S (1)
Seminar über Automatentheorie (Bachelor)	Thomas, Felscher,	ST (2)
Seminar über Automatentheorie (Master)	Löding, Lang,	S (2)
Seminar: Advanced Internet Technology	Wehrle, Thißen, Schmidt,	S (2)
Seminar: Logik, Komplexität, Spiele	Grädel,	ST (2)
Seminar: Mobile Internet Technology	Wehrle, Thißen, Schmidt,	S (2)
Software Engineering Praktikum (B.Sc.): Mobile & Locations Based Augmented Reality (AR) App/Game Entwicklung	Akbari, Leonhardt, Rumpe	P (4)
Software Engineering Praktikum (B.Sc.): Model-Based Robotics Software Development	Rumpe, Ringert, Wortmann	P (4)
Software-Architekturen	Rumpe, Nagl	VT (3)
Softwarepraktikum "Developing a Mini Racing Game"	Kobbelt, Krecklau, Li	PT (4)
Softwaretechnik	Rumpe, Horst,	VT (3)
Softwaretechnik	Rumpe, Horst,	Ü (2)
Softwaretechnik	Rumpe, Horst	KI
Systemprogrammierung	Kowalewski, Schommer, Gerlitz, Betreuer	P (3)
Turing-Award-Gewinner	Katoen, Noll,	PS (2)
Übung: Advanced Internet Technology	Wehrle, Thißen,	Ü (1)
Unternehmensgründung und neue Medien	Jarke, Klamma, Renzel, Nicolaescu	PT
Verifikationsverfahren	Giesl, Brockschmidt, Emmes, Fuhs, Otto, Ströder,	S (2)
Web Technologien (Web Tech 1) Bachelorprüfung	Schroeder, Chatti, Thüs,	
Web Technologien (WebTech 1)	Schroeder, Chatti, Thüs,	VÜ (3+2)

Master

Advanced Internet Technology	Wehrle, Thißen,	V (3)
Advanced Machine Learning	Leibe	VT (3+1)
Advanced Methods of Cryptography	Mathar,	V (2)
Advanced Methods of Cryptography	Mathar, Reyer, Maier	Ü (1)
Algorithmische Kryptographie	Unger	V (3)
Algorithmische Kryptographie	Geulen	Ü (2)
Angewandte Softwaretechnik im Lebenszyklus der Automobilelektronik	Rumpe, Schleicher, Müller	VT (V1Ü1)
Angewandte Softwaretechnik im Lebenszyklus der Automobilelektronik	Rumpe, Schleicher, Müller	KI (V1Ü1)
Arbeitsgemeinschaft Model Management	Jarke, Quix	AGT (2)
Arbeitsgemeinschaft: Advanced Community Information Systems	Jarke, Klamma	AGT (2)
Arbeitsgemeinschaft: Communication Systems Engineering	Wehrle, Thißen	AG (3)
Arbeitsgemeinschaft: Mobile Communications	Wehrle, Thißen	AG (3)
Arbeitsgemeinschaft: Probabilistic Model Checking	Katoen, Noll, Nguyen	S (2)
Arbeitsgemeinschaft: Programmverifikation	Giesl, Brockschmidt, Emmes, Fuhs, Otto, Plücker, Ströder	Ü (2)
Arbeitsgemeinschaft: Sensornetze	Wehrle, Thißen	AG (3)
Automatic Speech Recognition	Schlüter, Ney,	V (4)
Automatic Speech Recognition	Schlüter, Ney, Nußbaum	ÜT (2)
Basic Techniques in Computer Graphics	Kobbelt,	V (3)
Basic Techniques in Computer Graphics	Kobbelt, Sattler, Menzel, Campen, Kremer	Ü (2)
Basic Techniques in Computer Graphics (Klausur)	Kobbelt,	KI
Carolo Cup 2012	Kowalewski, Dernehl	P (4)
Computer Vision	Leibe	VÜT (3+1)
Current Research Topics in Computer Graphics and Geometry Processing	Kobbelt, Zimmer, Frohn	ST (2)
Das Graphisomorphieproblem	Grohe	VÜT (V3+Ü2)
Das Graphisomorphieproblem (Exam)	Grohe,	MP
Designing Interactive Systems I	Borchers, Völker, Corsten, Wacharamanotham,	VÜT (V3/Ü2)
Designing Interactive Systems I - Klausur	Borchers, Völker, Corsten, Wacharamanotham,	KI (V3/Ü2)
Die Softwaretechnik-Programmiersprache Ada	Nagl, Kurpick,	VT (3)

Die Softwaretechnik-Programmiersprache Ada	Nagl, Kurpick	ÜT (3)
Die Softwaretechnik-Programmiersprache Ada	Nagl, Kurpick	KI (3)
Dynamische Systeme für Informatiker	Kowalewski, Hänsch,	VÜ (3+1)
Einführung in die Bioinformatik	Berlage,	VT (2)
Einführung in statistische Klassifikation	Ney, Schlüter,	V (4)
Einführung in statistische Klassifikation	Ney, Wiesler, Lehnen	ÜT (2)
Entwicklung eines 3D Replikators	Kowalewski, Stollenwerk	P (2)
Erfolgreiche Anwendungen Formaler Methoden	Noll, Katoen,	S (2)
Erfüllbarkeitsüberprüfung (Satisfiability Checking)	Abraham, Corzilius, Jansen, Loup	VÜT (V3 Ü1)
Erfüllbarkeitsüberprüfung Prüfung	Abraham,	MP
Exploring Multimedia Data: Content-based Search and Retrieval	Seidl, Beecks, Ivanescu	VÜ (3+2)
Formale Grundlagen der UML	Katoen	KI
Formale Grundlagen von UML	Katoen,	V (3)
Formale Grundlagen von UML	Katoen	Ü (2)
Game Development	Kobbelt, Sibbing, Möbius, Ebke	P (4)
Game Programming	Kobbelt	VPS (3)
Game Programming	Kobbelt, Sibbing, Möbius, Ebke	MP
Generative Aspekte der Software Entwicklung in der Automotive Domäne	Rumpe, Berger	VT (V2)
Generative Aspekte der Software Entwicklung in der Automotive Domäne	Rumpe, Berger	KI
Hightech Entrepreneurship and new Media	Jarke, Klamma, Kravcik, Derntl, Hannemann	VPT (V1/ÜT4)
Implementation of Databases	Jarke, Quix, Kastrati, Li, Geisler	VÜT (V3/Ü1)
Infinite Computations	Thomas,	VT (3)
Infinite Computations	Thomas, Chaturvedi,	Ü (2)
Infinite Computations (Exam)	Thomas,	KI
Innovationen im Software Engineering	Rumpe, Hermerschmidt,	VT (2)
Innovationen im Software Engineering - Prüfung	Rumpe, Hermerschmidt	BP (2)
Introduction to Artificial Intelligence	Lakemeyer, Niemüller, Schwering,	VÜT (V3Ü2)
Introduction to Scientific Computing Languages	Bientinesi	VPT (V3/ÜE1)
Introduction to Scientific Computing Languages - Final Exam	Bientinesi,	MPT (V3/ÜE1)
iPhone Anwendungsprogrammierung	Borchers, Lichtschlag, Heller	(V3Ü2)

iPhone Anwendungsprogrammierung - Klausur (3 Credits)	Borchers, Lichtschlag, Heller,	KI (V3Ü2)
iPhone Anwendungsprogrammierung - Klausur (6 Credits)	Borchers, Lichtschlag, Heller,	KI (V3Ü2)
Klausur Advanced Methods of Cryptography	Mathar,	KI
Klausur Dynamische Systeme für Informatiker	Kowalewski,	KI
Klausur Einführung in die Bioinformatik	Berlage,	KI
Klausur Exploring Multimedia Data	Seidl	KI
Klausur Implementierung von Datenbanken	Jarke, Quix, Kastrati, Li, Geisler	KI
Klausur Introduction to Artificial Intelligence	Lakemeyer, Niemüller, Schwering	KIT
Klausur Objektorientierte Software-Konstruktion	Lichter	KIT
Klausur Parallele Programmierung I	Wolf,	KI
Klausur Web Science	Jarke, Klamma, Derntl, Petrushyna, Kovachev,	KI
Klausur: Advanced Internet Technology	Wehrle, Thißen,	KI (3+1)
Klausur: Multimedia Internet Technology	Wehrle, Thißen,	KI
Lab Course "Robot Communication and Coordination"	Lakemeyer, Schiffer, Niemüller, Schwering	P (4)
Languages for Scientific Computing	Bientinesi	ST (V2)
Lehrstuhlkolloquium	Kowalewski	EK
Lehrstuhlseminar	Katoen, Giesl, Abraham, Noll	S (2)
Master-Mentorenprogramm: Angewandte Informatik		T
Master-Mentorenprogramm: Daten- & Informationsmanagement		T
Master-Mentorenprogramm: Software & Kommunikation		
Master-Mentorenprogramm: Theoretische Informatik		T
Masterprüfung Automatic Speech Recognition	Ney,	MP
Masterprüfung Einführung in statistische Klassifikation	Ney,	MP
Mathematische Logik II	Grädel,	V (4)
Mathematische Logik II	Grädel,	Ü (2)
Medical Image Processing: Seminar	Deserno, Kobbelt, Ney, Rossmannith, Seidl, Spitzer	ST (2)
Medical Image Processing: Seminar	Deserno, Kobbelt, Ney, Rossmannith, Seidl, Spitzer	ST (2)
Modellbasierte Softwareentwicklung	Rumpe, Hölldobler, Schindler,	VÜT (2+3)
Modellbasierte Softwareentwicklung	Rumpe, Schindler, Hölldobler	KIT
Multimedia Internet Technology	Wehrle, Thißen,	VÜT

		(V3/Ü1)
Objektorientierte Software-Konstruktion	Lichter	VT (3)
Objektorientierte Software-Konstruktion	Lichter, Vianden, Pricope, Harun	ÜT (2)
Parallele Programmierung I	Wolf,	VT (V3)
Parallele Programmierung I	Wolf,	Ü (Ü2)
Praktikum "Communication Systems"	Wehrle, Thißen	P (4)
Praktikum automatische Spracherkennung	Ney, Schlüter, Sundermeyer	P (4)
Prüfung Advanced Machine Learning	Leibe,	MP
Prüfung Algorithmische Kryptographie	Unger,	MP
Prüfung Computer Vision	Leibe,	MP
Prüfung Mathematische Logik II (mündlich)	Grädel,	MP
Prüfung Rekursionstheorie	Thomas,	MP
Prüfung Statische Programmanalyse	Noll,	MP
Prüfung: Research Focus Class on Communication Systems	Wehrle	MP
Rekursionstheorie	Thomas	VT (2)
Rekursionstheorie	Thomas, Lang	Ü (1)
Research Focus Class on Communication Systems	Wehrle, Thißen	VÜ (V3+Ü2)
SCRUM-basierte Software-Entwicklung	Jarke, Zimmermann	P (5)
Selected Topics in Human Language Technology and Pattern Recognition	Ney	S (2)
Seminar "Aktuelle Entwicklungen des Multimedia Retrieval"	Seidl,	ST (2)
Seminar Information Management in the Web	Quix, Jarke, Geisler, Kastrati	S (2)
Seminar Learning Analytics & Educational Data Mining	Schroeder, Chatti, Thüs	HS (2)
Seminar Logik und Komplexität	Grohe	S (2)
Seminar Parallele Programmierung	Wolf, Simulation Sciences Dozenten	S (1)
Seminar über Automatentheorie (Bachelor)	Thomas, Felscher,	ST (2)
Seminar über Automatentheorie (Master)	Löding, Lang,	S (2)
Seminar: Advanced Internet Technology	Wehrle, Thißen, Schmidt,	S (2)
Seminar: Logik, Komplexität, Spiele	Grädel,	ST (2)
Seminar: Mobile Internet Technology	Wehrle, Thißen, Schmidt,	S (2)
Software Architektur Darstellung und Evaluierung	Lichter, Dragomir, Harun	S
Software Engineering Praktikum (M.Sc.): Global Software Engineering	Rumpe, Kurpick	P (4)
Software Engineering Praktikum (M.Sc.): Mobile & Locations Based Augmented Reality (AR) App/Game Entwicklung	Akbari, Leonhardt, Rumpe	P (4)
Software Engineering Praktikum (M.Sc.):	Rumpe, Ringert, Wortmann	P (4)

Model-Based Robotics Software Development		
Software Engineering Seminar (M.Sc.): Mobile & Locations Based Augmented Reality (AR) App/Game Entwicklung	Rumpe, Akbari, Leonhardt	S (2)
Software-Architekturen	Rumpe, Nagl	VT (3)
Statische Programmanalyse	Noll,	V (3)
Statische Programmanalyse	Noll, Jansen, Dehnert	Ü (2)
The Media Computing Project (Praktikum Hauptstudium)	Borchers, Wacharamanotham, Bohne,	PT (2)
Tree Automata	Löding	VT (2)
Tree Automata	Löding	Ü
Tree Automata (Exam)	Löding	MP
Übung: Advanced Internet Technology	Wehrle, Thißen,	Ü (1)
Verifikationsverfahren	Giesl, Brockschmidt, Emmes, Fuhs, Otto, Ströder,	S (2)
Virtuelle Realität	Kuhlen,	VÜT (3+1 oder 2+1)
Virtuelle Realität	Kuhlen,	MPT
Web Science	Jarke, Klamma, Derntl, Petrushyna, Kovachev	VT (V3/Ü1)
Web Technologien (Web Tech 1) Masterprüfung	Schroeder, Chatti, Thüs,	KIT
Web Technologien (WebTech 1)	Schroeder, Chatti, Thüs,	VÜ (3+2)

Diploma, Bachelor and Master Theses

Master Theses

Title German	Title English	First Name	Last name
Erreichbarkeit mit Ressourcenschranken für Pushdownsysteme	Ressource-bounded Reachability on Pushdown Systems	Martin	Lang
	Efficient Features for Histogram Intersection Kernel based Object Detection	Johannes	Frohn
	A Tool based Approach for the Extraction of Relevance Models Concepts	Ana-Maria-Cristina	Dragomir
	Prototyping Realtime Collaborative Applications	Jibran	Javed
	Prototyping Power Loading for CSMA-based Wireless Networks	Humberto	Escudero Argumanez
	Perceptually Tuned Color Reduction for Document Images	Adrian	Rodrigues Valadez
	Brainstorming using Multi-Touch Tabletop	Radu	Poenaru
Zuverlässigkeitsanalyse dynamischer Fehlerbäume	Reliability Analysis of Dynamic Fault Trees	Silvio	De Carolis
	Novel Techniques for Gesture Based Interaction with Magnetosensitive Devices in Digital Entertainment	Hengwei	Chang
Entwicklung eines Frameworks zur Generierung persistenter Datenmodelle	Development of a Framework for Generating Persistent Data Models	Jan	Marten
Erstellung eines Rahmenwerks zur Evaluierung von Community Erfolg am Beispiel von RESTful Web Services	Enabling a Framework for the Evaluation of Community Success by the Example of RESTful Web Services	Patrick	Schlebusch
Entwicklung von Softwarearchitektur-Produktlinien mittels Delta-Modellierung	Product Line Engineering of Software Architectures using Delta-Modeling	Thomas	Kutz
Kontrollflusssprache für Modelltransformationen in MontiCore	Control Flow Language for Model Transformations in MontiCore	Christian	Schreder
Verbesserung der User Experience von Mobile Video Media mit Cloud Services	Improving User Experience of Mobile Video Media Using Cloud Services	Michael	Lottko
	XMPP-based Mobile Multimedia Collaboration	Ismail Gökhan	Aksakalli
	Mobile Learning Game Engine	Marvin	Hoffmann

Title German	Title English	First Name	Last name
Entwicklung eines autonomen Flugkontrollsystems für MAVs	Development of an Autonomous Flight Control System for Micro Aerial Vehicles	Christian	Dernehl
	Ideaball: A Physical Artifact for Moderating and Analyzing Brainstorming Sessions	Clio	Kakoulli
	Passing by Interaction in Public	Tongyan	Ning
	Interactive, Cooperative Story Telling - The Storybroad System	Fabio	Mauri
	Implementing a Man-in-the-middle Attack on Bluetooth 2.1 Passkey Entry	Jian	Wang
	Design and Implementation of Collaborative Personal Learning Environment for Mobile Device	Ijaz	Ahmed
	Sketching Ideas: A Collaborative Interactive Space for Supporting Creativity	Neyla	Rojas Pena
Konzeptentwurf für Echtzeit in Android und Integration in die Plattform	Design and Integration of Real-Time into the Android Platform	Igor	Kalkov
	Resource Management in the Dynamic Accelerator-Cluster Architecture	Suraj	Prabhakaran
Design und Usability-Studie eines Learning Analytics Werkzeugs	Design and Usability Study of a Learning Analytics Tool	Mareike	Bültmann
	Real-time Map Matching in Car-to-X Applications	Gerti	Mitre
	Areceiver Base Rate Adaptation Mechanism for IEEE 802.II	Anwar	Hithnawi
Co-Optjects: Sofort zugängliche Benutzeroberflächen durch Alltagsgegenstände	Co-Optjects: Instant User Interfaces through Everyday Objects	Christian	Corsten
	Robust Expert Ranking in Community-based Fake Multimedia Detection Systems	Cristina	Balasoiu
	Comparison and Evaluation of Procedural and Stereo Modeling Techniques for Rapid Prototyping of Real Cities	Hanjie	Zhao
	Natural Interaction using Touchless Gestures - Usage in Book Navigation	Sanchayita	Sarkar
	Detecting and Visualizing Overlapping Facebook Communities with Node XL	Arber	Ceni
	Amicus - A Multisource Social Interaction and Communication	Petru	Nicolaescu

Title German	Title English	First Name	Last name
	Analysis Tool		
	Using Social Networking Information to Enhance Collaboration in the SSE Lab	Zied	Mansouri
Intraoperative Resektionsunterstützung in der Leberchirurgie	Intraoperative Resection Guidance in Liver Surgery	Ursula	Marciniak
Leichtgewichtige systemweite Leistungsüberwachung auf Hochleistungsrechnern	Light-weight System-wide Performance Monitoring on High-Performance Computing Systems	Christopher	Schleiden
	Implementation of User Defined Execution Environments using Virtualization in UNICORE	Kiran	Javaid
	Collective Activity Recognition based on Spatio-Temporal Distribution of Objects	Emmanouil	Tzouridis
	Open Street SLAM: Combining Visual SLAM with Cadastral Maps	Benito	van der Zander
	Semi-Supervised Online Learning for Low-Level Tracking	Theodora	Kontogianni
	Exploring Personalized Instructions with Mobile Augmented Reality to Assist Operating Physical Interfaces	Can	Liu
	Conjunctive Triple Queries Over Unstructured Data	Danilo	Djordjevic
	Tracking Hand Tremor on Touchscreens	Alexandru	Popa
Untersuchung der Dekodierung von parallelen Eingabeströmen in der Gebärdensprache	Investigations on Decoding of Parallel Input Streams in Sign Language	Christian	Oberdörfer
Informationssystem zur Navigation mit Landmarken in komplexen Gebäuden	Informationssystem for Landmark-based Navigation in Complex Buildings	Paul	Heiniz
	Limitation Analysis and Implementation of Paradigmatic Solutions for Unified Communication Software on Mobile Platforms	Zaheer	Ahmad
	Model-Based Resource Monitoring and Optimization	Canan	Kasaci
	Building an Effective Rewarding System Based on Reputation	Henri	Agaraj
	Optimizations for Packet Filters	Mircea	Gherzan
	Object Selection and Adaptive Trajectories in DRACON	Alisa	Novosad
	Agent-based Simulation of Effectual and Causal Behaviors of	Klesti	Hoxha

Title German	Title English	First Name	Last name
	Entrepreneurs		
	Occupancy and Behavior Profiling for Energy Efficiency in Buildings	Bateer	Siqin
Evaluierung von interaktiven Tablets für die Verbesserung des Kundenservices in Restaurants	Evaluation of Interactive Tablets for Improving Customer Service in Restaurants	Julian	Meichsner
	Towards Realistic Multi-Person Tracking by Integration of Social Forces	Philipp	Fischer
	Conception and Development of a Personalized Social Magazine for Tablets to Support Information Management	Irfan	Mirza
	A Classification of Interaction Styles that Span Multiple Systems	Ying	Zhang
	Sentence Boundary Detection for Broadcast news Recordings	Georgi	Dzhambazov
	Tag-Based Collaborative Filtering Recommendation in Plem (Personal Learning Environment Manager)	Simona	Dakova
	LumiNet 2 - A Wearable Sensor and Illumination Network for Fashion	Mariana	Bocoi
	Signal-based Estimation of the Number of Simultaneous Speakers	Umer	Rafi
Konzeptionelle Erweiterung von Projektdashboards für unerfahrene Anwender	Conceptual Extension of Project Dashboards for Inexperienced Users	Frederic	Evers
	Model-Based Criticality Analysis by Impact Isolation	Bernhard	Ern
	Development of an EJB-Based Business Goal Management Environment	Bogdan	Kyryliuk
	Generierung Javaee-basierter Cloud-Architekturen	Minh Quan	Tran
	A Global Oneway Control Channel for Opportunistic Networking	Alaa	Alhamoud
How's My Driving? Verbesserung des Fahrverhalten durch Feedback	How's My Driving? Providing Driver Feedback to Improve Driving	Christoph	Vobis
	The Impact of Body Posture on Couchtable Accuracy	Norbert	Dumont
	Lange-scale Image-based Localization using Learnt Projection for Local Features	Guoyu	Lu
Projected Spectral Clustering auf Graphen mit Feature Vektoren	Projected Spectral Clustering on Graphs with Feature Vectors	Sebastian	Raubach

Title German	Title English	First Name	Last name
	Residual Prediction in High Efficiency Video Coding	Tarek	Sheha
Prozedurale Modellierung von Lebewesen	Procedural Modeling of Creatures	Andreas	Neu
Absicherung von privater Aushandlung von geordneten Mengen gegen aktive Angreifer	Towards Securing Private Ordered Set Reconciliation against Active Attackers	Lucas	Brutschy
Quantitative Analyse von Markov-Automaten	Quantitative Analysis of Markov Automata	Dennis	Guck
	Service Negotiation and Selective Disclosure of End-Point Information for On-Path Middleboxes	Anupam	Ashish
	Design and Implementation of a Flat SGSN Functionality for 3GPP Release 11 Evolved Packet System	Dwianto Dana	Satriya
	Algorithmic Mechanism Design for Multi-Unit Auctions	Andreas	Tönnis
Mechanism-Design für Schedulingprobleme	Mechanism Design for Scheduling Problems	Martin	Blume
	Underdetermined bidirectional prediction	Philip	Driessen
	Fabiji: A tablet kiosk to facilitate creating and sharing documentation at fab labs	Zhao	He
	Efficient retrieval of mobility patterns on mobile devices	Simona-Claudia	Florescu
	Perceptual evaluation of BTF compression techniques	Sohail	Akhtar
	Coping with Jamming Attacks with the Help of Cross-Layer Design	Dominik	Dennisen
	Certificateless Encryption Using Biometric Identity	Kumar	Sharad
	Object-Oriented Data Model of the Semiconductor Industry aligned to SCOR on the example of Infineon with focus on product	Can	Sun
Optimierung eines Verfahrens zur Verifizierung von Diagnosedaten für Steuergeräte aus dem Nutzfahrzeugbereich	Optimization of a method for verification of diagnostic data for ECUs in the area of commercial vehicles	Thomas	Gatterdam
	Interlinking cross-application desktop hierarchies to overcome their semantic lacuna	Ramesh	Turshani
Approximationsalgorithmen für das VCPN-Problem	Approximation Algorithms for the VCPk-problem	Bernhard	Schamberg
	Gesture Interface for Micro-	Ivan	Golod

Title German	Title English	First Name	Last name
	Interactions in Domestic Spaces		
Evaluation und Implementierung von Sicherheitsstrategien für Massendaten in Cloud-Umgebungen	Evaluation and Implementation of Security and Privacy Strategies for Mass Data in the Cloud	Thomas	Freese
	Hybrid Server-Client Image-Based Localization and Tracking for Mobile Devices	Sven	Middelberg
Qualitätsgestufte Modellevolution in Ecore-Bibliotheken	Quality Staged Model Evolution in Ecore Libraries	Alexander	Roth
Aktives Lernen in der Informatik durch E-Learning-Plattformen am Beispiel eines Schülerwettbewerbs	Active Learning in Computer Science by Using E-Learning Platforms Considering the Example of a Pupil's Contest	Jennifer	Lierenfeld
Empfehlungssystemarchitektur für Ecore Bibliotheken	Recommender System Architecture for Ecore Libraries	Andrej	Dyck

Bachelor Theses

Title German	Title English	First Name	Last Name
Optimierung von Log-Linearen Modellen und stochastische Verfahren	Optimization of Log-Linear Models and Online Learning	Alexander	Richard
	Online Interval Scheduling	Sven	Schneider
Konzeption und Entwicklung einer Webapplikation zur Verwaltung und Visualisierung von Energiedaten	Conception and Development of an Energy Reporting Web Application	Benjamin	Meyer
Ein kollaboratives Lernwerkzeug für Sortieralgorithmen auf Multitouch Tischen	A Collaborative Learning Tool for Sorting Algorithms on Multitouch Tables	Torsten	Sehy
	A Mobile Payment Architecture for Smart Scales	Jan	Rüth
Automatenmodelle und Logiken für Wortrelationen	Automata and Logics for Relations over Words	Annette	Huhn
Syntaktische und semantische Analyse von Hyperkanteneretzungsgrammatiken zur Heapabstraktion	Syntactic and Semantic Analysis of Hyperedge Replacement Grammars for Heap Abstraction	Gereon	Kremer
Entwicklung eines Systems zur Spezifikation und Auswertung von Kennlinien für den Energiennavigator	Development of a characteristics specification and evaluation system for the energy navigator	Tuan Dung	Nguyen
Evaluation von Heuristiken zur Erkennung von Kryptoroutinen in Software	Evaluating Heuristics for Detection of Cryptography in Software	Felix	Matenaar

Title German	Title English	First Name	Last Name
Quellcodenavigation anhand von Callstack-Kontexten	Navigating Source Code via Call Stack Contexts	Joachim	Kurz
Entwicklung einer DSL für Modelle von virtuellen Systemen	Development of an DSL for models of virtual systems	Christian	Theis
Adaptives Filter-Framework für die MediaBase	Adaptive Filter-Framework for the MediaBase	Michael	Hackstein
Ein Codeanalysetool für RubySicherheitsaudits	A Code Analysis Toolkit for Ruby Security Audits	Cornelius	Aschermann
Entwicklung eines Tarifauswahlverfahrens für einen WLAN Roaming Client unter Android	Development of a Tariff Selection App for a WLAN Roaming Client for Android	David	Sosnitza
Erkennung von Ereignissen in Videos anhand von Objektpfaden	Event Detection in Videos Based on Object Trajectories	Anne	Kathrein
Projekterfassung für das Audiovisuelle Medienzentrum (AUMZ)	Project Management Tool for the audio-visual Media Center	Alexandra	Linden
Fortschritte in lateinischer Handschrift-Erkennung	Advances in latin script recognition	Hendrik	Pesch
Zustandspartitionierung für das Model-Checking von Binärcode	State Partitioning for Model Checking Binary Code	Florian	Caron
	Action Detection in Video with Local Self-Similarities	Sebastian	Mühr
Eine visuelle Erweiterung von digitalen Vinyl-Systemen zur Navigation in Musikstücken	An augmented In-Track Navigation Display for Digital Vinyl Systems	Justus	Lauten
	Enabling Runtime Migration of Application Context between iOS Devices	Christopher	Blum
Strombasierte Spezifikation in Isabelle/HOLCF	Stream-Based Specification in Isabelle/HOLCF - towards ALICE 2.0	Andreas	Krüger
Datenbankgestützte Analyse von Prozessartefakten in der modellbasierten Software-Produktlinien-Entwicklung	Database-Supported Analysis of Process Artefacts in Model-Based Software Product Line Development	Jeannette	Kraemer
TinyOS zur Frühwarnung vor Erdbeben	TinyOS for early landslide detection	Lucas	Braun
Touch-Studie: Ein Software Rahmen für die Gestaltung von Multi-Touch Nutzer Studien	Touch-Study: A Software Framework for Designing Multi-Touch User Studies	Thomas	Mauzer
Zustandsmodellierung technischer Anlagen am Anwendungsbeispiel des Energie-Navigators	State-based modelling of technical facilities using the example of the Energie-Navigator	Sebastian	Roidl
Eine Analyse sicherheitsrelevanter und hochverfügbarer Kommunikationsprotokolle im Kontext signaltechnisch sicherer	An Analysis of safe and highly available Communication Protocols in the context of Railway Signaling Systems and a Prototype	Sebastian	Löwenhag

Title German	Title English	First Name	Last Name
Bahnanwendungen und eine Prototypimplementierung in eingebetteten Systemen	Implementation in embedded Systems		
Ähnlichkeitssuche in Datenbanken von Bildfolgen	Similarity Search in Image Series Databases	Manfred	Smieschek
Eine Erweiterung der GiNaCRA Bibliothek für die zylindrische algebraische Zerlegung	An Extension of the GiNaCRA Library for the Cylindrical Algebraic Decomposition	Joachim	Redies
Verbesserung der Benutzbarkeit von Klassendiagrammvergleichen	Improving the Usability of Class Diagram Differencing	Jonathan	Reece
Die Überwachung und Koordination von verteilten S ² E Instanzen	Monitoring and Coordination of Distributed S ² E Instances	Russ	Jukic
Parallele symbolische verteilte Ausführung für skalierbares Testen in der Cloud	Parallalizing Symbolic Distributed Execution for Scalable Testing in the Cloud	Xinyu	Ge
Erweiterung von S ² E für das Testen von verteilten Systemen		Philipp	Kaiser
Erstellung und Evaluation einer Hardwareplattform zur präzisen Ladezustandserfassung von Blei-Gel-Akkumulatoren	Design of Hardware Platform to evaluate precise Charging States of Lead-Acid-Batteries	Dominik	Poppe
Clusterbasierte Suchstrategien für hohe Codeabdeckung in symbolischer verteilter Ausführung	Cluster Based Search Strategies for High Code Coverage in Symbolic Distributed Execution	Johannes	van der Giet
YUI-Prototyp zur Orchestrierung von cloud-basierten Services, Apps und Geräten	YUI-Prototype for Orchestrating Cloud-Based Services, Apps and Devices	André	Küpper
VisiCut: Ein Anwendungsgenre für Lasercutter in der persönlichen Fabrikation	Visicut: An Application Genre for Lasercutting in Personal Fabrication	Thomas	Oster
FabScan: Kostengünstiges 3D-Laserscannen physikalischer Objekte	FabScan: Affordable 3D Laser Scanning of Physical Objects	Francis	Engelmann
Analyse von Verhaltensspezifikationen von interaktiven verteilten Systemen mit Mona	Analysis of Behavioral Specifications for Distributed Interactive Systems with Mona	Dennis	Kirch
Visualisierung abstrahierter Zustände der Java Virtual Machine	Visualization of Abstracted States of the Java Virtual Machine	Jonas	Dederichs
Konzeptuelles Design und Implementierung einer mobilen Applikation für personalisierte Webdienste an Hochschulen auf Basis von Windows Phone 7 und Sharepoint 2010	Conceptual Design and Implementation of a Mobile Application for personalized Webservices in Higher Education based on Windows Phone 7 and Sharepoint 2010	Wjatscheslaw	Belopolski
Implementierung personalisierter karten- und ortsbasierender Dienste für Universitätsstudierende auf Basis von Windows Phone 7	Implementation of personalized Map and location based Services for students in higher education based on Windows Phone 7	Konstantin	Ostrovsky

Title German	Title English	First Name	Last Name
Entwicklung Web-basierter Editor und Simulationsumgebung für vernetzte Produktstrukturen	Development of a web-based editor and simulation environment for interconnected product structures	Paul	Chomicz
Entwicklung eines erweiterbaren Generator-Frameworks für Modelldokumentationen	Development of an extendable Modeldocumentation Generator Framework	Christoph	Hommelsheim
Community-Basierte Prozedurale Modellierung Moderner Architektur	Community-Based Procedural Modeling of Modern Architecture	Sebastian	Landwehr
Entwicklung einer Managementsoftware zum Hardwareinsatz in der medienunterstützten Lehre	Development of a Software Application for Managing Hardware Equipment in Medical Education	Roland	Doepke
Konstruktion und Effizienz eines hierarchischen, topologischen Overlays für WMNs	Construction and Performance of a Hierarchical, Topological Overlay for WMNs	Martin	Serror
Aufbau und Nutzung von dienstleistungsorientierten Drahtlosnetzwerken	On-demand content-centric Wi-Fi provisioning	David	Martin
Entwicklung einer wiederverwendbaren Komponentenbibliothek zur Überwachung von Online-Systemen	Development of a reusable component library to monitor online systems	Tim	Ix
Smartphone-basierte Gebäudekartenerstellung	Smartphone-based Indoor Mapping	André	Pomp
Erweiterung des Gargoyle Codegenerators um semantische Beziehungen	Extending the Gargoyle Codegen with semantic relationships	Tristan	Langer
Fehlertoleranz für das Real-Time Transport Protocol (RTP)	Error Tolerance for the Real-Time Transport Protocol (RTP)	David	Orlea
Ein web-basiertes Dashboard für große Mengen von Web 2.0 Artefakten	A Web-Based Reporting Dashboard for Large-Scale Collections of Web 2.0 Artifacts	Stephan	Erdtmann
Konzeption einer Internetplattform zur Dokumentation von Metriken	Ceception of an Internet Platform for the Documentation of Metrics	Michael	Schlimnat
Generierung von SSF-basierten grafischen Benutzeroberflächen für Web-basierte Informationssysteme	Generation of SSF-based Graphical User Interfaces for Web-based Information Systems	Claude	Mangen
Generierung von Systemtests für Web-basierte Informationssysteme	System Test Generation for Web-Based Information Systems	Michael	Krein
	Emulating BitTorrent swarms using a discrete-event based simulator	Alexander	Hocks
Verwendung von diskontinuierlichen Phrasen in der statistischen maschinellen Übersetzung	Discontinuous Phrases for Statistical Machine Translation	Erik	Scharwächter
	Advanced Trace-Based Analysis of Hybrid Programs	Felix	Voigtlaender
Unterstützung der	Autocompletion supoort for DSL	Alexander	Kogaj

Title German	Title English	First Name	Last Name
Autovervollständigung für IDEs von domainspezifischen Sprachen	IDEs		
Strombasierte Modellierung von Robotern unter Verwendung von I/O ^(omega) Automaten und MontiArc	Action-Stream-Based Modeling of Robots using I/O ^(omega) -automata and MontiArc	Philip	Martzok
Automatische Komplexitätsanalyse für Integer-Termersetzungssysteme	Automated Complexity Analysis for Integer Term Rewrite Systems	Marcel	Klinzing
Bewertung von Diskriminierungsnetzwerken für regelbasierte Systeme	Rating of Discrimination Networks for Rule-Based Systems	Fabian	Ohler
Integration von Hardwareabstraktion und Hardwareansteuerung im eingebetteten Echtzeitbetriebssystem ChibiOS	Integration of hardware abstraction and hardware control in the embedded real-time operating system ChibiOS	Florian	Sehl
Sichere Überquerung einer Kreuzung mit einer Fahrzeugkolonne	Safe crossing of an intersection with a platoon of vehicles	Ali	Tarzan
Effiziente Überquerung einer ampelgesteuerten Kreuzung mit einer Fahrzeugkolonne	Efficient Crossing of a Signalized Intersection with a Platoon of Vehicles	Lars	Tholen
Erstellung einer modellbasierten Engineering Software für ACPLT/csHMI	Building a model-based engineering software for process control environments with ACPLT/csHMI	Yannick	Rocks
Erhebungsinstrument auf Basis von Tablet-Geräten	Tablet-based survey instrument	Simon	Bruns
Eine Studie zur Produktivität und Performanz von modernen Vektorprozessoren	A Study on Productivity and Performance of Modern Vecotr Procesors	Paul	Springer
Echtzeitfähige bildbasierte Reflektionen	Real-time Image-Based Reflections	Christian	Hamm
	Folio: Augmenting books on interactive tabletops	Christian	Cherek
Entwicklung eines Dokumenten-Transformations-Services für die Online Software Transformation Plattform	Development of a document transformation service for the Online Software Transformation Platform	Daniel	Meckenstock
	Automated Termination Analysis for Java programs on cyclic data	Richard	Musiol
Optimierung einer oktagonbasierten Wertebereichsanalyse durch Lokalisierung abstrakter Speicherstellen	Optimization of an octagon based value range analysis using localization of abstract memories	Sebastian	Schmitz
Interaktive Visualisierung von Telekommunikations-Protokoll-Spezifikationen	Interactive Visualization of Telecommunication Protocol Specs	Mirko	Hartmann

Title German	Title English	First Name	Last Name
	Development and Integration of a Statistical Evaluation Framework for a Collaborative Web Platform	Michael	Hennings
Analyse des Privatsphäreverlustes bei der Nutzung des World Wide Web	Analysing the Privacy Leakage of Web Usage	Andreas	Kirmse
Unterstützung der Entwicklung von sensorbasierten Smartphone Anwendungen	Assisting the Development of Sensor-based Smartphone Applications	Vadim	Kraus
Auswertung von MSO-Formeln über Hypergraphsprachen	Deciding MSO over Languages of Hypergraphs	Max	Görtz
Support Vector Maschine Klassifikation basierend auf Kreuzkorrelation Prototypen in der Knochenalterbestimmung	Support Vector Machine Classification based on Correlation Prototypes applied to Bone Age Assessment	Markus	Harmsen
	Gossipmule: Scanning and Disseminating Information between Stations in Cooperative WLANs	Alexander	Paulus
	Low Memory Program Reversal	Bo	Wang
Verbesserung der Reisesicherheit im ÖPNV durch mobile Anwendungen		Stefan	Wüller
Zielbasierte Priorisierung von Verbesserungsmaßnahmen - nicht abgegeben	Goal based Ranking of Improvement Practices	Hong Minh	Dinh
	Recent and Future Botnet Techniques	Felix	Glaser
	A P2P Shared Storage System based on XMPP	Nicolas	Inden
	SMT-based termination analysis for integer rewrite systems	Matthias	Hoelzel
Datenbankgestützte Analyse von Signalfüssen in Simulink-Modellen	Database-Supported Analysis of Signal Flow in Simulink Models	Robert	Gleis
Visualisierung von Clusteringergebnissen in Graphen mit Knotenattributen	Visualization of Clustering Results in Graphs with Node Attributes	Roman	Haag
Gröbner Basen in SMT-konformen Entscheidungsverfahren	On Gröbner Bases in SMT-Compliant Decision Procedures	Jan	Junges
Gewichtete Aggregation von Markov Ketten	Weighted Lumpability on Markov Chains	Christoph	Worreschk
Reverse Engineering des Windows Phone Process Execution Models	Reverse Engineering of the Windows Phone Process Execution Model	Norman	Hansen
Kontextsensitive Autovervollständigung in der UML/P	context-sensitive autocompletion in the UML/P	Bao Loc	Nguyen Ngo
Regelbasierte Initialisierung von	Rule based Initialization of Project	Elena	Emelyanova

Title German	Title English	First Name	Last Name
Projektdashboards	Dashboards		
	Designing an Energy Consumption Visualization for an End User Home Automation Display	Konstantinos	Tsoleridis
Ein mobiles Dashboard für L2P	A mobile dashboard for L2P	Walter	Sanchez Ibrahim
Modellbasierte Komponententests mit Sequenzdiagrammen	Model-based testing of components using sequence diagrams	Roland	Moers
Verhaltensmodellierung von Robotern mit Iow Automaten	Behavioral Modeling of Robots with Iow Automata	Lidia	Lang
	Algorithms for Large Networks in the NoSQL Database ArangoDB	Lucas	Dohmen
Prozedurale Fassaden mit Kameraabhängigem Geometrischem Detail	View-Dependent Geometric Detail for Procedural Facades	Janis	Born
Zwei-Wege-Transducer über Wörtern	Two-Way Transducers over Words	Christoph	Matheja
Virtuelle Bildflächenvergrößerung mittels Blickverfolgungs-Technologie	Virtual Screen Enlargement using Gaze Tracking Technology	Max	Lyon
FPGA-Implementierung eines Algorithmus zur Ratenanpassung für IEEE 802.11	Implementing On-Demand Rate Adaption for IEEE 802.11	Erwin	Fang
Lastverteilungsverfahren für parallele ereignisorientierte Simulation auf Mehrprozessorsystemen	Load balancing mechanisms for parallel discrete event simulation on multiprocessor systems	Marc	Peiter
Einsatz von Metrik-Dashboards im industriellen Umfeld		Nils	Hans
Laufzeitumgebung für cloud-basierte Fahrzeuganwendungen	Runtime environment for cloud-based automotive applications	Peter	Damm
	Using Satisfiability Checking for Automated Return Oriented Programming	Felix	Wilhelm
Modulare und Boolesche Abstraktion von SPS-Programmen	Modular and Boolean Abstraction of PLC-Programs	Dimitri	Bohlender
Abstraktionsverfeinerung mittels Gegenbeispielen für die Verifikation hybrider SFCs	Counterexample-Guided Abstraction Refinement for Hybrid SFC Verification	Kai	Driessen
Bimaschinen und ihre Minimierung	Bimachines and their Minimization	Jera	Hensel
Typtheorie, Zertifizierte Programmierung und Compilerverifikation	Type Theory, Certified Programming and Compiler Verification	Jens	Katelaan
	City-Reconstructions by crowdsourcing	Ole	Untzelmann
Mesh-Entfaltungsstrategie für leichten Papiermodellbau	Mesh Unfolding Strategy for Easy Papercrafting	Frederic	Schiltz

Title German	Title English	First Name	Last Name
RF Jamming Interferenzen in WLAN basierten 802.11p Fahrzeugnetzwerken	RF Jamming in 802.11p-Based Vehicular Networks	Oliver	Kotulski
Entwicklung eines Abrechnungssystems für Cloud-basierte Anwendungen	Development of an Accountingsystem for cloud-based Applications	Martin	Lang
Visuelle Parameter-Exploration für Prozedurale Texturen	Visual Parameter Space Exploration for Procedural Textures	Markus	Over
Verifikation und Synthese für Parametrische Markov-Ketten	Verification and Synthesis for Parametric Markov Chains	Matthias	Volk
	Traffic Characterization in Wireless Cooperative Networks	Robert	Echelmeyer
Generative Entwicklung von User-Interfaces für Smart-Cars	Generative Engineering of User Interfaces for Smart-Cars	Alex	Tritthart
Lokale Suche in Globaler Optimierung mittels McCormick-Relaxationen	Local Search in Global Optimization by McCormick Relaxations	Angelika	Schwarz
Effiziente Approximative geodätische Berechnungen auf Dreiecksnetzen	Efficient Approximate Geodesics on Triangle Meshes	Martin	Heistermann
Implementierung des HIP DEX und Optimierungen für Sensornetzwerke	Implementation of the HIP Diet Exchange and Optimizations for Smart Object Networks	Jens	Hiller
Markierungsloses Tracking mit synthetisch trainierten Modellen	Markerless Tracking with synthetically trained Models	Florian	George
Inferenz von Grammatiken zur Heapabstraktion	Inferring Heap Abstraction Grammars	Alexander	Weinert
	HackIt!-Framework	Florian	Kerber
Entwicklung einer Rollenspezifischen Benutzerschnittstelle zur Konfiguration von Metrik-Dashboards	Development of a Role-specific User Interface for the Configuration of Metric Dashboards	Stefan	Guha
	Simulation and Visualization of compressible fluids interacting with rigid bodies	Philip	Trettner
Entwicklung eines adaptiven Frameworks zum automatischen Import von Sensordaten in Cyberphysical Systems am Beispiel des Energie Navigators	Development of an adaptable framework for automatic sensor data import in cyber-physical systems exemplified by the Energy Navigator	Rui	Ruhrländer
Entwicklung von Web-Demonstratoren für OSTP-Services	Development of Web-Demonstrators for OSTP-Services	Paul	Wiedeking
	Wireless Network Virtualization on Android Devices	Julian	Becker
Preprocessing für das Lösen nicht-linearer algebraischer Formeln	Preprocessing for Solving Non-Linear Algebraic Formulas	Dennis	Scully

Diploma, Bachelor and Master Theses

Master Theses

Title German	Title English	First Name	Last name
Erreichbarkeit mit Ressourcenschranken für Pushdownsysteme	Ressource-bounded Reachability on Pushdown Systems	Martin	Lang
	Efficient Features for Histogram Intersection Kernel based Object Detection	Johannes	Frohn
	A Tool based Approach for the Extraction of Relevance Models Concepts	Ana-Maria-Cristina	Dragomir
	Prototyping Realtime Collaborative Applications	Jibran	Javed
	Prototyping Power Loading for CSMA-based Wireless Networks	Humberto	Escudero Argumanez
	Perceptually Tuned Color Reduction for Document Images	Adrian	Rodrigues Valadez
	Brainstorming using Multi-Touch Tabletop	Radu	Poenaru
Zuverlässigkeitsanalyse dynamischer Fehlerbäume	Reliability Analysis of Dynamic Fault Trees	Silvio	De Carolis
	Novel Techniques for Gesture Based Interaction with Magnetosensitive Devices in Digital Entertainment	Hengwei	Chang
Entwicklung eines Frameworks zur Generierung persistenter Datenmodelle	Development of a Framework for Generating Persistent Data Models	Jan	Marten
Erstellung eines Rahmenwerks zur Evaluierung von Community Erfolg am Beispiel von RESTful Web Services	Enabling a Framework for the Evaluation of Community Success by the Example of RESTful Web Services	Patrick	Schlebusch
Entwicklung von Softwarearchitektur-Produktlinien mittels Delta-Modellierung	Product Line Engineering of Software Architectures using Delta-Modeling	Thomas	Kutz
Kontrollflusssprache für Modelltransformationen in MontiCore	Control Flow Language for Model Transformations in MontiCore	Christian	Schreder
Verbesserung der User Experience von Mobile Video Media mit Cloud Services	Improving User Experience of Mobile Video Media Using Cloud Services	Michael	Lottko
	XMPP-based Mobile Multimedia Collaboration	Ismail Gökhan	Aksakalli
	Mobile Learning Game Engine	Marvin	Hoffmann

Title German	Title English	First Name	Last name
Entwicklung eines autonomen Flugkontrollsystems für MAVs	Development of an Autonomous Flight Control System for Micro Aerial Vehicles	Christian	Dernehl
	Ideaball: A Physical Artifact for Moderating and Analyzing Brainstorming Sessions	Clio	Kakoulli
	Passing by Interaction in Public	Tongyan	Ning
	Interactive, Cooperative Story Telling - The Storybroad System	Fabio	Mauri
	Implementing a Man-in-the-middle Attack on Bluetooth 2.1 Passkey Entry	Jian	Wang
	Design and Implementation of Collaborative Personal Learning Environment for Mobile Device	Ijaz	Ahmed
	Sketching Ideas: A Collaborative Interactive Space for Supporting Creativity	Neyla	Rojas Pena
Konzeptentwurf für Echtzeit in Android und Integration in die Plattform	Design and Integration of Real-Time into the Android Platform	Igor	Kalkov
	Resource Management in the Dynamic Accelerator-Cluster Architecture	Suraj	Prabhakaran
Design und Usability-Studie eines Learning Analytics Werkzeugs	Design and Usability Study of a Learning Analytics Tool	Mareike	Bültmann
	Real-time Map Matching in Car-to-X Applications	Gerti	Mitre
	Areceiver Base Rate Adaptation Mechanism for IEEE 802.II	Anwar	Hithnawi
Co-Optjects: Sofort zugängliche Benutzeroberflächen durch Alltagsgegenstände	Co-Optjects: Instant User Interfaces through Everyday Objects	Christian	Corsten
	Robust Expert Ranking in Community-based Fake Multimedia Detection Systems	Cristina	Balasoiu
	Comparison and Evaluation of Procedural and Stereo Modeling Techniques for Rapid Prototyping of Real Cities	Hanjie	Zhao
	Natural Interaction using Touchless Gestures - Usage in Book Navigation	Sanchayita	Sarkar
	Detecting and Visualizing Overlapping Facebook Communities with Node XL	Arber	Ceni
	Amicus - A Multisource Social Interaction and Communication	Petru	Nicolaescu

Title German	Title English	First Name	Last name
	Analysis Tool		
	Using Social Networking Information to Enhance Collaboration in the SSE Lab	Zied	Mansouri
Intraoperative Resektionsunterstützung in der Leberchirurgie	Intraoperative Resection Guidance in Liver Surgery	Ursula	Marciniak
Leichtgewichtige systemweite Leistungsüberwachung auf Hochleistungsrechnern	Light-weight System-wide Performance Monitoring on High-Performance Computing Systems	Christopher	Schleiden
	Implementation of User Defined Execution Environments using Virtualization in UNICORE	Kiran	Javaid
	Collective Activity Recognition based on Spatio-Temporal Distribution of Objects	Emmanouil	Tzouridis
	Open Street SLAM: Combining Visual SLAM with Cadastral Maps	Benito	van der Zander
	Semi-Supervised Online Learning for Low-Level Tracking	Theodora	Kontogianni
	Exploring Personalized Instructions with Mobile Augmented Reality to Assist Operating Physical Interfaces	Can	Liu
	Conjunctive Triple Queries Over Unstructured Data	Danilo	Djordjevic
	Tracking Hand Tremor on Touchscreens	Alexandru	Popa
Untersuchung der Dekodierung von parallelen Eingabeströmen in der Gebärdensprache	Investigations on Decoding of Parallel Input Streams in Sign Language	Christian	Oberdörfer
Informationssystem zur Navigation mit Landmarken in komplexen Gebäuden	Informationssystem for Landmark-based Navigation in Complex Buildings	Paul	Heiniz
	Limitation Analysis and Implementation of Paradigmatic Solutions for Unified Communication Software on Mobile Platforms	Zaheer	Ahmad
	Model-Based Resource Monitoring and Optimization	Canan	Kasaci
	Building an Effective Rewarding System Based on Reputation	Henri	Agaraj
	Optimizations for Packet Filters	Mircea	Gherzan
	Object Selection and Adaptive Trajectories in DRACON	Alisa	Novosad
	Agent-based Simulation of Effectual and Causal Behaviors of	Klesti	Hoxha

Title German	Title English	First Name	Last name
	Entrepreneurs		
	Occupancy and Behavior Profiling for Energy Efficiency in Buildings	Bateer	Siqin
Evaluierung von interaktiven Tablets für die Verbesserung des Kundenservices in Restaurants	Evaluation of Interactive Tablets for Improving Customer Service in Restaurants	Julian	Meichsner
	Towards Realistic Multi-Person Tracking by Integration of Social Forces	Philipp	Fischer
	Conception and Development of a Personalized Social Magazine for Tablets to Support Information Management	Irfan	Mirza
	A Classification of Interaction Styles that Span Multiple Systems	Ying	Zhang
	Sentence Boundary Detection for Broadcast news Recordings	Georgi	Dzhambazov
	Tag-Based Collaborative Filtering Recommendation in Plem (Personal Learning Environment Manager)	Simona	Dakova
	LumiNet 2 - A Wearable Sensor and Illumination Network for Fashion	Mariana	Bocoi
	Signal-based Estimation of the Number of Simultaneous Speakers	Umer	Rafi
Konzeptionelle Erweiterung von Projektdashboards für unerfahrene Anwender	Conceptual Extension of Project Dashboards for Inexperienced Users	Frederic	Evers
	Model-Based Criticality Analysis by Impact Isolation	Bernhard	Ern
	Development of an EJB-Based Business Goal Management Environment	Bogdan	Kyryliuk
	Generierung Javaee-basierter Cloud-Architekturen	Minh Quan	Tran
	A Global Oneway Control Channel for Opportunistic Networking	Alaa	Alhamoud
How's My Driving? Verbesserung des Fahrverhalten durch Feedback	How's My Driving? Providing Driver Feedback to Improve Driving	Christoph	Vobis
	The Impact of Body Posture on Couchtable Accuracy	Norbert	Dumont
	Lange-scale Image-based Localization using Learnt Projection for Local Features	Guoyu	Lu
Projected Spectral Clustering auf Graphen mit Feature Vektoren	Projected Spectral Clustering on Graphs with Feature Vectors	Sebastian	Raubach

Title German	Title English	First Name	Last name
	Residual Prediction in High Efficiency Video Coding	Tarek	Sheha
Prozedurale Modellierung von Lebewesen	Procedural Modeling of Creatures	Andreas	Neu
Absicherung von privater Aushandlung von geordneten Mengen gegen aktive Angreifer	Towards Securing Private Ordered Set Reconciliation against Active Attackers	Lucas	Brutschy
Quantitative Analyse von Markov-Automaten	Quantitative Analysis of Markov Automata	Dennis	Guck
	Service Negotiation and Selective Disclosure of End-Point Information for On-Path Middleboxes	Anupam	Ashish
	Design and Implementation of a Flat SGSN Functionality for 3GPP Release 11 Evolved Packet System	Dwianto Dana	Satriya
	Algorithmic Mechanism Design for Multi-Unit Auctions	Andreas	Tönnis
Mechanism-Design für Schedulingprobleme	Mechanism Design for Scheduling Problems	Martin	Blume
	Underdetermined bidirectional prediction	Philip	Driessen
	Fabiji: A tablet kiosk to facilitate creating and sharing documentation at fab labs	Zhao	He
	Efficient retrieval of mobility patterns on mobile devices	Simona-Claudia	Florescu
	Perceptual evaluation of BTF compression techniques	Sohail	Akhtar
	Coping with Jamming Attacks with the Help of Cross-Layer Design	Dominik	Dennisen
	Certificateless Encryption Using Biometric Identity	Kumar	Sharad
	Object-Oriented Data Model of the Semiconductor Industry aligned to SCOR on the example of Infineon with focus on product	Can	Sun
Optimierung eines Verfahrens zur Verifizierung von Diagnosedaten für Steuergeräte aus dem Nutzfahrzeugbereich	Optimization of a method for verification of diagnostic data for ECUs in the area of commercial vehicles	Thomas	Gatterdam
	Interlinking cross-application desktop hierarchies to overcome their semantic lacuna	Ramesh	Turshani
Approximationsalgorithmen für das VCPN-Problem	Approximation Algorithms for the VCPk-problem	Bernhard	Schamberg
	Gesture Interface for Micro-	Ivan	Golod

Title German	Title English	First Name	Last name
	Interactions in Domestic Spaces		
Evaluation und Implementierung von Sicherheitsstrategien für Massendaten in Cloud-Umgebungen	Evaluation and Implementation of Security and Privacy Strategies for Mass Data in the Cloud	Thomas	Freese
	Hybrid Server-Client Image-Based Localization and Tracking for Mobile Devices	Sven	Middelberg
Qualitätsgestufte Modellevolution in Ecore-Bibliotheken	Quality Staged Model Evolution in Ecore Libraries	Alexander	Roth
Aktives Lernen in der Informatik durch E-Learning-Plattformen am Beispiel eines Schülerwettbewerbs	Active Learning in Computer Science by Using E-Learning Platforms Considering the Example of a Pupil's Contest	Jennifer	Lierenfeld
Empfehlungssystemarchitektur für Ecore Bibliotheken	Recommender System Architecture for Ecore Libraries	Andrej	Dyck

Bachelor Theses

Title German	Title English	First Name	Last Name
Optimierung von Log-Linearen Modellen und stochastische Verfahren	Optimization of Log-Linear Models and Online Learning	Alexander	Richard
	Online Interval Scheduling	Sven	Schneider
Konzeption und Entwicklung einer Webapplikation zur Verwaltung und Visualisierung von Energiedaten	Conception and Development of an Energy Reporting Web Application	Benjamin	Meyer
Ein kollaboratives Lernwerkzeug für Sortieralgorithmen auf Multitouch Tischen	A Collaborative Learning Tool for Sorting Algorithms on Multitouch Tables	Torsten	Sehy
	A Mobile Payment Architecture for Smart Scales	Jan	Rüth
Automatenmodelle und Logiken für Wortrelationen	Automata and Logics for Relations over Words	Annette	Huhn
Syntaktische und semantische Analyse von Hyperkantenersetzungsgrammatiken zur Heapabstraktion	Syntactic and Semantic Analysis of Hyperedge Replacement Grammars for Heap Abstraction	Gereon	Kremer
Entwicklung eines Systems zur Spezifikation und Auswertung von Kennlinien für den Energiennavigator	Development of a characteristics specification and evaluation system for the energy navigator	Tuan Dung	Nguyen
Evaluation von Heuristiken zur Erkennung von Kryptoroutinen in Software	Evaluating Heuristics for Detection of Cryptography in Software	Felix	Matenaar

Title German	Title English	First Name	Last Name
Quellcodenavigation anhand von Callstack-Kontexten	Navigating Source Code via Call Stack Contexts	Joachim	Kurz
Entwicklung einer DSL für Modelle von virtuellen Systemen	Development of an DSL for models of virtual systems	Christian	Theis
Adaptives Filter-Framework für die MediaBase	Adaptive Filter-Framework for the MediaBase	Michael	Hackstein
Ein Codeanalysetool für RubySicherheitsaudits	A Code Analysis Toolkit for Ruby Security Audits	Cornelius	Aschermann
Entwicklung eines Tarifauswahlverfahrens für einen WLAN Roaming Client unter Android	Development of a Tariff Selection App for a WLAN Roaming Client for Android	David	Sosnitza
Erkennung von Ereignissen in Videos anhand von Objektpfaden	Event Detection in Videos Based on Object Trajectories	Anne	Kathrein
Projekterfassung für das Audiovisuelle Medienzentrum (AUMZ)	Project Management Tool for the audio-visual Media Center	Alexandra	Linden
Fortschritte in lateinischer Handschrift-Erkennung	Advances in latin script recognition	Hendrik	Pesch
Zustandspartitionierung für das Model-Checking von Binärcode	State Partitioning for Model Checking Binary Code	Florian	Caron
	Action Detection in Video with Local Self-Similarities	Sebastian	Mühr
Eine visuelle Erweiterung von digitalen Vinyl-Systemen zur Navigation in Musikstücken	An augmented In-Track Navigation Display for Digital Vinyl Systems	Justus	Lauten
	Enabling Runtime Migration of Application Context between iOS Devices	Christopher	Blum
Strombasierte Spezifikation in Isabelle/HOLCF	Stream-Based Specification in Isabelle/HOLCF - towards ALICE 2.0	Andreas	Krüger
Datenbankgestützte Analyse von Prozessartefakten in der modellbasierten Software-Produktlinien-Entwicklung	Database-Supported Analysis of Process Artefacts in Model-Based Software Product Line Development	Jeannette	Kraemer
TinyOS zur Frühwarnung vor Erdbeben	TinyOS for early landslide detection	Lucas	Braun
Touch-Studie: Ein Software Rahmen für die Gestaltung von Multi-Touch Nutzer Studien	Touch-Study: A Software Framework for Designing Multi-Touch User Studies	Thomas	Mauzer
Zustandsmodellierung technischer Anlagen am Anwendungsbeispiel des Energie-Navigators	State-based modelling of technical facilities using the example of the Energie-Navigator	Sebastian	Roidl
Eine Analyse sicherheitsrelevanter und hochverfügbarer Kommunikationsprotokolle im Kontext signaltechnisch sicherer	An Analysis of safe and highly available Communication Protocols in the context of Railway Signaling Systems and a Prototype	Sebastian	Löwenhag

Title German	Title English	First Name	Last Name
Bahnanwendungen und eine Prototypimplementierung in eingebetteten Systemen	Implementation in embedded Systems		
Ähnlichkeitssuche in Datenbanken von Bildfolgen	Similarity Search in Image Series Databases	Manfred	Smieschek
Eine Erweiterung der GiNaCRA Bibliothek für die zylindrische algebraische Zerlegung	An Extension of the GiNaCRA Library for the Cylindrical Algebraic Decomposition	Joachim	Redies
Verbesserung der Benutzbarkeit von Klassendiagrammvergleichen	Improving the Usability of Class Diagram Differencing	Jonathan	Reece
Die Überwachung und Koordination von verteilten S ² E Instanzen	Monitoring and Coordination of Distributed S ² E Instances	Russ	Jukic
Parallele symbolische verteilte Ausführung für skalierbares Testen in der Cloud	Parallalizing Symbolic Distributed Execution for Scalable Testing in the Cloud	Xinyu	Ge
Erweiterung von S ² E für das Testen von verteilten Systemen		Philipp	Kaiser
Erstellung und Evaluation einer Hardwareplattform zur präzisen Ladezustandserfassung von Blei-Gel-Akkumulatoren	Design of Hardware Platform to evaluate precise Charging States of Lead-Acid-Batteries	Dominik	Poppe
Clusterbasierte Suchstrategien für hohe Codeabdeckung in symbolischer verteilter Ausführung	Cluster Based Search Strategies for High Code Coverage in Symbolic Distributed Execution	Johannes	van der Giet
YUI-Prototyp zur Orchestrierung von cloud-basierten Services, Apps und Geräten	YUI-Prototype for Orchestrating Cloud-Based Services, Apps and Devices	André	Küpper
VisiCut: Ein Anwendungsgenre für Lasercutter in der persönlichen Fabrikation	Visicut: An Application Genre for Lasercutting in Personal Fabrication	Thomas	Oster
FabScan: Kostengünstiges 3D-Laserscannen physikalischer Objekte	FabScan: Affordable 3D Laser Scanning of Physical Objects	Francis	Engelmann
Analyse von Verhaltensspezifikationen von interaktiven verteilten Systemen mit Mona	Analysis of Behavioral Specifications for Distributed Interactive Systems with Mona	Dennis	Kirch
Visualisierung abstrahierter Zustände der Java Virtual Machine	Visualization of Abstracted States of the Java Virtual Machine	Jonas	Dederichs
Konzeptuelles Design und Implementierung einer mobilen Applikation für personalisierte Webdienste an Hochschulen auf Basis von Windows Phone 7 und Sharepoint 2010	Conceptual Design and Implementation of a Mobile Application for personalized Webservices in Higher Education based on Windows Phone 7 and Sharepoint 2010	Wjatscheslaw	Belopolski
Implementierung personalisierter karten- und ortsbasierender Dienste für Universitätsstudierende auf Basis von Windows Phone 7	Implementation of personalized Map and location based Services for students in higher education based on Windows Phone 7	Konstantin	Ostrovsky

Title German	Title English	First Name	Last Name
Entwicklung Web-basierter Editor und Simulationsumgebung für vernetzte Produktstrukturen	Development of a web-based editor and simulation environment for interconnected product structures	Paul	Chomicz
Entwicklung eines erweiterbaren Generator-Frameworks für Modelldokumentationen	Development of an extendable Modeldocumentation Generator Framework	Christoph	Hommelsheim
Community-Basierte Prozedurale Modellierung Moderner Architektur	Community-Based Procedural Modeling of Modern Architecture	Sebastian	Landwehr
Entwicklung einer Managementsoftware zum Hardwareeinsatz in der medienunterstützten Lehre	Development of a Software Application for Managing Hardware Equipment in Medical Education	Roland	Doepke
Konstruktion und Effizienz eines hierarchischen, topologischen Overlays für WMNs	Construction and Performance of a Hierarchical, Topological Overlay for WMNs	Martin	Serror
Aufbau und Nutzung von dienstleistungsorientierten Drahtlosnetzwerken	On-demand content-centric Wi-Fi provisioning	David	Martin
Entwicklung einer wiederverwendbaren Komponentenbibliothek zur Überwachung von Online-Systemen	Development of a reusable component library to monitor online systems	Tim	Ix
Smartphone-basierte Gebäudekartenerstellung	Smartphone-based Indoor Mapping	André	Pomp
Erweiterung des Gargoyle Codegenerators um semantische Beziehungen	Extending the Gargoyle Codegen with semantic relationships	Tristan	Langer
Fehlertoleranz für das Real-Time Transport Protocol (RTP)	Error Tolerance for the Real-Time Transport Protocol (RTP)	David	Orlea
Ein web-basiertes Dashboard für große Mengen von Web 2.0 Artefakten	A Web-Based Reporting Dashboard for Large-Scale Collections of Web 2.0 Artifacts	Stephan	Erdtmann
Konzeption einer Internetplattform zur Dokumentation von Metriken	Cenception of an Internet Platform for the Documentation of Metrics	Michael	Schlimnat
Generierung von SSF-basierten grafischen Benutzeroberflächen für Web-basierte Informationssysteme	Generation of SSF-based Graphical User Interfaces for Web-based Information Systems	Claude	Mangen
Generierung von Systemtests für Web-basierte Informationssysteme	System Test Generation for Web-Based Information Systems	Michael	Krein
	Emulating BitTorrent swarms using a discrete-event based simulator	Alexander	Hocks
Verwendung von diskontinuierlichen Phrasen in der statistischen maschinellen Übersetzung	Discontinuous Phrases for Statistical Machine Translation	Erik	Scharwächter
	Advanced Trace-Based Analysis of Hybrid Programs	Felix	Voigtlaender
Unterstützung der	Autocompletion supoort for DSL	Alexander	Kogaj

Title German	Title English	First Name	Last Name
Autovervollständigung für IDEs von domainspezifischen Sprachen	IDEs		
Strombasierte Modellierung von Robotern unter Verwendung von I/O ^(omega) Automaten und MontiArc	Action-Stream-Based Modeling of Robots using I/O ^(omega) -automata and MontiArc	Philip	Martzok
Automatische Komplexitätsanalyse für Integer-Termersetzungssysteme	Automated Complexity Analysis for Integer Term Rewrite Systems	Marcel	Klinzing
Bewertung von Diskriminierungsnetzwerken für regelbasierte Systeme	Rating of Discrimination Networks for Rule-Based Systems	Fabian	Ohler
Integration von Hardwareabstraktion und Hardwareansteuerung im eingebetteten Echtzeitbetriebssystem ChibiOS	Integration of hardware abstraction and hardware control in the embedded real-time operating system ChibiOS	Florian	Sehl
Sichere Überquerung einer Kreuzung mit einer Fahrzeugkolonne	Safe crossing of an intersection with a platoon of vehicles	Ali	Tarzan
Effiziente Überquerung einer ampelgesteuerten Kreuzung mit einer Fahrzeugkolonne	Efficient Crossing of a Signalized Intersection with a Platoon of Vehicles	Lars	Tholen
Erstellung einer modellbasierten Engineering Software für ACPLT/csHMI	Building a model-based engineering software for process control environments with ACPLT/csHMI	Yannick	Rocks
Erhebungsinstrument auf Basis von Tablet-Geräten	Tablet-based survey instrument	Simon	Bruns
Eine Studie zur Produktivität und Performanz von modernen Vektorprozessoren	A Study on Productivity and Performance of Modern Vecotr Procesors	Paul	Springer
Echtzeitfähige bildbasierte Reflektionen	Real-time Image-Based Reflections	Christian	Hamm
	Folio: Augmenting books on interactive tabletops	Christian	Cherek
Entwicklung eines Dokumenten-Transformations-Services für die Online Software Transformation Plattform	Development of a document transformation service for the Online Software Transformation Platform	Daniel	Meckenstock
	Automated Termination Analysis for Java programs on cyclic data	Richard	Musiol
Optimierung einer oktagonbasierten Wertebereichsanalyse durch Lokalisierung abstrakter Speicherstellen	Optimization of an octagon based value range analysis using localization of abstract memories	Sebastian	Schmitz
Interaktive Visualisierung von Telekommunikations-Protokoll-Spezifikationen	Interactive Visualization of Telecommunication Protocol Specs	Mirko	Hartmann

Title German	Title English	First Name	Last Name
	Development and Integration of a Statistical Evaluation Framework for a Collaborative Web Platform	Michael	Hennings
Analyse des Privatsphäreverlustes bei der Nutzung des World Wide Web	Analysing the Privacy Leakage of Web Usage	Andreas	Kirmse
Unterstützung der Entwicklung von sensorbasierten Smartphone Anwendungen	Assisting the Development of Sensor-based Smartphone Applications	Vadim	Kraus
Auswertung von MSO-Formeln über Hypergraphsprachen	Deciding MSO over Languages of Hypergraphs	Max	Görtz
Support Vector Maschine Klassifikation basierend auf Kreuzkorrelation Prototypen in der Knochenalterbestimmung	Support Vector Machine Classification based on Correlation Prototypes applied to Bone Age Assessment	Markus	Harmsen
	Gossipmule: Scanning and Disseminating Information between Stations in Cooperative WLANs	Alexander	Paulus
	Low Memory Program Reversal	Bo	Wang
Verbesserung der Reisesicherheit im ÖPNV durch mobile Anwendungen		Stefan	Wüller
Zielbasierte Priorisierung von Verbesserungsmaßnahmen - nicht abgegeben	Goal based Ranking of Improvement Practices	Hong Minh	Dinh
	Recent and Future Botnet Techniques	Felix	Glaser
	A P2P Shared Storage System based on XMPP	Nicolas	Inden
	SMT-based termination analysis for integer rewrite systems	Matthias	Hoelzel
Datenbankgestützte Analyse von Signalfüssen in Simulink-Modellen	Database-Supported Analysis of Signal Flow in Simulink Models	Robert	Gleis
Visualisierung von Clusteringergebnissen in Graphen mit Knotenattributen	Visualization of Clustering Results in Graphs with Node Attributes	Roman	Haag
Gröbner Basen in SMT-konformen Entscheidungsverfahren	On Gröbner Bases in SMT-Compliant Decision Procedures	Jan	Junges
Gewichtete Aggregation von Markov Ketten	Weighted Lumpability on Markov Chains	Christoph	Worreschk
Reverse Engineering des Windows Phone Process Execution Models	Reverse Engineering of the Windows Phone Process Execution Model	Norman	Hansen
Kontextsensitive Autovervollständigung in der UML/P	context-sensitive autocompletion in the UML/P	Bao Loc	Nguyen Ngo
Regelbasierte Initialisierung von	Rule based Initialization of Project	Elena	Emelyanova

Title German	Title English	First Name	Last Name
Projektdashboards	Dashboards		
	Designing an Energy Consumption Visualization for an End User Home Automation Display	Konstantinos	Tsoleridis
Ein mobiles Dashboard für L2P	A mobile dashboard for L2P	Walter	Sanchez Ibrahim
Modellbasierte Komponententests mit Sequenzdiagrammen	Model-based testing of components using sequence diagrams	Roland	Moers
Verhaltensmodellierung von Robotern mit Iow Automaten	Behavioral Modeling of Robots with Iow Automata	Lidia	Lang
	Algorithms for Large Networks in the NoSQL Database ArangoDB	Lucas	Dohmen
Prozedurale Fassaden mit Kameraabhängigem Geometrischem Detail	View-Dependent Geometric Detail for Procedural Facades	Janis	Born
Zwei-Wege-Transducer über Wörtern	Two-Way Transducers over Words	Christoph	Matheja
Virtuelle Bildflächenvergrößerung mittels Blickverfolgungs-Technologie	Virtual Screen Enlargement using Gaze Tracking Technology	Max	Lyon
FPGA-Implementierung eines Algorithmus zur Ratenanpassung für IEEE 802.11	Implementing On-Demand Rate Adaption for IEEE 802.11	Erwin	Fang
Lastverteilungsverfahren für parallele ereignisorientierte Simulation auf Mehrprozessorsystemen	Load balancing mechanisms for parallel discrete event simulation on multiprocessor systems	Marc	Peiter
Einsatz von Metrik-Dashboards im industriellen Umfeld		Nils	Hans
Laufzeitumgebung für cloud-basierte Fahrzeuganwendungen	Runtime environment for cloud-based automotive applications	Peter	Damm
	Using Satisfiability Checking for Automated Return Oriented Programming	Felix	Wilhelm
Modulare und Boolesche Abstraktion von SPS-Programmen	Modular and Boolean Abstraction of PLC-Programs	Dimitri	Bohlender
Abstraktionsverfeinerung mittels Gegenbeispielen für die Verifikation hybrider SFCs	Counterexample-Guided Abstraction Refinement for Hybrid SFC Verification	Kai	Driessen
Bimaschinen und ihre Minimierung	Bimachines and their Minimization	Jera	Hensel
Typtheorie, Zertifizierte Programmierung und Compilerverifikation	Type Theory, Certified Programming and Compiler Verification	Jens	Katelaan
	City-Reconstructions by crowdsourcing	Ole	Untzelmann
Mesh-Entfaltungsstrategie für leichten Papiermodellbau	Mesh Unfolding Strategy for Easy Papercrafting	Frederic	Schiltz

Title German	Title English	First Name	Last Name
RF Jamming Interferenzen in WLAN basierten 802.11p Fahrzeugnetzwerken	RF Jamming in 802.11p-Based Vehicular Networks	Oliver	Kotulski
Entwicklung eines Abrechnungssystems für Cloud-basierte Anwendungen	Development of an Accountingsystem for cloud-based Applications	Martin	Lang
Visuelle Parameter-Exploration für Prozedurale Texturen	Visual Parameter Space Exploration for Procedural Textures	Markus	Over
Verifikation und Synthese für Parametrische Markov-Ketten	Verification and Synthesis for Parametric Markov Chains	Matthias	Volk
	Traffic Characterization in Wireless Cooperative Networks	Robert	Echelmeyer
Generative Entwicklung von User-Interfaces für Smart-Cars	Generative Engineering of User Interfaces for Smart-Cars	Alex	Tritthart
Lokale Suche in Globaler Optimierung mittels McCormick-Relaxationen	Local Search in Global Optimization by McCormick Relaxations	Angelika	Schwarz
Effiziente Approximative geodätische Berechnungen auf Dreiecksnetzen	Efficient Approximate Geodesics on Triangle Meshes	Martin	Heistermann
Implementierung des HIP DEX und Optimierungen für Sensornetzwerke	Implementation of the HIP Diet Exchange and Optimizations for Smart Object Networks	Jens	Hiller
Markierungsloses Tracking mit synthetisch trainierten Modellen	Markerless Tracking with synthetically trained Models	Florian	George
Inferenz von Grammatiken zur Heapabstraktion	Inferring Heap Abstraction Grammars	Alexander	Weinert
	HackIt!-Framework	Florian	Kerber
Entwicklung einer Rollenspezifischen Benutzerschnittstelle zur Konfiguration von Metrik-Dashboards	Development of a Role-specific User Interface for the Configuration of Metric Dashboards	Stefan	Guha
	Simulation and Visualization of compressible fluids interacting with rigid bodies	Philip	Trettner
Entwicklung eines adaptiven Frameworks zum automatischen Import von Sensordaten in Cyberphysical Systems am Beispiel des Energie Navigators	Development of an adaptable framework for automatic sensor data import in cyber-physical systems exemplified by the Energy Navigator	Rui	Ruhrländer
Entwicklung von Web-Demonstratoren für OSTP-Services	Development of Web-Demonstrators for OSTP-Services	Paul	Wiedeking
	Wireless Network Virtualization on Android Devices	Julian	Becker
Preprocessing für das Lösen nicht-linearer algebraischer Formeln	Preprocessing for Solving Non-Linear Algebraic Formulas	Dennis	Scully

Computer Science Colloquium – Talks

- 28 September 2012 Dr. Maurizio Bocca, Signal and Processing Across Networks Lab, University of Utah
Device-Free Localization from Wireless Network Signal Strength Measurements
10. August 2012 Prof. Dr. Dariu M. Gavrilă, Daimler R&D und University of Amsterdam
Human-Aware Intelligent Systems
- 26 July 2012 Professor Deok-Soo Kim, Ph.D., Hanyang University, Seoul, Korea
Understanding molecular geometry
- 17 July 2012 Prof. Dr. Rainer Spurzem, National Astronomical Observatory Beijing and University of Heidelberg
GPU Supercomputing on Three Continents and Application to Supermassive Black Holes and Gravitational Waves from Galactic Nuclei
- 5 July 2012 Dr. Sebastian Theophil, think-cell AG
LaTeX-less Layout
- 27 June 2012 Hans Meinhardt, Max-Planck-Institut Tübingen
Aufbau und Abbau von Mustern in der Biologie
- 31 May 2012 Dr. Ralf Huuck, NICTA / UNSW / Red Lizard Software
Software Bug Detection in Millions of Lines of C/C++ Code
- 23 May 2012 Wolfgang Coy, Humboldt-Universität Berlin
Turing Test Revisited
- 18 May 2012 Prof. Dr. Chris J. Myers, University of Utah, USA
Formal Verification of Genetic Circuits
- 25 April 2012 Johannes Blömer, Universität Paderborn
Alan Turing, die Enigma und die Geburt der modernen Kryptographie
20. April 2012 Dr. Christoph Quix, Lehrstuhl Informatik 5, RWTH Aachen
Ein generischer Ansatz zur Verwaltung von komplexen, heterogenen Datenmodellen
- 16 April 2012 Wolfgang Thomas
Alan Turing und die Grundfrage der Informatik: Was können Algorithmen?
- 30 March 2012 Prof. Torsten Hoefler
Performance Modeling for Systematic Performance Tuning
- 16 March 2012 Prof. Martin Ester, Simon Fraser University, Vancouver, Kanada
Probabilistic Models for Data Mining in Social Media
- 2 February 2012 Dr. Carsten Weise (IVU Traffic Technologies AG)
Das Smartphone steuert den Bus

- 25 January 2012 Thomas Noll
*Correctness, Safety and Fault Tolerance in Aerospace Systems: The
ESA COMPASS Project*
- 8 November 2011 Martin Jaensch (Daimler AG)
*Modulorientierter Ansatz für den modellbasierten Elektrik/Elektronik-
Architekturentwurf*

Research

Algorithms and Complexity



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Dipl.-Inform. Marcel Ochel
Dipl.-Math. Klaus Radke
Dipl.-Inform. Rebecca Reiffenhäuser (since December 2011)
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- **Guests**
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Tobias Harks (Maastricht University)
Chien-Chung Huang (TU Berlin)



Piotr Krysta (University of Liverpool)
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Thomas Sauerwald (MPI für Informatik)
Alexander Skopalik (TU Dortmund)
Chaitanya Swamy (University of Waterloo)

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. The algorithms and complexity group works on the design and analysis of algorithms, especially

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

A focus of our work during the last year was lying on approximation and online algorithms for mechanism design. In this field, algorithmic problems are studied in a game theoretic setting in which the input of the algorithm is not publicly known but distributed among a set of participants which only reveal their private valuations if it is in their best interest. A mechanism aggregates the preferences of the participants towards a joint decision. It is called incentive compatible if it is designed in such a way that it is a dominant strategy for each bidder to report preferences in a truthful manner. The general relevance of this research field is highlighted by this year's Nobel Prize in economics which is awarded to Alvin Roth and Lloyd Shapley for their work in mechanism design, especially "for the theory of stable allocations and the practice of market design".

One highlight of our research was, e.g., the design and analysis of an incentive-compatible approximation scheme for multi-unit auctions which was presented at SODA 2012, the top-ranked conference on algorithm analysis. Our mechanism is truthful in the universal sense, that is, it is a randomized mechanism corresponding to a distribution over deterministically truthful mechanisms. Previously known approximation schemes were truthful in expectation which is a weaker notion of randomized truthfulness assuming risk neutral bidders. The existence of such a mechanism was questioned by previous work showing that certain technical variants of multi-unit auctions do not admit a universally truthful approximation scheme.

The following report describes our research results and lists our publications and presentations. The scientific relevance of our work is, e.g., documented by an invited plenary talk given by Berthold Vöcking at ICALP, the leading European conference in theoretical computer science, and an invited keynote talk given by Thomas Kesselheim at the ALGOSENSORS symposium. The latter invitation is even more remarkable as Thomas Kesselheim received this honour as a Ph.D. student. As another highlight, we received a best paper award at ICALP 2012 for the paper "Online Mechanism Design (Randomized Rounding on the Fly)" by Piotr Krysta and Berthold Vöcking.

Research Projects

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.

Distributed Algorithms for Wireless Networks

J. Dams, M. Hoefer

Funded by DFG.

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

In the previous year we most prominently analyzed the scheduling of transmissions under Rayleigh-fading interference in which selfish agents in a wireless network scenario have to decide whether to transmit. Here simultaneous transmissions interfere with each other in a stochastic manner.

For the following years we plan to address further questions related to wireless networks. We plan to analyze aspects like scheduling transmissions for broadcasting a message to all nodes and problems dealing with unavailable channels and channels blocked by adversarial jammers. The main challenge here is the design of simple and reliable algorithms, which cope with local information, asymmetric interference relations and dynamically adjusting request structure.

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. We have used this algorithm as starting point for the battery management in a hybrid car.

In cooperation with the Institute for Control Engineering and the Hybrid Systems Group we have build a Simulink model of a hybrid car to simulate different algorithms for the battery management and to compare the results. Basis to compare the algorithms we have developed

is the equivalence factor strategy which is used in today's hybrid cars. We have furthermore implemented a no-regret learning algorithm which uses algorithms for the management of the battery which have theoretically proved bounds on its performance as well as algorithms which are used by the engineers in today's hybrid cars, as for example the equivalence factor strategy or heuristics used for the management of the battery. The performance of the no-regret learning algorithm shall then be compared to the results of the equivalence factor strategy used as reference value.

Approximation Algorithms for Combinatorial Auctions

O. Göbel, B. Vöcking

Funded by AlgoSyn.

A combinatorial auction is a setting where 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, as bidder's overlappings with respect to their desired items can be represented in a conflict graph. A set of bidders without conflicts is then an Independent Set. The problem 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 auction's underlying conflict graph 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 allocation in online auctions, that is when bidders are not known in advance but appear one after another. In online scenarios, it can be differentiated between items arriving in adversarial (i.e. worst-case) and in stochastic order. Basically, we consider the second one to be appropriate in our work.

The results of our work in the last year are approximation algorithms for the unweighted and the weighted case. Furthermore, by giving lower bounds, we show that with weighted disks, algorithms cannot do much better than the performance of our result. Ongoing work considers lower bounds for variations of disk graphs, e.g. such with equal diameter. In future research we try to transfer our results to conflict graphs which do not consist of disks, but rather have a bounded inductive independence number. This property is a generalization of the graphs considered so far and covers a more general class.

Design and Analysis of Algorithms in Wireless Networks

M. Hoefer, 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, engineers study heuristics under complex, more realistic models. However, they do not derive general performance guarantees.

The project aims at narrowing this gap. We use the interference models based on the signal-to-interference-plus-noise ratio (SINR) that are common among engineers. Applying techniques from analysis of algorithms allows us to prove that our algorithms calculate near-optimal solutions in arbitrary network topologies (that is, not only random or regular ones).

In the last year, we were able to transfer most of our results from previous years to more sophisticated scenarios. For example, we considered a setting in which communication requests arise over time, for which we could give a general transformation of previously developed algorithms. We also considered more advanced models, in which transmissions are able to adapt to different interference conditions or in which signal propagation is modeled more accurately. In each of these cases, results obtained in simpler cases turned out to be the key to understanding the advanced scenarios.

We also made a very first step towards application of our results in practice. We evaluated algorithms we developed in simulations on realistic networks that were generated randomly. Many theoretical results could be observed in these simulations as well. Altogether, this gives rise to the hope that this project can contribute to the fundamental understanding of designing scheduling algorithms for wireless networks.

Decentralized Matching Problems in large Networks

M. Hoefer, L. Wagner

Funded by DFG

In large networks it is a challenging task to compute (and administer) centralized solutions for a variety of coordination problems. This motivates the design and analysis of multi-agent

systems with decision-making under local information. In these cases agents act independently, they have to dynamically react and adjust their behavior. This raises stability and convergence problems. Furthermore, it is important to analyze social welfare criteria for stable states.

In this project, we analyze simple network design problems when actors in a network are rational selfish agents. We focus on fundamental matching problems, where agents want to match in a way that maximizes their own profit and have limited information about the network. Their information changes dynamically depending on the current matching. Our focus is on the question of convergence to a stable state where no agent has an incentive to deviate and the quality of such a state.

For locally stable matchings we showed a number of NP-hardness results regarding the reachability of given or even arbitrary stable matchings. In addition, there are games in which an exponential number of local changes to the matching are necessary until a stable state is reached. Additionally, we explored how the presence of different kinds of memory influences reachability. We also obtained NP-hardness and inapproximability results for computing maximum locally stable matchings.

In the future we want to focus on matchings in contribution games, where we analyze how agents can be motivated to ensure that the results of selfish behavior do not harm the social welfare too much. We aim at strategies to stabilize the social optimum and as well strategies which rule out the worst matchings and thus lower the price of anarchy.

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 addresses 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 α) 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, 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.

Randomized methods in algorithmic mechanism design

K. Radke, R. Reiffenhäuser, B. Vöcking

In this recently initiated project, we want to advance the state of the art in randomized mechanism design for combinatorial auctions with multi-dimensional bidders. Towards this end, we explore innovative algorithmic approaches for various kinds of combinatorial auctions in online and offline settings with the objective to improve upper and lower bounds on approximation ratios that can be guaranteed by incentive compatible mechanisms. Furthermore, we investigate whether randomness is crucial for obtaining incentive compatible approximation schemes for multi-unit auctions and related problems. The goal of this study is to gain a better understanding of the role of randomization in algorithmic mechanism design.

Motivated by our recent work about priority and online algorithms, we will develop and analyze secretary-type algorithms that consider bidders in random arrival order and use those bidders arriving first for computing prices for the remaining bidders. Within a competitive analysis we intend to derive upper and lower bounds on the approximation (competitive) ratio for combinatorial auctions with different classes of valuation functions. For example, we want to tackle the challenging question whether a constant factor approximation for combinatorial auctions with submodular or XOS valuations can be achieved by an incentive compatible online algorithm. Our goal is not only to derive upper and lower bounds on the approximation ratio for one particular variant of combinatorial auctions but to identify the properties and parameters that determine the quality of approximation in different problem variants.

In addition, we investigate whether and to which extent randomization is essential for the design of incentive compatible approximation schemes. Our study focuses on multi-unit auctions and related problems for which previous work yields an interesting landscape of different degrees of approximation achievable for different notions of incentive compatibility. We plan to tackle this question from two sides: On the one hand, we investigate which of the computational tasks solved by known approximation schemes can be solved without randomization. On the other hand, we want to sharpen the known characterizations imposed

by different notions of incentive compatibility. In particular, we aim at lower bounds on approximation ratios that can be achieved without randomization.

Algorithms for Covering Special Structures in Graphs

B. Ries, W. Unger

We consider the problem of covering special structures, e.g., paths of a certain length k . Our research is motivated by security issues in wireless sensor networks. A wireless sensor network can be modeled as graph, in which vertices represent sensor devices and edges represent communication channels between pairs of sensor devices. We aim to guarantee data integrity in the network. This can be done, for example under the assumption that there exists at least one node on every path of length k in the communication graph. The problem of covering all paths of length k with at least one node is known as the k -path vertex cover problem.

So far, we focused our research on the k -path vertex cover problem, which is a generalization of the well-studied vertex cover problem. Hence, most of the negative results for general graphs can be transferred. We consider special graph classes like d -regular graphs or circle graphs. For d -regular graphs we achieve different approximation factors depending on k and d . Moreover we have found a polynomial time algorithm for fixed but arbitrary k on circle graphs. In future we want to find out, whether there exists a polynomial time algorithm for arbitrary k , or if the problem is NP-hard. Furthermore, we would like to consider other graph classes or different variations of the k -path vertex cover problem, e.g., the set of nodes should be connected. In addition we change the topic from considering paths of length k to, e.g., circles of length k or other, more complex structures. Hence, our approximation factors result from worst case instances. We perform experiments on random generated graphs, in order to see, how the algorithms perform in arbitrary instances.

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 already did achieve good results. For these algorithms, precise upper bounds on the number of advice bits are introduced. Furthermore, we got first results on matchings of bipartite graphs in this model.

Other Activities

Courses

Our group offered the following lectures and seminars:

Winter semester 2011/12

- Lecture on Computability and Complexity Theory
- Lecture on Methods in Network Analysis
- Lecture on Algorithmic Graph Theory
- Seminar on Game-theoretic Mechanisms and Auctions
- Proseminar on Online Algorithms

Summer semester 2012

- Lecture on Efficient Algorithms
- Lecture on Algorithmic Game Theory
- Lecture on Theory of Distributed Systems
- Seminar on The Probabilistic Method
- Proseminar on Algorithms on Graphs
- Proseminar on Network Algorithms
- Proseminar on Randomized Algorithms

Berthold Vöckings scientific activities

- DFG-Fachkollegiat for Theoretical Computer Science
- 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 4th Symposium on Algorithmic Game Theory (SAGT), Salerno, Italy, October 17-19, 2011
- Member of the program committee of 26th IEEE International Parallel and Distributed Processing Symposium (IPDPS), Shanghai, China, May 21-25, 2012
- Member of the program committee of 13th ACM Conference on Electronic Commerce (EC), Valencia, Spain, June 4-8, 2012
- Member of the program committee of 39th International Colloquium on Automata, Languages and Programming (ICALP), Track C, Warwick, UK, July 9-13, 2012
- Member of the program committee of 31st Annual ACM SIGACT-SIGOPS Symposium on Principles of Distributed Computing (PODC), Madeira, Portugal, July 16-18, 2012

- Member of the program committee of 53rd Annual IEEE Symposium on Foundations of Computer Science (FOCS), New Brunswick, New Jersey, USA, October 20-23, 2012
- Organisation of the session "Polynomial-time algorithms for mechanism design" at the 21st International Symposium on Mathematical Programming (ISMP), Berlin, Germany, August 19-24, 2012

Martin Hoefers scientific activities

- Member of the program committee of 8th International Conference on Algorithmic Aspects of Information and Management (AAIM), Beijing, China, May 14-16, 2012
- Member of the program committee of 13th ACM Conference on Electronic Commerce (EC), Valencia, Spain, June 4-8, 2012
- Member of the program committee of 24th ACM Symposium on Parallelism in Algorithms and Architectures (SPAA), Pittsburgh, Pennsylvania, USA, June 25-27, 2012
- Member of the program committee of 20th European Symposium on Algorithms (ESA), Ljubljana, Slovenia, September 10-12, 2012
- Member of the program committee of 10th Workshop on Approximation and Online Algorithms (WAOA), Ljubljana, Slovenia, September 13-14, 2012
- Member of the program committee of 5th International Symposium on Algorithmic Game Theory (SAGT), Barcelona, Spain, October 22-23, 2012
- Member of the program committee of 8th Workshop on Internet and Network Economics (WINE), Liverpool, UK, December 9-12, 2012

Talks and Publications

Talks

Johannes Dams: Scheduling in Wireless Networks with Rayleigh-Fading Interference. ACM Symposium on Parallelism in Algorithms and Architectures (SPAA), Pittsburgh, Pennsylvania, USA, June 2012.

Johannes Dams: Distributed Wireless Capacity Maximization with Stochastic Channel Availabilities. Workshop on Realistic models for Algorithms in Wireless Networks (WRAWN), Warwick, UK, July 2012.

Martin Hoefer: Local Matching Dynamics in Social Networks. Universität Freiburg, Germany, November 2011.

Martin Hoefer: Local Matching Dynamics in Social Networks. University of Warwick, UK, February 2012.

Martin Hoefer: Local Matching Dynamics in Social Networks. Max-Planck-Institut für Informatik, Saarbrücken, Germany, May 2012.

Martin Hoefer: Local Matching Dynamics in Social Networks. Google Research, New York City, USA, May 2012.

Martin Hoefer: Secondary Spectrum Auctions with Symmetric and Submodular Bidders. ACM Conference on Electronic Commerce (EC), Valencia, Spain, June 2012.

Martin Hoefer: Algorithms for Strategic Interaction in Networks. Universität des Saarlandes, Saarbrücken, Germany, June 2012.

Martin Hoefer: Strategic Aspects in Wireless Networks. Summer School on Algorithmic Game Theory, Samos, Greece, July 2012.

Martin Hoefer: Contribution Games in Networks. International Symposium on Mathematical Programming (ISMP), Berlin, Germany, August 2012.

Martin Hoefer: Local Matching Dynamics in Social Networks. Blankensee Colloquium "Neighborhood Technologies", Berlin, Germany, August 2012.

Thomas Kesselheim: Approximation Algorithms for Capacity-Maximization Problems. Tutorial at the Workshop on Realistic models for Algorithms in Wireless Networks (WRAWN), Warwick, UK, July 2012.

Thomas Kesselheim: Approximation Algorithms for Wireless Link Scheduling with Flexible Data Rates. Workshop on Realistic models for Algorithms in Wireless Networks (WRAWN), Warwick, UK, July 2012.

Thomas Kesselheim: Dynamic Packet Scheduling in Wireless Networks. ACM SIGACT-SIGOPS Symposium on Principles of Distributed Computing (PODC), Madeira, Portugal, July 2012.

Thomas Kesselheim: Wireless Scheduling Algorithms with Rate Adaptation (Invited to Special Session on Interesting New Research Directions). ACM SIGACT International Workshop on Foundations of Mobile Computing (FOMC), Madeira, Portugal, July 2012.

Thomas Kesselheim: Approximation Algorithms for Wireless Link Scheduling with Flexible Data Rates. European Symposium on Algorithms (ESA), Ljubljana, Slovenia, September 2012.

Thomas Kesselheim: Approximation Algorithms for Wireless Spectrum Allocation with Power Control. Opening Keynote at the International Symposium on Algorithms for Sensor Systems, Wireless Ad Hoc Networks and Autonomous Mobile Entities (ALGOSENSORS), Ljubljana, Slovenia, September 2012.

Thomas Kesselheim: Comparative Study of Approximation Algorithms and Heuristics for SINR Scheduling with Power Control. International Symposium on Algorithms for Sensor Systems, Wireless Ad Hoc Networks and Autonomous Mobile Entities (ALGOSENSORS), Ljubljana, Slovenia, September 2012.

Klaus Radke: Online Packing with Gradually Improving Capacity Estimations and Applications to Network Lifetime Maximization. International Colloquium on Automata, Languages, and Programming (ICALP), Warwick, UK, July 2012.

Berthold Vöcking: A universally-truthful approximation scheme for multi-unit auctions. Annual ACM-SIAM Symposium on Discrete Algorithms (SODA), Kyoto, Japan, January 2012.

Berthold Vöcking: A universally-truthful approximation scheme for multi-unit auctions. Stanford University, USA, June 2012.

Berthold Vöcking: Randomized Mechanisms for Multi-unit Auctions. Keynote Talk at the International Colloquium on Automata, Languages, and Programming (ICALP), Warwick, UK, July 2012.

Berthold Vöcking: A universally-truthful approximation scheme for multi-unit auctions. International Symposium on Mathematical Programming (ISMP), Berlin, Germany, August 2012.

Berthold Vöcking: Randomized Mechanism Design: Approximation and Online Algorithms. Tutorial at the Max Planck Advanced Course on the Foundations of Computer Science (ADFOCS), Saarbrücken, Germany, August 2012.

Publications

Elliot Anshelevich and Martin Hoefer. Contribution Games in Networks. *Algorithmica* 63(1):51-90, 2012.

Lukas Belke, Thomas Kesselheim, Arie M. C. A. Koster, and Berthold Vöcking. Experimental study of approximation algorithms and heuristics for SINR scheduling with power control. In *Proceedings of the 8th International Symposium on Algorithms for Sensor Systems, Wireless Ad Hoc Networks and Autonomous Mobile Entities (ALGOSENSORS)*, Ljubljana, Slovenia. To appear.

Patrick Briest, Luciano Gual, Martin Hoefer, and Carmine Ventre. On Stackelberg Pricing with Computationally Bounded Customers. *Networks* 60(1):31-44, 2012.

Patrick Briest, Martin Hoefer, and Piotr Krysta. Stackelberg Network Pricing Games. *Algorithmica* 62(3-4):733-753, 2012.

Patrick Briest, Piotr Krysta, and Berthold Vöcking. Approximation Techniques for Utilitarian Mechanism Design. *SIAM Journal on Computing* 40(6):1587-1622, 2011.

Johannes Dams, Martin Hoefer, and Thomas Kesselheim. Scheduling in Wireless Networks with Rayleigh-Fading Interference. In *Proceedings of the 24th ACM Symposium on Parallelism in Algorithms and Architectures (SPAA)*, Pittsburgh, Pennsylvania, USA, pp. 327-335, 2012.

- Andreas Emil Feldmann, Heiko Röglin, and Berthold Vöcking. Computing approximate Nash equilibria in network congestion games. *Networks* 59(4):380-386, 2012.
- Martin Hoefer and Thomas Kesselheim. Secondary Spectrum Auctions for Symmetric and Submodular Bidders. In *Proceedings of the 13th ACM Conference on Electronic Commerce (EC)*, Valencia, Spain, pp. 657-671, 2012.
- Martin Hoefer and Siddharth Suri. Dynamics in network interaction games. *Distributed Computing* 25(5):359-370, 2012.
- Thomas Kesselheim. Approximation Algorithms for Wireless Link Scheduling with Flexible Data Rates. In *Proceedings of the 20th European Symposium on Algorithms (ESA)*, Ljubljana, Slovenia, pp. 659-670, 2012.
- Thomas Kesselheim. Dynamic Packet Scheduling in Wireless Networks. In *Proceedings of the 31st Annual ACM SIGACT-SIGOPS Symposium on Principles of Distributed Computing (PODC)*, Madeira, Portugal, pp. 281-290, 2012.
- Piotr Krysta and Berthold Vöcking. Online Mechanism Design (Randomized Rounding on the Fly). In *Proceedings of the 39th International Colloquium on Automata, Languages, and Programming (ICALP)*, Part II, Warwick, UK, pp. 636-647, 2012.
- Marcel Ochel, Klaus Radke, and Berthold Vöcking. Online Packing with Gradually Improving Capacity Estimations and Applications to Network Lifetime Maximization. In *Proceedings of the 39th International Colloquium on Automata, Languages, and Programming (ICALP)*, Part II, Warwick, UK, pp. 648-659, 2012.
- Berthold Vöcking. A universally-truthful approximation scheme for multi-unit auctions. In *Proceedings of the 23rd Annual ACM-SIAM Symposium on Discrete Algorithms (SODA)*, Kyoto, Japan, pp. 846-855, 2012.
- Berthold Vöcking. Randomized Mechanisms for Multi-unit Auctions (Extended Abstract). In *Proceedings of the 39th International Colloquium on Automata, Languages, and Programming (ICALP)*, Part II, Warwick, UK, pp. 27-29, 2012.

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, Felix Reidl, 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.

Theoretical and Practical Aspects of Kernelization

Alexander Langer, Somnath Sikdar, Felix Reidl, Peter Rossmanith

DFG-funded under grant RO 927/12

Kernelization is an area of parameterized complexity that deals with the study of preprocessing algorithms. A kernelization algorithm essentially strips away the easy parts of a problem instance exposing the core or the kernel. This is an area that has attracted the attention of both theoreticians and practitioners for the interesting mathematical problems it poses and the practical utility of many of the solutions.

The objective of this project is to study both theoretical and practical aspects of kernelization algorithms. On the theoretical side, we plan to investigate topics such as kernelization using non-standard parameters where some structural aspect of the input (other than the solution size) is used as parameter. Other topics include strong polynomial kernels, Turing kernels, and the connection between kernelization and approximability. On the practical side, we plan to design kernelization algorithms for concrete problems with the aim of implementing these algorithms. In particular, we want to investigate the possibility of improving kernels for several problems on planar graphs (among others).

Other Activities

Courses

Our group offered the following lectures and seminars:

Winter 2011/2012

- Lecture on "Parameterized Algorithms"
- Lab Course on "Design and Implementation of a Router Planner"
- Seminar on "Medizinische Bildverarbeitung" (with Deserno, Kobbelt, Ney, Seidl, Spitzer)

Summer 2012

- Lecture on "Analysis of Algorithms"
- Seminar on "Kompressionsalgorithmen"

Talks and Publications

Talks

Somnath Sikdar: Lower Bounds on the Complexity of MSO1 Model-Checking. LAMSADE, Université Paris Dauphine, Paris, November 2011.

Somnath Sikdar: Linear Kernels for Problems on Sparse Graphs. LAMSADE, Université Paris Dauphine, Paris, November 2011.

Felix Reidl: Linear kernels for graphs excluding a topological minor. DIAMANT TACO workshop on Treewidth and Combinatorial Optimization, Maastricht University, Maastricht, The Netherlands, January 2012.

Somnath Sikdar: Lower Bounds on the Complexity of MSO1 Model-Checking. DIAMANT TACO workshop on Treewidth and Combinatorial Optimization, Maastricht University, Maastricht, The Netherlands, January 2012.

Alexander Langer: Evaluation of an MSO-Solver. Meeting on Algorithm Engineering & Experiments (ALENEX), The Westin Miyako, Kyoto, Japan, January 2012.

Peter Rossmanith: Wie können Roboter Hindernisse in einem Labyrinth finden: Ein Schülerpraktikum. HSGYM - Hochschultag der Zürcher Mittelschulen, ETH Zürich, Zürich, Schweiz, February 2012.

Felix Reidl: Linear Kernels on Graphs Excluding Topological Minors. International Workshop on Approximation, Parameterized and Exact algorithms (APEX), Paris, France, February 2012.

Somnath Sikdar: Lower Bounds on the Complexity of MSO1 Model-Checking. Symposium on Theoretical Aspects of Computer Science (STACS), University Pierre et Marie Curie, Paris, France, March 2012.

Peter Rossmanith: Implementing Courcelle's Theorem. Department of Software Engineering and Theoretical Computer Science, TU Berlin, Berlin, German, May 2012.

Somnath Sikdar: Linear Kernels on Graphs Excluding Topological Minors. Dagstuhl Workshop on Data Reduction and Problem Kernels, Schloss Dagstuhl, Germany, June 2012.

Peter Rossmanith: Practical Approach to Solving Hard Graph Problems. Department of Computer Science and Information Engineering, Hungkuang University, Taiwan, July 2012.

Peter Rossmanith: Solving MSO-definable Graph Problems Efficiently. Graduiertenkolleg "Methods for Discrete Structures", TU Berlin, Berlin, October 2012.

Publications

Sounaka Mishra, Venkatesh Raman, Saket Saurabh, Somnath Sikdar, C. R. Subramanian: The Complexity of König Subgraph Problems and Above-Guarantee Vertex Cover. *Algorithmica* 61(4): 857-881 (2011)

Philipp Kranen, Felix Reidl, Fernando Sanchez Villaamil, Thomas Seidl: Hierarchical Clustering for Real-Time Stream Data with Noise. *Proceedings of SSDBM 2011, LNCS 6809*, pages 405-413, Springer, 2011.

Alexander Langer, Felix Reidl, Peter Rossmanith, Somnath Sikdar: Evaluation of an MSO-Solver. *Proceedings of ALENEX 2012*, pages 55-63, SIAM / Omnipress, 2012.

Dániel Marx, Peter Rossmanith (Eds.): Parameterized and Exact Computation – 6th International Symposium, IPEC 2011, Saarbrücken, Germany, September 6-8, 2011. Revised Selected Papers, LNCS 7112, Springer, 2012.

Robert Ganian, Petr Hliněný, Alexander Langer, Jan Obdržálek, Peter Rossmanith, Somnath Sikdar: Lower Bounds on the Complexity of MSO₁ Model-Checking. Proceedings of STACS 2012, LIPIcs 14, pages 326-337, Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2012.

Hans-Joachim Böckenhauer, Dennis Komm, Richard Královic, Peter Rossmanith: On the Advice Complexity of the Knapsack Problem. Proceedings of LATIN 2012, LNCS 7256, pages 61-72, Springer, 2012.

Michael Dom, Michael R. Fellows, Frances A. Rosamond, Somnath Sikdar: The Parameterized Complexity of Stabbing Rectangles. *Algorithmica* 62(1-2): 564-594 (2012)

Neeldhara Misra, Geevarghese Philip, Venkatesh Raman, Saket Saurabh, Somnath Sikdar: FPT algorithms for Connected Feedback Vertex Set. *J. Comb. Optim.* 24(2): 131-146 (2012)

Technical Reports

Alexander Langer, Felix Reidl, Peter Rossmanith, Somnath Sikdar: Linear Kernels on Graphs Excluding Topological Minors CoRR abs/1201.2780: (2012)

Eun Jung Kim, Alexander Langer, Christophe Paul, Felix Reidl, Peter Rossmanith, Ignasi Sau, Somnath Sikdar: Linear kernels and single-exponential algorithms via protrusion decompositions CoRR abs/1207.0835: (2012)

Software Modelling and Verification



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Dipl.-Inform. Sabrina von Styp
Dipl.-Inform. Hao Wu
Dipl.-Inform. Haidi Yue



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Dennis Guck
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Christoph Worreschk

- **Student Researchers**

Henrik Barthels
Philipp Berger
Thomas Heinemann
Sergey Sazonov
Lisa von Büttner

- **Visiting Scientists**

Pedro D'Argenio (University of Cordoba, ARG)
Peter Höfner (NICTA Sydney, AUS)
Ian Larson (Michigan University, USA)
Prof. Dr. Chris J. Myers (University of Utah, USA)
Nils Müllner (University of Oldenburg, GER)
Johann Schuster (Universität der Bundeswehr München, GER)
B. Srivathsan (LaBRI, Bordeaux, FRA)
Daniel Stan (ENS Cachan, FRA)
Gerjan Stokkink (University of Twente, NED)
Mark Timmer (University of Twente, NED)

Overview

2012 has been an exciting year. New projects, several new group members, and several successes in terms of prizes and awards. Several changes occurred in the personnel. Maximilian Odenbrett left our group, whereas Souymodip Chakraborty, Christian Dehnert and Hao Wu joined our group. Souy, Chris, and Stephen welcome to the chair! In July, Balaguru Srivathsan joined our group as a postdoctoral researcher. He received his PhD degree from LaBRI Bordeaux, France, for his dissertation on Timed Automata. Prior to this, he studied at IIT Bombay in India. In autumn of 2012, Sri gave a successful 10-hour lecture series on Timed Automata. Sri, welcome to our group!

Thomas Noll received this year the title of "außerplanmäßiger Professor" (shortly apl. Prof.). We congratulate Thomas with this great achievement! Dino Distefano received the prestigious Roger Needham Award for his work on software verification. This award is for a distinguished research contribution in computer science by a UK based researcher who has completed up to 10 years of post-doctoral research. Dino Distefano was one of the first PhD students supervised by Joost-Pieter Katoen and is currently professor at Queen Mary University, London. Marijn Jongerden received the German MMB (Messung, Modellierung und Bewertung von Rechensystemen) Award 2012 of the GI/ITG-Committee for Measurement, Modelling and Evaluation of Computing Systems for his PhD-thesis on "Model-based energy analysis of battery powered systems". His work was co-supervised by Boudewijn Haverkort (Twente). Finally, Joost-Pieter Katoen has been elected as Chairman of the QEST Steering Committee. QEST is an international annual conference on the Quantitative Evaluation of Systems.

We have successfully acquired two new European projects that started in autumn. SENSATION (Self Energy-Supporting Autonomous Computation), coordinated by the CISS Embedded System Institute in Aalborg (Denmark), aims at devising energy-centric modelling and optimisation tools for the design of resource-optimal reliable systems. The D-MILS (Distributed MILS for Dependable ICT) project, coordinated by The Open Group in Brussels, focuses on component-based modelling, as well as exploiting the compositional structure in the analysis.

We provided courses on Theoretical Foundations of the UML, Static Program Analysis, Advanced Model Checking, Compiler Construction, and Data Structures and Algorithms. In addition, we organised seminars on Foundations of Multi-Core Memory Models, Turing Award Winners, and Success Stories in Formal Methods. Numerous students completed their bachelor, master and diploma thesis at our chair in 2012.

Joost-Pieter Katoen

Research Projects

CARP: Correct and Efficient Accelerator Programming

J.-P. Katoen, C. Dehnert, F. Gretz, C. Jansen

EU FP7 project, coordinator: Imperial College London (A. Donaldson)

In recent years, massively parallel accelerator processors, primarily GPUs, have become widely available to end-users. Accelerators offer tremendous computing power at a low cost, and tasks such as media processing, simulation, medical imaging and eye-tracking can be accelerated to beat CPU performance by orders of magnitude. Performance is gained in energy efficiency and execution speed, allowing intensive media processing software to run in low-power consumer devices.

However, accelerators present a serious challenge for software developers. A system may contain one or more of the plethora of accelerators on the market, with many more products anticipated in the immediate future. Applications must exhibit portable correctness, operating correctly on any configuration of accelerators, and portable performance, exploiting processing power and energy efficiency offered by a wide range of devices.

The aim of CARP is to design techniques and tools for correct and efficient accelerator programming. In particular, a new portable programming language is to be developed, which can be both easily written and efficiently compiled to a lower level programming language for accelerator programming such as OpenCL and CUDA. With this new language, programmers can achieve portability of their applications, because the same source code may be compiled into efficient code for a number of accelerators, each having its own capabilities and limitations. Besides, programmers can focus on writing code without having to worry about hardware-specific effects of certain code optimisations.

Our main contribution in this EU-funded project is to provide the compiler backend with techniques to estimate quantitative aspects of accelerator programs. That is, given a program and an accelerator architecture, we aim for estimating the runtime and energy consumption of this program executing on this specific accelerator. The main motivation is that it is not at all obvious whether a program is well-suited for an accelerator, because of platform-dependent details, i.e. a program running well on one target platform might produce a poor performance on another. We aim for developing a (quantitative) formal model of an application executing on an accelerator, which is to be analysed using formal techniques. Integrating these techniques into the compiler will provide it with a means to evaluate the quality of generated low-level code with respect to multiple objectives and hence with a technique to select the most suited generated code for the target device and intended purpose.

Furthermore within the scope of the CARP project we aim at developing static verification techniques for automated analysis of software for accelerators. Due to a high degree of parallelism occurring especially in the case of highly optimised accelerator code, the error potential of this software is enormous. We focus on techniques allowing to analyse pointer manipulating behaviour of accelerator programs for both the portable programming language developed in CARP as well as low-level applications written in OpenCL.

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- 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 formulae 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.

Verifying Pointer Programs with Unbounded Heap Structures

J. Heinen, C. Jansen, J.-P. Katoen, Th. Noll

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.

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.

While in past years our focus was set on correctness and efficiency of the state space creation, we concentrated on the actual analysis this year. We developed an algorithm to check languages defined by graph grammars against MSO-formulae, allowing us to express complex properties of heap structures, such as reachability and shape properties. To express temporal properties we extended CTL* to quantified CTL*. While using CTL* allows to express temporal properties of the entire heap, quantified CTL* allows us to track objects over time and describe how their relation to other objects on the heap changes during the execution. We developed an on-the-fly algorithm for Quantified CTL*.

Another research topic was the investigation of the relations between our approach and Separation Logic. In Separation Logic heap structures are represented as formulae, which are strongly related to our abstract graph representation. We formalised the relation which will give us the possibility to carry over results from one approach to the other in the future.

Formal Models of Microcontroller Systems

Th. Noll,

J. Brauer (Chair of Software for Embedded Systems)

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 wrap-around 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.

Model-Based Energy Optimization of Automotive Control Systems

J.-P. Katoen, Th. Noll, H. Wu,

*joint project together with Th. Santen, D. Seifert
(Microsoft Research, Advanced Technology Labs Europe)*

funded by Microsoft Research and RWTH Aachen University Seed Fund

Reducing the energy consumption of controllers in vehicles requires sophisticated regulation mechanisms. Better power management can be enabled by allowing the controller to shut down sensors, actuators or embedded control units in a way that keeps the car safe and comfortable for the user, with the goal of optimising the (average or maximal) energy consumption. In this project, we develop an approach to systematically explore the design space of software-to-hardware mappings to determine energy-optimal deployments. It employs constraint-solving techniques for generating deployment candidates and probabilistic analyses for computing the expected energy consumption of the respective deployments. The feasibility and scalability of the method have been demonstrated by several case studies. Current efforts are concentrating on transferring the results to other application domains, such as the analysis of service-level requirements in cloud computing environments.

COMPASS: Correctness, Modelling and Performance of Aerospace Systems

C. Dehnert, J.-P. Katoen, V.Y. Nguyen, Th. Noll,

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

funded by European Space Agency (ESA), Thales Alenia Space and EU FP7 Programme

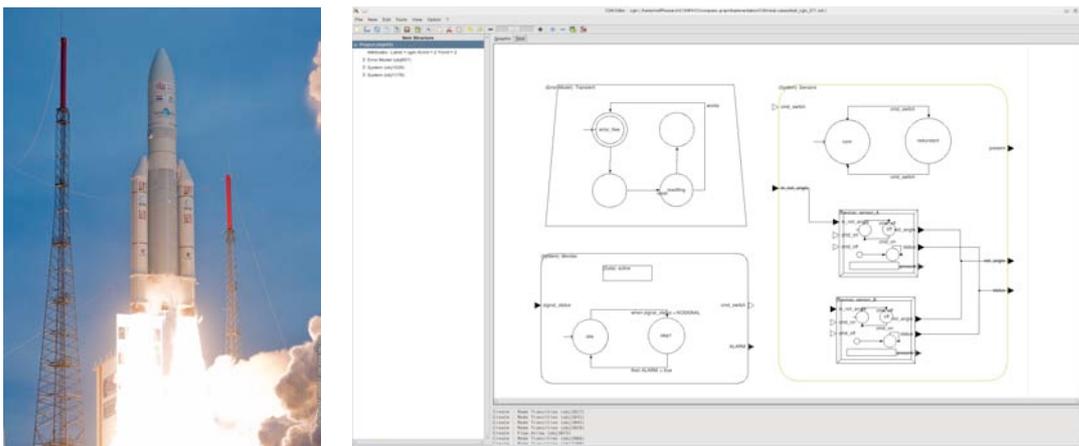
The size and complexity of software in spacecraft is increasing exponentially, and with that comes a strong need to validate it more effectively within the context of the overall (spacecraft) system. Current validation methods are labour-intensive as they rely on manual analysis, review and inspection. In the past four years we developed, with requirements from the European space industry, a novel modeling language and toolset to (semi-)automate validation activities. The AADL modeling language enables engineers to express the system, software and their reliability aspects, and the COMPASS toolset analyses them on correctness, safety, dependability and performance requirements using state-of-the-art model checking techniques and probabilistic versions thereof.

The results and experiences gained from this project have triggered follow-up activities to drive the further development of the overall technology. Several case studies have been performed with industrial involvement, of which two were conducted on a spacecraft in

development at system-level, namely a satellite platform. These efforts were carried out in parallel with the conventional software development for this system. The whole effort revealed numerous inconsistencies in the early design documents, and the use of formal analyses provided additional insight on discrete system behaviour (comprising nearly 50 million states), on hybrid system behaviour involving discrete and continuous variables, and enabled the automated generation of large fault trees (66 nodes) for safety analysis that typically are constructed by hand. The model's size pushed the computational tractability of the algorithms underlying the formal analyses, and revealed bottlenecks for future theoretical research. Additionally, the effort led to newly learned practices from which subsequent formal modelling and analysis efforts shall benefit, especially when they are injected in the conventional software development lifecycle. The case demonstrates the feasibility of fully capturing a system-level design as a single comprehensive formal model and analyse it automatically using a toolset based on (probabilistic) model checkers.

A more research-oriented follow-up activity is a PhD project on "Extending and Improving Formal Methods for System/Software Co-Engineering" within ESA's Networking Partnering Initiative that started in 2010 and aims to extend the currently used formal methods to cover a broader class of models in terms of expressiveness and scalability. 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.

Another closely related project named Distributed MILS (Multiple Independent Layers of Security), funded by the European Union in the framework of the FP7 programme, has recently been started. It aims to investigate and develop models and certification techniques for security architectures in heterogeneous, networked, service and computing environments. The ADL modelling language is also a cornerstone in this project, and it is aimed to leverage (parts of) the COMPASS toolset to provide analyses that support the assessment and certification of security aspects.



More information on COMPASS is available at <http://compass.informatik.rwth-aachen.de>.

Efficient Reachability Analysis for Probabilistic Timed Automata

J.-P. Katoen, B. Srivathsan

Soon after the success of conventional model-checking in the 80's where qualitative temporal properties of systems could be automatically verified, people started considering real-time properties. This gave birth to the timed automaton (TA) model in the early 90's. Timed automata are finite automata extended with clocks whose values can be compared with constants and can be set to zero during transitions. They model systems where events happen according to certain timing constraints, for instance a car-brake controller system which has to accentuate the hardware within a fixed number of seconds.

A timed automaton expresses a system model purely in terms of non-determinism. However, in some situations, it is desirable to express the probability of a system exhibiting a certain behaviour. To model such behaviour in systems, the model of probabilistic timed automata (PTA) has been introduced and has been implemented in the tool PRISM. Advances in timed automata technology have a direct influence on probabilistic timed automata.

A fundamental property in verification is state reachability. This problem is known to be decidable both for these automaton models and has been an active subject of research for over two decades now. Currently, there are mature tools implementing efficient reachability algorithms and have been used for industrial case studies.

The standard solution to the reachability problems for both TA and PTA involve the so-called abstractions of zones. A very recent work on TA has proposed a new reachability algorithm that involves non-convex abstractions and an on-the-fly learning of parameters for abstraction. Prototype implementation has shown a three-fold gain in some standard benchmarks.

The goal of this project is to understand to what extent the new results on abstractions for timed automata apply to probabilistic timed automata. The work would involve theory development as well as implementation to validate the gains.

Infinite-State Probabilistic Systems

H. Fu, J.-P. Katoen,

funded by China Scholarship Council (CSC)

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 decide if two given system are equivalent under a pre-established equivalence relation. In model checking, the task is to verify that 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 the probabilistic setting, or instead discover new techniques if necessary.

UMIC: Ultra High Speed Mobile Information and Communication

J.-P. Katoen, H. Yue

The evaluation of the quality-of-service of Wireless Sensor Networks is mostly done by simulation. In the context of the UMIC project, and in cooperation with the company CHESSE, 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 minimal energy demand.

The new GMAC protocol is modelled with a specific radio model, the 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 types of networks. However, it also delayed message propagation. Besides that, 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. Furthermore, we observed the existence of the Pareto Principle in the system, i.e., 20% of the nodes consumes 80% of the energy of the system.

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 CHES by means of the SINR model.

In cooperation with the UMIC Mobile Network Performance Group, we modelled and examined a newly developed Wireless Token Ring Protocol (WTRP), which aims to establish robust wireless communication for real-time applications, such as the braking system in vehicles. Due to the high requirement on correctness from the application layer, the protocol should be ultra reliable and robust to all possible failures. Traditional evaluation techniques like simulation provide essential characteristics of the WTRP, and model checking gives evidence on the correctness of the protocol.

We model the WTRP as a PTA (probabilistic timed automaton) in PRISM, a tool for formal modelling and analysis of systems that exhibit random, probabilistic, or timed behaviour. The WTRP has several components, and our starting point is the core part, the normal ring module, and the ring consists of five stations. With PRISM, we not only verified the "eventually" path property of the protocol under reliable channel assumption, but also calculated the probability of token missing when the channel is unreliable.

Since the latter situation is more common and almost inevitable in real applications, our future research will focus on the relation between channel failure rate and the number of necessary retransmissions of messages, to obtain a wireless communication as reliable as possible.

SYRUP: SYmbolic RedUction of Probabilistic Models

J.-P. Katoen

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

funded by the Dutch Research Council (NWO)

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.

MoVeS: Modeling, Verification and Control of Complex Systems

S. Chakraborty, J.-P. Katoen, F. Sher

EU FP7 project, coordinator: ETH Zurich (J. Lygeros)

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 application 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.

Minimisation of Markov Models

J.-P. Katoen, A. Sharma

funded by the India4EU Programme

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 with (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 and Markov decision processes and also to non-probabilistic systems.

Synthesising of Model Based Testing for Process Control Engineering

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

L. Yu, U. Epple (Chair of Process Control Engineering)

In Process Control Engineering, controller for plants that are not correct to their specification can cause fatal disasters, i. e. when tanks with acid run over people get injured or to 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 with respect 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 to automate and systematise the testing process in order to reduce costs and time.

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 simple controller, i.e. a motor controller, which allow 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 behaviour is an important feature of the plant controllers, i.e. the next action depends on the current filling level of a tank and it may 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 semantics is defined. This semantics then is employed 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 application 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.

Model Based Testing for AADL Models

S. von Styp, S. Sazonov, J.-P. Katoen

The COMPASS toolset allows model checking the specification given as an AADL model. To verify whether the actual implementation conforms to this specification model based testing is needed. So far model based testing using an AADL model for specification is not possible. Therefore a translation from AADL to transition systems with data and data-dependent control flow is developed. This transition system then is used by the test tool JTorX which finally will be integrated into the COMPASS toolset. Furthermore a theory is developed, allowing testing single components and its composition providing an method of simply adding components without regenerating the whole transition system again.

**ROCKS: Rigorous Dependability Analysis
using Model Checking Techniques for Stochastic Systems**

S. Chakraborty, H. Fu, F. Gretz, J.-P. Katoen, A. Sharma, F. Sher

funded by the Dutch Research Council (NWO) and DFG

Today's society relies increasingly on the correct and timely functioning of a large variety of information and communication 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

- Deputy Chair 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)
- Chair of the Steering Committee of QEST (Quantitative Evaluation of Systems), since September 2012.
- 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.
- Member editorial board The Scientific World Journal, Hindawi Publishers.
- Board Member of the Dutch Society on Theoretical Computer Science (NVTI).
- Senior member of the Association of Computing Machinery (ACM)
- **Member of the Program Committees of the following events:**
 - 15th International Conference on Foundations of Software Science and Computation Structures (FoSSaCS 2012)
 - 17th International Workshop on Formal Methods for Industrial Critical Systems (FMICS 2012)
 - 17th International Conference on Implementation and Application of Automata (CIAA 2012)
 - 9th International Conference on Quantitative Evaluation of SysTems (QEST 2012)
 - 10th International Symposium on Automated Technology for Verification and Analysis (ATVA 2012)
 - 10th Summer School on Modelling and Verifying Parallel Processes (MOVEP 2012)
- **Invited speaker at:**
 - Workshop on the 15th Anniversary of LSV, ENS Cachan, France
 - Tutorial at Joint Conference iFM & ABZ 2012, Pisa, Italy
 - 33rd International Joint Conference Petri Nets & ACSD 2012, Hamburg, Germany
 - NATO Summer School on Engineering Dependable Software Systems, Marktoberdorf 2012
 - Tutorial at Automated Software Engineering (ASE), Essen, Germany
 - ROCKS Autumn School, Vahrn, Italy
- Member of the IFIP Working Group 1.8 on Concurrency Theory.
- Member of the IFIP Working Group 2.2 on Programming Concepts.
- Member of several external international PhD committees.
- Member Selection Committee of Professorship at Free University of Brussels, Belgium.

- Member Selection Committee of Associate Professor DTU Lyngby, Denmark.
- Chairman of Selection Committee of Full Professorship on Logics and Automata Theory.
- Chairman of the Examination Board of Department of Computer Science (until April 2012).
- Head of Computer Science Department (since April 2012).

Thomas Noll

- Student advisor for the following applied subjects within CS:
Electrical Engineering, Civil Engineering, and Medicine
- Member of the examination board for Computer Science
- Member of CS Commission for Teaching Service
- **Member of the Program Committees of the following events:**
 - Software Engineering Track at the 28th Annual ACM Symposium on Applied Computing (SAC 2013)
 - 3rd Analytic Virtual Integration of Cyber-Physical Systems Workshop (AVICPS 2012) at the 33rd IEEE Real-Time Systems Symposium (RTSS 2012)
 - 1st International Workshop on Formal Techniques for Safety-Critical Systems (FTSCS 2012) at the 14th International Conference on Formal Engineering Methods (ICFEM 2012)
 - 6th International Conference on Software Security and Reliability (SERE 2012)

Talks and Publications

Talks

Marco Bozzano, and Joost-Pieter Katoen. Safety, Dependability and Performance Analysis of Extended AADL Models. Tutorial at 9th Int. Conf. on Integrated Formal Methods (iFM), 2012.

Marco Bozzano, Joost-Pieter Katoen, and Thomas Noll. Safety, Dependability and Performance Analysis of Extended AADL Models. Tutorial at 27th IEEE/ACM Int. Conf. on Automated Software Engineering (ASE), 2012.

Pierre Dissaux, Viet Yen Nguyen, and Thomas Noll. Tutorial on COMPASS Toolset. AADL Standards Meeting at SAE AeroTech Congress & Exhibition, Toulouse, France, 2011.

Hongfei Fu. Computing Game Metrics on Markov Decision Processes. Talk, ICALP, Birmingham, 2012.

Hongfei Fu. Computing Game Metrics on Markov Decision Processes. Talk, Oxford University, Oxford, 2012.

Friedrich Gretz. Prinsys - A Software Tool for the Synthesis of Probabilistic Invariants. Talk, WING workshop, Manchester, 2012.

Friedrich Gretz. PRINSYS – Probabilistic INvariant SYnthesiS . Talk, GRK Workshop, Dagstuhl, 2012. Gemeinsamer Workshop der DFG Informatik-Graduiertenkollegs.

Friedrich Gretz. Towards Analysis of Sequential Probabilistic Programs. Talk, Oxford, 2012.

Friedrich Gretz. Average Runtime Estimation. Talk, CARP, Cambridge, 2012. CARP Project Meeting at ARM .

Friedrich Gretz. Operational versus Weakest Precondition Semantics for the Probabilistic Guarded Command Language. Talk, QEST, London, 2012.

Jonathan Heinen. Analysis and Verification of Heap-Manipulating Programs. Talk at D-CON, Kaiserslautern, 2012.

Jonathan Heinen. Juggernaut: The Analysis of Object Oriented Programs. Talk at mac, Uni Bamberg, 2012.

Christina Jansen. Verifying Pointer Programs Using Hyperedge Replacement Grammars. Talk, ULB Bruxelles, 2012. Invited Presentation.

Joost-Pieter Katoen. Towards Trustworthy Aerospace Design Using Formal Methods: An Experience Report. Talk at PUMA Graduiertenkolleg, TU Munich,, 2012.

Joost-Pieter Katoen. Analyzing Probabilistic Programs: Pushing the Limits of Automation. Invited Talk at Workshop on 15 Years of LSV, ENS Cachan, 2012.

Joost-Pieter Katoen. One Can Do Much More With Model Checking Than You Think! . Invited Talk at Opening of the FUNDP Research Centre Fundamentals of Computer Science (FOCUS). Namur, Belgium, 2012.

Joost-Pieter Katoen. Towards Trustworthy Aerospace Design Using Formal Methods: An Experience Report. Talk at Embedded Systems Institute, Eindhoven, NL, 2012.

Joost-Pieter Katoen. Revisiting GSPNs: New Semantics and Analysis Algorithms. Invited Talk at 33rd International Conference on Application and Theory of Petri Nets and

Concurrency (ICATPN) and 12th International Conference on Application of Concurrency to System Design (ACSD), Hamburg, Germany, 2012.

Joost-Pieter Katoen. Performance Analysis by Model Checking. Five Lectures at NATO Summer School on Engineering Dependable Software Systems. Marktoberdorf, Germany, 2012.

Joost-Pieter Katoen. Revisiting GSPNs: New Semantics and Analysis Algorithms. Talk at IFIP WG 2.2 Meeting, CWI Amsterdam, NL, 2012.

Joost-Pieter Katoen. Revisiting GSPNs: New Semantics and Analysis Algorithms. Kolloquium at IMT Lucca, Italy, 2012.

Joost-Pieter Katoen. Towards Trustworthy Aerospace Design Using Formal Methods: An Experience Report. Invited lecture at ROCKS Autumn School, Vahrn, Italy, 2012.

Viet Yen Nguyen. COMPASS Graphical Modeller. Talk at ESTEC Final Presentation Days, 2012.

Viet Yen Nguyen. Formal Correctness, Safety, Dependability and Performance of a Satellite. Talk at ICSE 2012, 2012.

Viet Yen Nguyen. Satellite Platform Case Study With SLIM and COMPASS. Talk, Dagstuhl Seminar on Architecture-Driven Semantic Analysis of Embedded Systems, 2012.

Thomas Noll. Correctness, Safety and Fault Tolerance in Aerospace Systems: The ESA COMPASS Project. Talk, RWTH Aachen University, 2012. CS Colloquium.

Thomas Noll. Correctness, Safety and Fault Tolerance in Aerospace Systems: The ESA COMPASS Project. Talk, Dagstuhl Seminar on Architecture-Driven Semantic Analysis of Embedded Systems, 2012.

Arpit Sharma. Weighted Probabilistic Equivalence Preserves ω -Regular Properties. MMB/DFT Conference, Kaiserslautern, Germany, 2012.

Falak Sher. Compositional Abstraction Techniques for Probabilistic Automata. Talk, TCS, Amsterdam, 2012.

Publications

Christel Baier, E. Moritz Hahn, Boudewijn R. Haverkort, Holger Hermanns, and Joost-Pieter Katoen. Model Checking for Performability. *Mathematical Structures in Computer Science*. pages 1–42. 2013.

Kamal Barakat, and Thomas Noll. A Native Approach to Modeling Timed Behavior in the Pi-Calculus (short paper). In *Proc. of 6th IEEE Int. Symp. on Theoretical Aspects of Software Engineering (TASE)*. pages 253–256. IEEE, 2012.

Marco Bozzano, Alessandro Cimatti, Joost-Pieter Katoen, Viet Yen Nguyen, Thomas Noll, and Marco Roveri. Safety, Dependability, and Performance Analysis of Extended AADL Models. *The Computer Journal*, 54(5):754–775, 2011.

Alessandro D’Innocenzo, Alessandro Abate, and Joost-Pieter Katoen. Robust PCTL Model Checking. In *Hybrid Systems: Computation and Control (HSCC)*. pages 275–286. ACM Press, 2012.

Marie-Aude Esteve, Joost-Pieter Katoen, Viet Yen Nguyen, Bart Postma, and Yuri Yushtein. Formal Correctness, Safety, Dependability and Performance Analysis of a Satellite. In *34th*

- International Conference on Software Engineering (ICSE). pages 1022–1031. ACM and IEEE CS Press, 2012.
- Hongfei Fu. Computing Game Metrics on Markov Decision Processes. In 39th International Colloquium on Automata, Languages and Programming (ICALP). pages 227–238. Volume 7392 of LNCS. Springer-Verlag, 2012.
- Hongfei Fu, and Joost-Pieter Katoen. Deciding Probabilistic Simulation between Probabilistic Pushdown Automata and Finite-State Systems. In Foundations of Software Technology and Theoretical Computer Science (FSTTCS). LIPIcs. Schloss Dagstuhl, 2011.
- Friedrich Gretz, Joost-Pieter Katoen, and Annabelle McIver. Operational versus Weakest Precondition Semantics for the Probabilistic Guarded Command Language. In Quantitative Evaluation of Systems (QEST). IEEE CS Press, 2012.
- Dennis Guck, Tingting Han, Joost-Pieter Katoen, and Martin R. Neuhäuser. Quantitative Timed Analysis of Interactive Markov Chains. In NASA Formal Methods Symposium (NFM). pages 8–23. Volume 7226 of LNCS. Springer-Verlag, 2012.
- Jonathan Heinen, Christina Jansen, and Henrik Barthels. Juggernaut - An Abstract JVM. In 2nd Int. Conf. on Formal Verification of Object-Oriented Software (FoVeOOS). Volume 7421 of LNCS. Springer-Verlag, 2012.
- Frédéric Herbreteau, B Srivathsan, and Igor Walukiewicz. Efficient emptiness check for timed Büchi automata. *Formal Methods in System Design*, 40(2):122–146, 2012.
- Frédéric Herbreteau, B Srivathsan, and Igor Walukiewicz. Better abstractions for timed automata. In LICS. pages 375–384. IEEE, 2012.
- Nils Jansen, Erika Abraham, Matthias Volk, Ralf Wimmer, Joost-Pieter Katoen, and Bernd Becker. The COMICS Tool - Computing Minimal Counterexamples for DTMCs. In Proc. of the 10th Int. Symp. on Automated Technology for Verification and Analysis (ATVA). pages 349–353. Volume 7561 of LNCS. Springer-Verlag, 2012.
- Joost-Pieter Katoen, Jaco van de Pol, Marielle Stoelinga, and Mark Timmer. A linear process-algebraic format with data for probabilistic automata. *Theoretical Computer Science*, 413:36–57, 2012.
- Joost-Pieter Katoen, Daniel Klink, Martin Leucker, and Verena Wolf. Three-Valued Abstraction for Probabilistic Systems. *Journal on Logic and Algebraic Programming*, 81(4):356–389, 2012.
- Joost-Pieter Katoen. Model Checking: One Can Do Much More Than You Think!. In *Fundamentals of Software Engineering (FSEN)*. pages 1–14. Volume 7141 of LNCS. Springer-Verlag, 2012.
- Joost-Pieter Katoen. GSPNs Revisited: Simple Semantics and New Analysis Algorithms. In *Applications of Concurrency to System Design (ACSD)*. pages 6–12. IEEE CS Press, 2012.
- Etienne Lozes, Florent Jacquemard, Jules Villard, and Ralf Treinen. Multiple Congruence Relations, First-Order Theories on Terms, and the Frames of the Applied Pi-Calculus. In *Theory of Security and Applications (TOSCA 2011)*. pages 166–185. Volume 6993 of LNCS. Springer-Verlag, 2012.
- Thomas Noll. Correctness, Safety and Fault Tolerance in Aerospace Systems: The ESA COMPASS Project (Abstract). In *Architecture-Driven Semantic Analysis of Embedded Systems (Dagstuhl Seminar 12272)*. pages 42–42. Volume 2 of Dagstuhl Reports. Schloss Dagstuhl–Leibniz-Zentrum für Informatik, 2012.

Arpit Sharma, and Joost-Pieter Katoen. Weighted Lumpability on Markov Chains. In 8th Ershov Informatics Conference (PSI) . pages 322–339. Volume 7162 of LNCS. Springer-Verlag, 2012.

Arpit Sharma. Weighted Probabilistic Equivalence Preserves ω -Regular Properties. In 16th Measurement, Modeling, and Evaluation of Computing Systems and Dependability and Fault Tolerance Conference (MMB/DFT). pages 121–135. Volume 7201 of LNCS. Springer Verlag, 2012.

Falak Sher, and Joost-Pieter Katoen. Compositional Abstraction Techniques for Probabilistic Automata. In IFIP Conference on Theoretical Computer Science (TCS). pages 325–341. Volume 7604 of LNCS. Springer-Verlag, 2012.

B Srivathsan, and Igor Walukiewicz. An alternate proof of Statman’s finite completeness theorem. *Information Processing Letters*, 112(14-15):612–616, 2012.

Mani Swaminathan, Joost-Pieter Katoen, and Ernst-Rüdiger Olderog. Layered Reasoning for Randomized Distributed Algorithms. *Formal Aspects of Computing*, 24(4–6):477–496, 2012.

Bart Theelen, Joost-Pieter Katoen, and Hao Wu. Model Checking of Scenario-Aware Dataflow with CADP. In *Design, Automation, and Test in Europe (DATE)*. pages 653–658. IEEE CS Press, 2012.

Mark Timmer, Joost-Pieter Katoen, Jaco van de Pol, and Marielle Stoelinga. Efficient Modelling and Generation of Markov Automata. In *Concurrency Theory (CONCUR)*. pages 364–379. Volume 7454 of LNCS. Springer-Verlag, 2012.

Ralf Wimmer, Nils Jansen, Erika Abraham, Joost-Pieter Katoen, and Bernd Becker. Minimal Critical Subsystems as Counterexamples for ω -Regular DTMC Properties. In *Methoden und Beschreibungssprachen zur Modellierung und Verifikation von Schaltungen und Systemen (MBMV)*. pages 169–180. Verlag Dr. Kovac, 2012.

Ralf Wimmer, Nils Jansen, Erika Abraham, Bernd Becker, and Joost-Pieter Katoen. Minimal Critical Subsystems for Discrete-Time Markov Models. In *Tools and Algorithms for the Construction and Analysis of Systems (TACAS)*. pages 299–314. Volume 7214 of LNCS . Springer-Verlag, 2012.

Technical Reports

Ralf Wimmer, Nils Jansen, Erika Abraham, Joost-Pieter Katoen, and Bernd Becker. Minimal Counterexamples for Refuting ω -Regular Properties of Markov Decision Processes. Technical Report 88, Reports of SFB/TR 14 AVACS, 2012. ISSN: 1860-9821.

Programming Languages and Verification



Staff

- **Faculty**

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- **Secretary**

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- **Research Assistants**

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Dipl.-Inform. Fabian Emmes
Dipl.-Inform. Carsten Fuhs (*funded by GIF, until December 2011*)
Dipl.-Inform. Carsten Otto (*funded by DFG*)
Dipl.-Inform. Martin Plücker
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Janine Repke

- **Technical Staff**

Arnd Gehrman



Overview

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

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

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

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

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

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

In the winter term 2011/12, we held the first-year course on *Programming Concepts* for more than 500 students, a seminar on *Automated Termination Analysis*, and a seminar on *Satisfiability Checking* (together with the group of Prof. Dr. E. Ábrahám). In the summer term 2012, we held the lecture on *Functional Programming*, a proseminar on *Advanced Programming Concepts in Java, Haskell, and Prolog*, and again a seminar on *Satisfiability Checking* (with the group of Prof. Dr. E. Ábrahám).

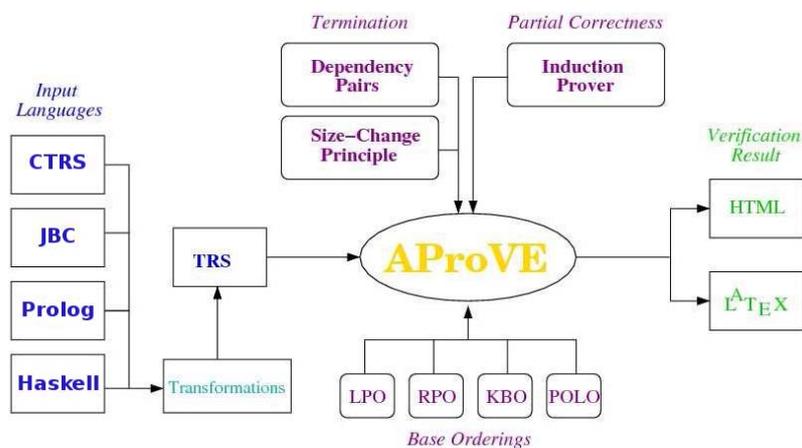
In January 2012, Carsten Fuhs left our research group and took up a postdoc position in the group of Prof. Dr. Byron Cook at Queen Mary University resp. University College London, UK. He defended his PhD thesis on December 21, 2011.

Research Projects

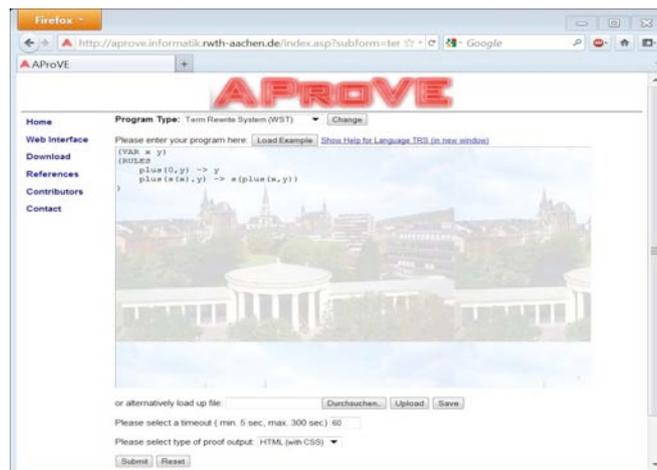
AProVE: Automated Program Verification Environment

J. Giesl, M. Brockschmidt, F. Emmes, C. Fuhs, C. Otto, M. Plücker, T. Ströder

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



Our verification framework is also applicable for teaching purposes in courses on formal methods, term rewriting, or program verification. The tool is written in Java and verification can be performed fully automatically.



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 and Complexity Analysis for Logic Programs

J. Giesl, T. Ströder, F. Emmes, P. Schneider-Kamp, C. Fuhs

In this project we cooperate with the University of Southern Denmark and the University College London, funded by the DFG. 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 languages. This includes the handling of “non-logical” features such as *cuts* in Prolog. To this end, we work on new approaches to transform logic programs into term rewrite systems such that termination of the resulting term rewrite system implies termination of the original program. Then all existing techniques and systems for termination analysis of term rewriting can also be used to verify termination of Prolog programs. Our goal is to develop this approach into a general methodology for analyzing logic programs. For example, we have shown how to use this technique to also analyze properties like complexity and determinacy in addition to termination.

Termination Analysis for Imperative Programs

J. Giesl, M. Brockschmidt, C. Otto, T. Ströder, M. Plücker

The goal of this project (funded by the DFG) is to use a similar approach as for logic languages also for the termination analysis of imperative languages like Java or C. In our approach, imperative 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 investigate how to use termination graphs for other program analyses besides termination analysis. To handle languages like C, we also work on an extension of our approach to deal with operations for direct heap manipulation and pointer arithmetic.

Satisfiability Checking for Termination Analysis and Program Synthesis

J. Giesl, M. Brockschmidt, C. Fuhs, B. Cook, M. Codish, A. Ben-Amram, 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 College London, 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. This also includes the coupling of different approaches to generate ranking functions or well-founded orders for termination proofs.

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 proof is automatically certified by Isabelle afterwards.

Automated Complexity Analysis

J. Giesl, F. Emmes, T. Ströder, L. Noschinski

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 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:

- Joint Invited Speaker of the *14th International Symposium on Principles and Practice of Declarative Programming (PPDP '12)* and the *22nd International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR '12)*, Leuven, Belgium, September 2012
- Invited Speaker of the *Summer School 2012 on Verification Technology, Systems & Applications (VTSA '12)*, Saarbrücken, Germany, September 2012
- Chair of the *IFIP Working Group 1.6 on Term Rewriting*
- PC-Member and participant of the *6th International Joint Conference on Automated Reasoning (IJCAR '12)*, Manchester, UK, June/July 2012
- Member of the Steering Committee of the *Federated Logic Conference (FLoC)*
- Member of the Steering Committee of the *ACM/IEEE Symposium on Logic in Computer Science (LICS)*
- Member of the Steering Committee of the *International School on Rewriting (ISR)*
- Member of the Steering Committee of the *Annual Termination Competition*
- Participant of the *AlgoSyn Meeting*, Rolduc, The Netherlands, November 2011
- Participant of the *TeReSe Workshops* in Utrecht (December 2011) and Aachen (March 2012)
- Participant of the *12th International Workshop on Termination*, Obergurgl, Austria, February 2012
- Participant of the *24th International Conference on Computer Aided Verification (CAV '12)*, Berkeley, CA, USA, July 2012
- Member of the Committee for the PhD thesis of Matthias Raffelsieper (Technical University Eindhoven, The Netherlands), 2011
- Reviewer for the PhD thesis of Andreas Schnabl (University of Innsbruck, Austria), 2012
- Project reviewer for the DFG (several projects)
- Reviewer for many international journals and conferences

M. Brockschmidt:

- Research visit and participant of the *Deduktionstreffen der GI-Fachgruppe Deduktionssysteme*, KIT, Karlsruhe, Germany, October 2012
- Participant of the *TeReSe Workshops* in Utrecht (December 2011) and Aachen (March 2012)
- Participant of the *12th International Workshop on Termination*, Obergurgl, Austria, February 2012
- Participant of the *24th International Conference on Computer Aided Verification (CAV '12)*, Berkeley, CA, USA, July 2012
- Research visit to the University College London, September 2012
- Reviewer for several international journals and conferences

F. Emmes:

- Participant of the *Deduktionstreffen der GI-Fachgruppe Deduktionssysteme*, KIT, Karlsruhe, Germany, October 2012
- Participant of the *TeReSe* Workshops in Utrecht (December 2011) and Aachen (March 2012)
- Participant of the *12th International Workshop on Termination*, Obergurgl, Austria, February 2012
- Participant of the *6th International Joint Conference on Automated Reasoning (IJCAR '12)*, Manchester, UK, June/July 2012
- Participant of the *Summer School 2012 on Verification Technology, Systems & Applications (VTSA '12)*, Saarbrücken, Germany, September 2012
- Reviewer for several international journals and conferences

C. Fuhs:

- Editor of the *Department Of Computer Science Technical Reports* of RWTH Aachen (until December 2011)
- Participant of the *TeReSe* Workshop in Utrecht (December 2011)
- Reviewer for several international journals and conferences

C. Otto:

- Participant of the *TeReSe* Workshops in Utrecht (December 2011) and Aachen (March 2012)
- Participant of the Workshop *Entwicklung und Evolution von Forschungssoftware (EEFSW)*, Rolduc, The Netherlands, November 2011
- Reviewer for several international journals and conferences

M. Plücker:

- Participant of the *TeReSe* Workshops in Utrecht (December 2011) and Aachen (March 2012)

T. Ströder:

- Editor of the *Department Of Computer Science Technical Reports* of RWTH Aachen (since January 2012)
- *Friedrich-Wilhelm Award* for excellent diploma thesis, November 2011
- Organizer and participant of the *TeReSe* Workshop in Aachen, March 2012
- *Chair of the AlgoSyn Scholarship Holders and Collegiates Steering Committee*, October 2011-September 2012
- Participant of the Workshop *Entwicklung und Evolution von Forschungssoftware (EEFSW)*, Rolduc, The Netherlands, November 2011
- Participant of the *AlgoSyn Meeting*, Rolduc, The Netherlands, November 2011
- Participant of the *TeReSe* Workshop in Utrecht (December 2011)
- Research visit to the University of Southern Denmark, Odense, January 2012
- Member of the Organization Team of the *Girls' Day*, RWTH Aachen, April 2012

- Participant of the *Joint Workshop of the German Research Training Groups in Computer Science*, Dagstuhl, Germany, June 2012
- Research visit to the University College London, September 2012
- Reviewer for several international journals and conferences

Talks and Publications

Talks

- J. Giesl: *Detecting Non-Looping Non-Termination*, 12th International Workshop on Termination, Obergurgl, Austria, February 2012
- J. Giesl: *Detecting Non-Looping Non-Termination*, TeReSe Workshop, Aachen, Germany, March 2012
- J. Giesl: *Programmiersprachen und Verifikation*, Ringvorlesung für Oberstufenschülerinnen und -schüler, RWTH Aachen, June 2012
- J. Giesl: *Detecting Non-Looping Non-Termination*, 6th International Joint Conference on Automated Reasoning (IJCAR '12), Manchester, UK, June 2012
- J. Giesl: *Automated Termination Analysis*, Summer School 2012 on Verification Technology, Systems & Applications (VTSA '12), Saarbrücken, Germany, September 2012
- J. Giesl: *Symbolic Evaluation Graphs and Term Rewriting - A General Methodology for Analyzing Logic Programs*, 14th International Symposium on Principles and Practice of Declarative Programming (PPDP '12) and 22nd International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR '12), Leuven, Belgium, September 2012
- M. Brockschmidt: *Automated Detection of Non-Termination and NullPointerExceptions for Java Bytecode*, KIT, Karlsruhe, October 2011
- M. Brockschmidt: *Termination Graphs for Java Bytecode*, Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, KIT, Karlsruhe, Germany, October 2011
- M. Brockschmidt: *Statische Analyse von Java-Programmen*, RWTH Aachen, Tag der Informatik, December 2011
- M. Brockschmidt: *Proving Termination of Java Bytecode with Cyclic Data*, 12th International Workshop on Termination, Obergurgl, Austria, February 2012
- M. Brockschmidt: *Proving Non-Termination of Java Bytecode*, 12th International Workshop on Termination, Obergurgl, Austria, February 2012
- M. Brockschmidt: *Automated Termination Proofs for Java Programs with Cyclic Data*, 24th International Conference on Computer Aided Verification (CAV '12), Berkeley, CA, USA, July 2012
- M. Brockschmidt: *Reducing the Ugly to the Bad*, University College London, September 2012
- F. Emmes: *A Dependency Pair Framework for Innermost Complexity Analysis of Term Rewrite Systems*, Deduktionstreffen der GI-Fachgruppe Deduktionssysteme, KIT, Karlsruhe, Germany, October 2011
- F. Emmes: *Automatically Analyzing Runtime Complexity via Term Rewriting*, AlgoSyn Seminar, RWTH Aachen, October 2011
- F. Emmes: *Automated Runtime Complexity Analysis for Prolog by Term Rewriting*, 12th International Workshop on Termination, Obergurgl, Austria, February 2012
- C. Fuhs: *Harnessing First Order Termination Provers Using Higher Order Dependency Pairs*, TeReSe Workshop, Utrecht, The Netherlands, December 2011
- C. Fuhs: *SAT Encodings: From Constraint-Based Termination Analysis to Circuit*

Synthesis, PhD Talk, RWTH Aachen, December 2011

- T. Ströder: *Benchmarking in Computer Science: Requirements and Problems*, *AlgoSyn Meeting*, Rolduc, The Netherlands, November 2011
- T. Ströder: *Synthesis of Term Rewrite Systems for Automated Runtime Complexity Analysis of Prolog Programs*, *AlgoSyn Seminar*, RWTH Aachen, April 2012
- T. Ströder: *Graph-Based Methods for Analysis and Synthesis of Programs*, *AlgoSyn Seminar*, RWTH Aachen, June 2012
- T. Ströder: *Graph-Based Methods for Analysis and Synthesis of Programs*, *Proceedings of the Joint Workshop of the German Research Training Groups in Computer Science*, Dagstuhl, Germany, June 2012
- T. Ströder: *Graphbasierte Terminierungsanalyse*, *Schüleruniversität*, RWTH Aachen, August 2012
- T. Ströder: *Programmiersprachen - Überblick und Konzepte*, *Schüleruniversität*, RWTH Aachen, August 2012
- T. Ströder: *Automated Termination Analysis of Imperative Programs with Pointer Arithmetic and Heap Manipulations*, University College London, September 2012
- S. Falke: *Termination Analysis of Imperative Programs Using Bitvector Arithmetic*, *Lehrstuhlseminar*, RWTH Aachen, April 2012
- S. Falke: *A Theory of Arrays with Set and Copy Operations*, *Lehrstuhlseminar*, RWTH Aachen, September 2012
- J. Repke: *Automatische Terminierungsanalyse von LLVM Programmen*, *Lehrstuhlseminar*, RWTH Aachen, December 2011.
- P. Kabasci: *Automated Program Verification Using SAT- and SMT-Encodings of Diophantine Constraints*, *Lehrstuhlseminar*, RWTH Aachen, February 2012.
- R. Musiol: *Automated Termination Analysis for Java Programs on Cyclic Data*, *Lehrstuhlseminar*, RWTH Aachen, March 2012
- M. Klinzing: *Automated Complexity Analysis for Integer Term Rewrite Systems*, *Lehrstuhlseminar*, RWTH Aachen, April 2012
- M. Hoelzel: *SMT-based Termination Analysis of Integer Rewrite Systems*, *Lehrstuhlseminar*, RWTH Aachen, August 2012

Publications

- J. Giesl, T. Ströder, P. Schneider-Kamp, F. Emmes, and C. Fuhs. Symbolic Evaluation Graphs and Term Rewriting - A General Methodology for Analyzing Logic Programs. In *Proceedings of the 14th International Symposium on Principles and Practice of Declarative Programming (PPDP '12)*, Leuven, Belgium, pages 1-12, ACM Press, 2012.
- M. Brockschmidt, R. Musiol, C. Otto, and J. Giesl. Automated Termination Proofs for Java Programs with Cyclic Data. In *Proceedings of the 24th International Conference on Computer Aided Verification (CAV '12)*, Berkeley, CA, USA, Lecture Notes in Computer Science 7358, pages 105-122, Springer-Verlag, 2012.
- F. Emmes, T. Enger, and J. Giesl. Proving Non-Looping Non-Termination Automatically. In *Proceedings of the 6th International Joint Conference on Automated Reasoning (IJCAR '12)*, Manchester, UK, Lecture Notes in Artificial Intelligence 7364, pages 225-240, Springer-Verlag, 2012.

- M. Codish, Y. Fekete, C. Fuhs, J. Giesl, and J. Waldmann. Exotic Semiring Constraints (Extended Abstract). In *Proceedings of the 10th International Workshop on Satisfiability Modulo Theories (SMT '12)*, Manchester, UK, pages 87-96, 2012.
- M. Brockschmidt, T. Ströder, C. Otto, and J. Giesl. Automated Detection of Non-Termination and NullPointerExceptions for Java Bytecode. In *Proceedings of the 2nd International Conference on Formal Verification of Object-Oriented Software (FoVeOOS '11)*, Turin, Italy, Lecture Notes in Computer Science 7421, pages 123-141, Springer-Verlag, 2012.
- T. Bormer, M. Brockschmidt, D. Distefano, G. Ernst, J. Filiâtre, R. Grigore, M. Huisman, V. Klebanov, C. Marché, R. Monahan, W. Mostowski, N. Polikarpova, C. Scheben, G. Schellhorn, B. Tofan, J. Tschannen, and M. Ulbrich. The COST IC0701 Verification Competition 2011. In *Proceedings of the 2nd International Conference on Formal Verification of Object-Oriented Software (FoVeOOS '11)*, Turin, Italy, Lecture Notes in Computer Science 7421, pages 3-21, Springer-Verlag, 2012.
- T. Ströder, F. Emmes, P. Schneider-Kamp, J. Giesl, and C. Fuhs. A Linear Operational Semantics for Termination and Complexity Analysis of ISO Prolog. In *Proceedings of the 21st International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR '11)*, Odense, Denmark, Lecture Notes in Computer Science 7225, pages 237-252, Springer-Verlag, 2012.
- M. Codish, J. Giesl, P. Schneider-Kamp, and R. Thiemann. SAT Solving for Termination Proofs with Recursive Path Orders and Dependency Pairs. *Journal of Automated Reasoning*, 49(1):53-93, 2012.
- J. Giesl and R. Hähnle (eds.). Special Issue on the 5th International Joint Conference on Automated Reasoning (IJCAR 2010). *Journal of Automated Reasoning*, 47(4), Springer-Verlag, 2011.
- M. Brockschmidt, T. Ströder, C. Otto, and J. Giesl. Proving Non-Termination for Java Bytecode. In *Proceedings of the 12th International Workshop on Termination*, Obergurgl, Austria, 2012.
- F. Emmes, T. Enger, and J. Giesl. Detecting Non-Looping Non-Termination. In *Proceedings of the 12th International Workshop on Termination*, Obergurgl, Austria, 2012.
- M. Codish, I. Gonopolskiy, A. Ben-Amram, C. Fuhs, and J. Giesl. Termination Analysis via Monotonicity Constraints over the Integers and SAT Solving. In *Proceedings of the 12th International Workshop on Termination*, Obergurgl, Austria, 2012.
- M. Brockschmidt, R. Musiol, C. Otto, and J. Giesl. Proving Termination of Java Bytecode with Cyclic Data. In *Proceedings of the 12th International Workshop on Termination*, Obergurgl, Austria, 2012.
- T. Ströder, F. Emmes, P. Schneider-Kamp and J. Giesl. Automated Runtime Complexity Analysis for Prolog by Term Rewriting. In *Proceedings of the 12th International Workshop on Termination*, Obergurgl, Austria, 2012.

- T. Ströder. Graph-based Methods for Analysis and Synthesis of Programs. In *Proceedings of the Joint Workshop of the German Research Training Groups in Computer Science*, Dagstuhl, Germany, 2012.
- J. Giesl, T. Ströder, P. Schneider-Kamp, F. Emmes, and C. Fuhs. Symbolic Evaluation Graphs and Term Rewriting - A General Methodology for Analyzing Logic Programs. Technical Report AIB-2012-12, RWTH Aachen, Germany, 2012.
- M. Brockschmidt, R. Musiol, C. Otto, and J. Giesl. Automated Termination Proofs for Java Programs with Cyclic Data. Technical Report AIB-2012-06, RWTH Aachen, Germany, 2012.
- T. Ströder, F. Emmes, J. Giesl, P. Schneider-Kamp, and C. Fuhs. Automated Complexity Analysis for Prolog by Term Rewriting. Technical Report AIB-2012-05, RWTH Aachen, Germany, 2012.
- C. Fuhs. SAT Encodings: From Constraint-Based Termination Analysis to Circuit Synthesis. Technical Report AIB-2011-17, RWTH Aachen, Germany, 2011.
- J. Repke. Automatische Terminierungsanalyse von LLVM Programmen, Diploma Thesis, LuFG Informatik 2, RWTH Aachen, November 2011.
- P. Kabasci. Automated Program Verification Using SAT- and SMT-Encodings of Diophantine Constraints, Diploma Thesis, LuFG Informatik 2, RWTH Aachen, January 2012.
- R. Musiol: Automated Termination Analysis for Java Programs on Cyclic Data, Bachelor Thesis, LuFG Informatik 2, RWTH Aachen, March 2012.
- M. Klinzing. Automated Complexity Analysis for Integer Term Rewrite Systems, Bachelor Thesis, LuFG Informatik 2, RWTH Aachen, April 2012.
- Matthias Hoelzel, SMT-based Termination Analysis of Integer Rewrite Systems, Bachelor Thesis, LuFG Informatik 2, RWTH Aachen, July 2012.

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Daniela Lepri (University of Oslo, N)
Anne Remke Ph.D. (University of Twente, NL)
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Dr. Tobias Schubert (Albert-Ludwigs-University Freiburg, D)
Dr. Johann Schuster (University of the Federal Armed Forces Munich, D)
Dr. Olga Tveretina (Karlsruhe University, D)
Dr. Ralf Wimmer (Albert-Ludwigs-University Freiburg, D)

Overview

Our junior research group "Theory of Hybrid Systems", led by Erika Ábrahám, was set up 2008 in the context of the Excellence Initiative as part of the Software Modeling and Verification chair (Informatik 2).

Our main *research* interests cover

- the modeling, synthesis and analysis of hybrid systems,
- the analysis of probabilistic systems, and
- decision procedures for real algebra, especially Sat-Modulo-Theories (SMT) solving, and their application in the above two areas.

These research areas are currently supported by four third-party-funded projects: In the AlgoSyn Research Training Group (DFG) and the OASys project (DFG) we focus on hybrid-systems-related topics, joining knowledge and effort from the Engineering Sciences and from Computer Science. Our work in the projects CEBug (DFG) and ROCKS (DFG/NWO) could successfully improve state-of-the-art techniques for the generation of counterexamples for probabilistic systems.

Whereas in the last years we concentrated on developing the theoretical foundations for different projects, we are happy that in 2012 we could make several implementations publicly available. We made a big step in improving the state-of-the-art in satisfiability checking by releasing the GiNaCRA C++ library for real-algebraic computations and the SMT-RAT tool box for the support of the development of SMT-solvers for real arithmetic. Our HyTMan tool offers the reachability analysis of hybrid systems, using Taylor models to over-approximate state sets. Finally, our COMICS tool can be used to specify, visualize and analyze probabilistic systems and to compute and to visualize counterexamples for violated properties.

Besides research, we attach great importance to *teaching*. The evaluation of our courses by the students (average mark 1.7) shows that they enjoy our lectures and find them helpful for their education. In the tradition of the last years, we have also organized different events (Schüleruniversität Informatik, RWTH MINT Camp, Ringvorlesung "Was ist Informatik?", Aachener Informatiktage) for high-school students to inform them about the contents of computer science and its study at RWTH Aachen University.

Besides research and teaching, we took active part in the life of our Department and of our university. We participated in the exciting process of preparing and presenting the successful RWTH proposal for the second round of the Excellence Initiative. Furthermore, Erika Ábrahám was elected this year to deputy equal opportunity commissioner of the RWTH Aachen University, and Johanna Nellen and Nils Jansen to a steering committee member of the AlgoSyn Research Training Group. Johanna Nellen and Nils Jansen also support as mentors the TANDEMkids and TANDEMschool mentoring programs.

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).

Modular Synthesis and Analysis in Process Control Engineering

E. Ábrahám, J. Nellen, U. Eppe (ACPLT), and D. Kampert (ACPLT)

Sequential function charts (SFCs) are a popular formalism to specify programmable logic controllers. In this research project we want to develop a verification tool for the analysis and synthesis of SFCs. However, in the absence of the controlled system, SFC verification can only consider the controller's behavior, but cannot tell anything about the controlled system.

Our method will be able to check properties concerning the plant system as well, so that we integrate the dynamic behavior of the plant in our verification method.

We extend the SFC model with additional information about the dynamic behavior of the plant and automatically transform the resulting HSFCs to hybrid automata. For the analysis, we use the SpaceEx tool that computes an over-approximation of the reachable states. Therefore we adapted our theoretical work to be compatible with the SpaceEx tool. As a result of the analysis, SpaceEx either returns that the model is safe or returns a counterexample that we can use for abstraction refinement.

We plan to integrate other verification tools for hybrid automata into our implementation for a comparison and to extend our verification method to the synthesis of SFCs. When the plant is

extended by some components we want to reuse previous correctness proofs and extend them for the integration of the new behavior.

SMT Solving for Real Algebra

E. Ábrahám, F. Corzilius, and U. Loup

Propositional logic is widely used in verification. E.g. for the verification of Boolean circuits, their behavior and required properties can be encoded in propositional logic and checked using efficient SAT solvers. Intense research in the field of SAT solving even brought SAT solvers to the industrial sector. However, the analysis of more complex systems such as real-time, probabilistic, or even hybrid systems requires more expressive logics. A sufficiently expressive and still decidable logic is (non-linear) real algebra. A real-algebraic formula is a Boolean combination of polynomial constraints over multiple, real-valued variables.

Deciding real algebra is NP hard and, even worse, many decision procedures for real algebra have a doubly exponential complexity bound. Our research aims at integrating different real-algebraic decision procedures into the Satisfiability-Modulo-Theories (SMT) context.

In order to integrate real algebraic solvers into an efficient SMT solver, some adaptations of the original decision procedures have to be done. In this project, we tackle the virtual substitution method, the cylindrical algebraic decomposition method, Gröbner-bases based methods, and methods relying on interval arithmetic.

We implemented and published the modular toolbox SMT-RAT for the development of SMT compliant theory solvers for real algebra, offering modules for the above-listed decision procedures. The efficiency of these modules can be further increased by combining them according to a user-defined strategy.

As a by-product of these developments, we established the rich C++ library GiNaCRA providing functionalities regarding real algebra, required for the implementation of the decision procedures.

Reachability Analysis for Hybrid Systems

E. Ábrahám, X. Chen, and S. Sankaranarayanan (University of Colorado Boulder)

Since the reachability problem for hybrid systems is not decidable, we over-approximate the exact reachable sets in the property verification work. A significant task is to compare the current over-approximation representations. Since different representations are adept at different cases, combining them in reasonable ways can handle a wide class of systems, and

improvements can be derived from such comparison. We use a combination of Taylor model and geometric representations for the reachable sets such that we can handle the continuous dynamics defined by highly non-linear ODEs, and achieve a reasonable trade-off between accuracy and efficiency.

We developed a tool named Hybrid Taylor Model Analyzer (HyTMA) with Prof. Sriram Sankaranarayanan from the University of Colorado at Boulder. HyTMA is an open source tool which computes the Taylor model flowpipes for a given nonlinear hybrid system. In the future, the tool will be extended by adding the following modules: (1) stability analysis for nonlinear differential dynamical and hybrid systems, (2) reachability based controller synthesis for nonlinear hybrid systems. We will also apply the tool to analyze some medical devices such as infusion pumps.

Other Activities

Erika Ábrahám

- Project reviewer for the City University of Hong Kong
- Reviewer for 5 journals (Computers and Mathematics for Applications, IEEE Transactions on Automatic Control, Journal of Computational and Applied Mathematics, Optimization Letters, Science of Computer Programming)
- Reviewer for 13 conferences and workshops (ATVA'12, FACS'12, FMOODS-FORTE'12, FORMATS'12, FTSCS'12, HSCC'12, IJCAR'12, NSV'12, QEST'12, RP'12, SAC/RVT'12, SIMULTECH'12, WRLA'12)
- Program committee member:
 - Hybrid Systems: Computation and Control (HSCC'12)
 - 9th Int. Conference on Quantitative Evaluation of SysTems (QEST'12)
 - 9th Int. Symposium on Formal Aspects of Component Software (FACS'12)
 - 1st Int. Workshop on Formal Techniques for Safety-Critical Systems (FTSCS'12)
 - 5th Int. Workshop on Numerical Software Verification (NSV'12)
 - 5th Int. Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH'12)
- Co-organizer of the ROCKS Autumn School "RigorOus Dependability Analysis for Stochastic Systems" 2012
- Examiner for Theoretical Computer Science in two Ph.D. defenses
- Member of two appointment committees at RWTH Aachen University
- Member of the Computer Science Department commission "High-school activities"
- Member of the Computer Science Department commission "Numerus Clausus"
- Deputy equal opportunity commissioner (Vertreterin der Gleichstellungsbeauftragten) of RWTH Aachen University
- Member of the RWTH commission "Gender measures of the RWTH research training groups"
- Deputy faculty board member
- Participant of the RWTH Strategy Workshops

Nils Jansen

- Mentor in the TANDEMschool and TANDEMkids mentoring programs
- Member of the comission for teaching of the Computer Science Department

Ulrich Loup

- Member of the Steering Committee of the AlgoSyn Research Training Group
- Mentor in the TANDEMschool mentoring program
- Member of the comission for service teaching of the Computer Science Department

Johanna Nellen

- Member of the Steering Committee of the AlgoSyn Research Training Group
- Mentor in the TANDEMschool mentoring program

Courses

Winter semester 2011/12

- Lecture: Satisfiability checking
- Seminar: Satisfiability checking
- Practical course: Explorative Suche mit Lego Mindstorms Robotern

Summer semester 2012

- Lecture: Modeling and analysis of hybrid systems
- Seminar: Satisfiability checking
- Practical course: Simplex in SMT
- Practical course: Modeling of a solar power plant

RWTH Events Organized for Highschool Pupils

- Organization of the Aachener Informatiktage 2012
- Organization of the Schüleruniversität Informatik 2012
- Organization of the Ringvorlesung "Was ist Informatik?" 2012
- Organization of the RWTH MINT Camp 2012
- Demo "Roboterprogrammierung mit Lego Mindstorms' for the Girls" Day 2012
- Vortrag "Rechnen mit Nullen und Einsen" for Helle Köpfe 2012

Talks and Publications

Talks

Erika Ábrahám. SMT Solving Mechanisms for Non-Linear Real Arithmetic. Invited talk, Albert-Ludwigs-University, Freiburg, Germany, 2012.

Erika Ábrahám. Hybrid Systems. Invited talk, University of Twente, Enschede, The Netherlands, 2012.

Erika Ábrahám. Computing Counterexamples for Discrete-Time Probabilistic Systems. Tutorial, ROCKS Autumn School "Rigorous Dependability Analysis for Stochastic Systems", Vahrn, Italy, 2012.

Erika Ábrahám. Rechnen mit Nullen und Einsen. Talk, Helle Köpfe in der Informatik, 2012.

Erika Ábrahám. Eine kurze Einführung in die Unentscheidbarkeit. Talk for students of a Greek high-school, RWTH Aachen University, Aachen, Germany, 2012.

Erika Ábrahám. Eine kurze Einführung in die Unentscheidbarkeit. Talk, Ringvorlesung "Was ist Informatik?", 2012.

Xin Chen. Taylor Model Over-approximations for Flowpipe/Guard Intersections. Talk in the 5th Int. Workshop on Numerical Software Verification (NSVü12), 2012.

Xin Chen. Using Taylor Models in the Reachability Analysis of Non-linear Hybrid Systems. Talk in the 5th Small Workshop on Interval Methods (SWIMü12), 2012.

Nils Jansen, and Matthias Volk. The COMICS Tool - Computing Minimal Counterexamples for DTMCs. Talk, AlgoSyn seminar, 2012.

Nils Jansen, and Matthias Volk. The Comics Tool - Computing Minimal Counterexamples for DTMCs. Talk, ROCKS Meeting, 2012.

Nils Jansen. The COMICS Tool - Computing Minimal Counterexamples for DTMCs. Talk, ATVA, 2012.

Nils Jansen. Symbolic Counterexample Generation for Discrete-time Markov Chains. Talk, FACS, 2012.

Nils Jansen. Symbolic Counterexample Generation for Discrete-time Markov Chains, Talk, AlgoSyn Seminar, 2012.

Ulrich Loup. SMT-RAT: An SMT-Compliant Nonlinear Real Arithmetic Toolbox. Talk, AlgoSyn seminar, 2012.

Ulrich Loup. SMT-RAT: An SMT-Compliant Nonlinear Real Arithmetic Toolbox. Talk, SAT, Trento, 2012.

Ulrich Loup and Johanna Nellen. OASys: An Interdisciplinary DFG Project with Roots in AlgoSyn. Talk, AlgoSyn seminar, 2012.

Publications

Xin Chen, Erika Ábrahám, and Sriram Sankaranarayanan. Taylor Model Flowpipe Construction for Non-linear Hybrid Systems. In Proc. of the 33rd IEEE Real-Time Systems Symposium (RTSS'12). IEEE Computer Society, 2012.

Florian Corzilius, Ulrich Loup, Sebastian Junges, and Erika Ábrahám. SMT-RAT: An SMT-Compliant Nonlinear Real Arithmetic Toolbox (Tool Presentation). In Int. Conf. on Theory and Applications of Satisfiability Testing (SAT'12). pages 442-448. Volume 7317 of Lecture Notes in Computer Science. Springer-Verlag, 2012.

Muhammad Fadlisyah, Peter Csaba Ölveczky, and Erika Ábrahám. Some Like It Very Hot: Formal Modeling and Analysis of Extreme Heat Exposure to the Human Body in HI-Maude. In Proc. of the 9th International Workshop on Rewriting Logic and its Applications (WRLA'12). LNCS. Springer-Verlag, 2012.

Nils Jansen, Erika Ábrahám, Matthias Volk, Ralf Wimmer, Joost-Pieter Katoen, and Bernd Becker. The COMICS Tool - Computing Minimal Counterexamples for DTMCs. In Proc. of the 10th Int. Symp. on Automated Technology for Verification and Analysis (ATVA'12) . pages 349-353. Volume 7561 of LNCS. Springer-Verlag, 2012.

Nils Jansen, Erika Ábrahám, Barna Zajzon , Ralf Wimmer, Johann Schuster, Joost-Pieter Katoen, and Bernd Becker. Symbolic Counterexample Generation for Discrete-time Markov Chains . In 9th International Symposium on Formal Aspects of Component Software (FACS'12). LNCS (to appear). 2012.

Daniela Lepri, Erika Ábrahám, and Peter Csaba Ölveczky. Timed CTL Model Checking in Real-Time Maude. In Proc. of the 9th International Workshop on Rewriting Logic and its Applications (WRLA'12). LNCS. Springer-Verlag, 2012.

Johanna Nellen, and Erika Ábrahám. Hybrid Sequential Function Charts. In Methoden und Beschreibungssprachen zur Modellierung und Verifikation von Schaltungen und Systemen (MBMV'12). 2012.

Ralf Wimmer, Nils Jansen, Erika Ábrahám, Joost-Pieter Katoen, and Bernd Becker. Minimal Critical Subsystems as Counterexamples for omega-Regular DTMC Properties. In Methoden und Beschreibungssprachen zur Modellierung und Verifikation von Schaltungen und Systemen (MBMV'12). 2012.

Ralf Wimmer, Nils Jansen, Erika Ábrahám, Bernd Becker, and Joost-Pieter Katoen. Minimal Critical Subsystems for Discrete-Time Markov Models. In Tools and Algorithms for the Construction and Analysis of Systems (TACAS'12). pages 299-314. Volume 7214 of LNCS . Springer, 2012.

Technical Reports

Ralf Wimmer, Nils Jansen, Erika Ábrahám, Joost-Pieter Katoen, and Bernd Becker. Minimal Counterexamples for Refuting ω -Regular Properties of Markov Decision Processes. Technical Report 88, Reports of SFB/TR 14 AVACS, 2012. ISSN: 1860-9821.

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Overview

In our fourth year with Bernhard Rumpe as Head of Chair for Software Engineering, we have been able to strongly extend our cooperation and research activities in all four fields: automotive, cloud computing, energy optimization and model-based software development.

Goals of the Software Engineering group

- Improvement of software development
- through research for

Methods, concepts and tools for

- better and smarter development of software systems
- such that we get a qualitative result
- shortly,
- while flexibly integrating rapidly adapting requirements



(mission statement)

- Evidence through development of appropriate software and systems in appropriate domains



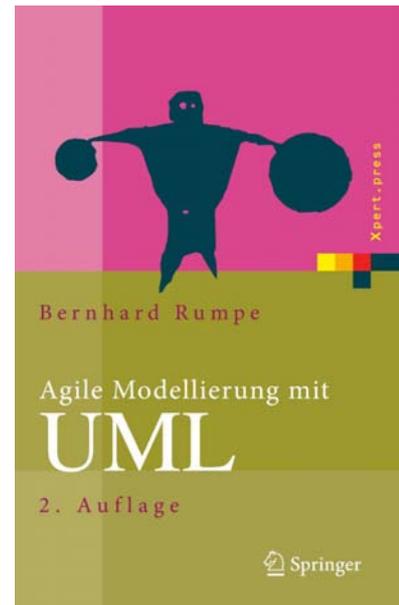
Our core research domains are the application of UML as well as domain specific languages (DSLs) and models for software development. At the heart of research lays the question, how to improve software development based on well founded modelling techniques, either based on UML or on domain specific languages. 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. Our recent work “Semantically Configurable Consistency Analysis for Class and Object Diagrams” has been awarded the Springer Best Paper Award MoDELS 2011 and the ACM SIGSOFT Distinguished Paper Award on the International Conference on Model Driven Engineering Languages and Systems.

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 two new lectures “Generative Software Engineering for the Automotive Domain” and “Innovations in Software Engineering”. We reissued the second version of the second book concerning the topics of the lecture Model Based Software Development “Agile Modellierung mit UML: Codegenerierung, Testfälle, Refactoring”. 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. Additionally we are part of the Prüfungsausschuss Informatik, that deals with objects and questions concerning examinations. 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 received several fundings 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 pleasure to see the completion of three doctoral dissertations. Namely Martin Schindler, Ingo Weisemoeller and Cem Mengi finished their work and started their careers. 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. All three Ph.D. theses are available at the book series “Aachener Informatik-Berichte, Software Engineering” by Shaker publishing, Aachen.



Funding comes from various sources, including DFG, EU, BMBF, BMWI and a number of industrial partners like e.g. Daimler, DSA and Volkswagen.

We expect an interesting and challenging forthcoming next academic year.

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

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

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

Book “Modellierung mit UML”, 2nd edition: <http://www.se-rwth.de/mbse/>

Teaching

During the winter term 2011/2012 and the summer term 2012 we consolidated and slightly extended our teaching activities on undergraduate and graduate level for computer science students as well as students in electric engineering and information technology.

In the winter semester we established two new lectures “Generative Software Engineering for the Automotive Domain” and “Innovations in Software Engineering”. Apart from that we offer several courses including lectures, proseminars, and practicals on a regular basis on undergraduate level. In Addition to this, on graduate level the group offered specialised courses focussing on “Software Engineering” during the last year. We updated our lecture Generative Software Development to include state-of-the-art approaches and to show the students recent developments in this field. With the lecture “Generative Software Engineering for the Automotive Domain” we created a lecture that imparts the challenges from another domain on the one hand and the applicability of the learnt concepts from other lectures to this new domain on the other hand. The new lecture “Innovations in Software Engineering” shows the participating students new research activities and approaches in software engineering. Using the foundations learnt in other courses we offer this lecture to show how they relate to open questions and how different research problems can be tackled.

Namely, the following lectures were held:

- Software-Engineering (L3+E2), winter
- Model-Based Software Engineering (L3+E2), winter
- Applied Software Engineering within the lifecycle of Automotive Electronics (L1), winter
- Generative Software Engineering for the Automotive Domain (L2), winter
- Innovations in Software Engineering (L2), winter and summer
- Software Architectures (L3+E2), winter
- Generative Software Development (L3+E2), summer
- Processes and Methods for Software Testing (L2), summer
- The SE Programming Language Ada 95 (L3+E2), summer

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

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

We offered two practicals over the year, one coping with current problems from the energy domain and the other focusing on mobile & location based augmented reality. In addition to this two seminars have been held focussing on model based software engineering.

For the undergraduate course “Software Engineering” we doubled the amount of our exercise courses to cope with the higher number of students due to a shift within the curriculum.

Link to education activities of the group:

<http://se-rwth.de/teaching/>

Research Projects

Algorithmic Synthesis of Reactive and Discrete-Continuous Systems

Dr. S. Maoz, 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.

We presented some early results of joint work with other members of the software engineering group and discussed these in AlgoSyn's scientific meetings. Our presentations covered work on the development of a language for the specification of partial views for the structure of component and connector architectures, algorithms to check whether an architecture satisfies a view or a views specification, and an approach for the synthesis of architectures from views specifications. Many interesting discussions with other AlgoSyn researchers have emerged from these talks.

Semantically Configurable Consistency Analysis for Class and Object Diagrams

Shahar Maoz, J.O. Ringert and B. Rumpe

Our work on checking the consistency of class diagrams and object diagrams received the Springer Best Paper Award MODELS 2011 and the ACM SIGSOFT Distinguished Paper Award at the international conference on Model Driven Engineering Languages and Systems (MoDELS) in Wellington, New Zealand.

Class and object diagrams (CDs and ODs) are popular modeling languages for describing the structure of object oriented systems. While class diagrams capture possible instantiations of objects in a generic way, object diagrams typically describe instances in an exemplary way. Applications of these languages throughout the development of a software system have shown to interpret the meaning of CDs and ODs in differing ways (i.e., employ semantic variability) according to the purpose of their use. We have developed an automated and

configurable analysis technique parameterized with semantic choices to adapt to the desired semantics.

Evaluation of Driving Safety Simulation Frameworks and their Usage

A. Haber and B. Rumpe

N. Landa

In cooperation with VOLKSWAGEN AG

Main task is the evaluation of driving safety simulation frameworks for VOLKSWAGEN AG in Wolfsburg. The project is split into two phases. In the first phase the tools Virtual Test Drive (*VTD*) and the Automotive Date- and Time-Triggered Framework (*ADTF*) are evaluated using a set of simulation specific criteria.



Task in the second phase is to develop a concept for signal flow evaluation in ADTF to prepare automatic test scenario evaluation. Two different concepts are tested and prototype demonstrators are developed.

Automotive Software
Processes, Models and Variability

C. Mengi, M. Nagl

Software is indispensable and a primary innovation driver for the development of functionality in the development of cars. But it is also a serious complexity and cost factor. An essential reason for that is the insufficient application of adequate methods and concepts for systematically capturing and handling software variants.

At the chair of Software Engineering this variant problem was addressed¹. Thereby, three development phases with their resulting documents are consulted: (1) the conceptual design with function nets, (2) the architectural design with Simulink models, and (3) the implementation with C code. For all three phases or document types different approaches are developed. They allow the design of software in a way that it can be adapted to different variants.

The solutions range from the identification of commonalities and variability to the realization of variation point with their binding through variants. New processes and models are proposed to support reusability.

Out of the solutions a set of tool was developed and applied to modeling tasks to make use of variation modeling. Both form a proof-of-concept for the described approaches.

The dissertation project was successfully finished this year (cf. the section Dissertation descriptions).

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

A. Horst and B. Rumpe

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

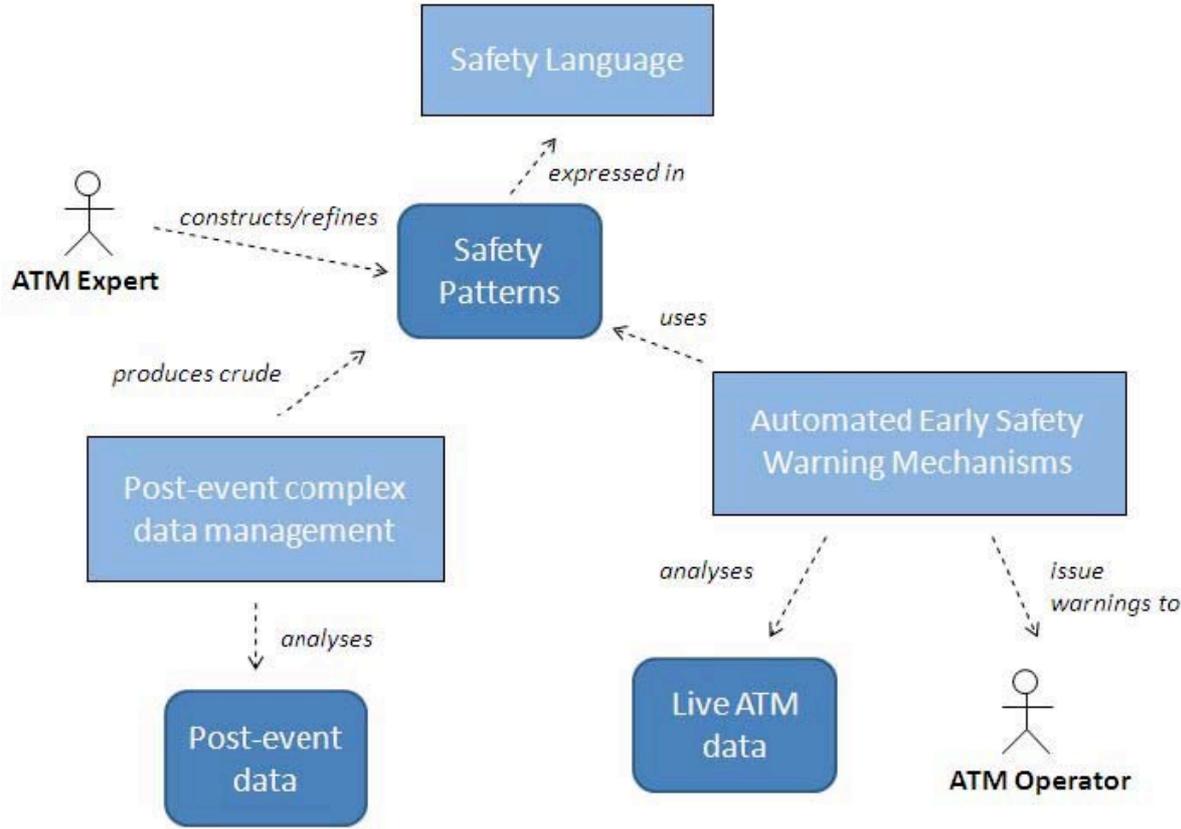
Air Traffic Management (ATM) systems are complex and heterogeneous; they comprise a large number of communicating and interdependent components and sub-systems. They are also predominantly safety-related systems; failures can result in major accidents, loss of property, or loss of life. During the operation 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

¹ This research was carried out in the context of the Graduate School GRK 643 „Software for mobile communication systems“ and in cooperation with several companies from 2007 to 2012.

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 are happening and issue warnings to operators early enough to take action and prevent catastrophic failures.



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.

Delta-Modeling Simulink Models

Arne Haber, Pedram Mir Seyed Nazari and Bernhard Rumpe

In cooperation with

Daimler AG, TU Braunschweig

The diversity of today's software systems lead to the need of new modeling languages for handling the variability. One technique is delta modeling where a designated core model is specified and a set of deltas, which define modifications for the core model. A new variant is created by applying these deltas to the core model in a specific order.

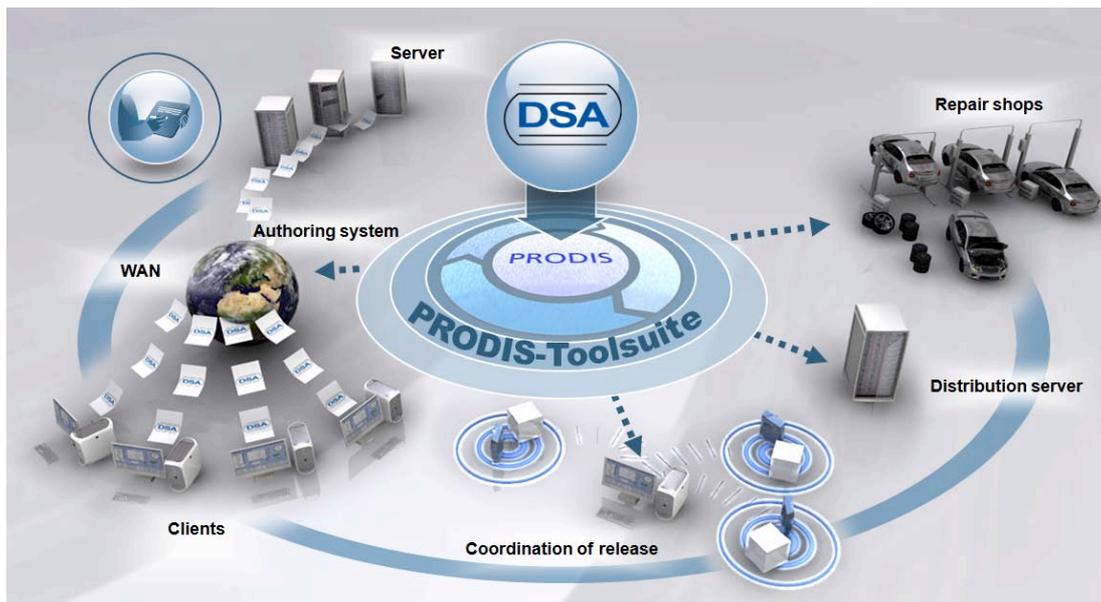
Matlab/Simulink is an environment for graphical modeling and simulation of embedded systems. Because variability is an important factor in the automotive industry, we developed an approach for using delta modeling in Matlab/Simulink. We also developed a prototype to prove our concept.

Domain specific configuration of systems using the example of vehicle diagnostics and vehicle programming

K. Müller and B. Rumpe

In cooperation with DSA GmbH, Aachen

DSA Daten- und Systemtechnik GmbH, Aachen/Germany, is a leading supplier of automotive hardware and software test systems. In more than 30 years of close cooperation with automotive manufacturers and their system suppliers, DSA has developed an extensive family of electrical and electronic diagnostic systems for use in electronic component design, vehicle production, and servicing. Today, DSA technology can be found in production at more than 130 automobile assembly plants, at more than 18.000 dealerships, and at many other locations of well-know automobile manufacturers worldwide.



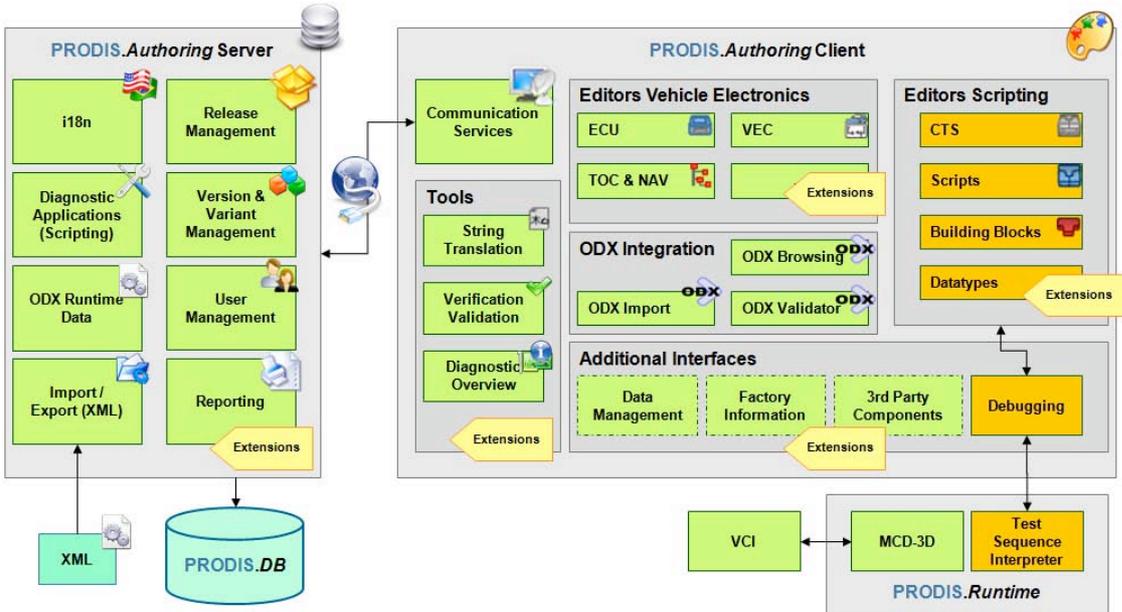
One of the most prominent DSA software solutions is *PRODIS.Authoring*. It is a comprehensive system for the creation and maintenance of diagnostic data and test sequences. As the focal point of corporate automotive diagnostic data, *PRODIS.Authoring* offers multi-user collaboration, integrated version management, versatile variant management, and embraces automotive standards like ODX, OTX, and many more. *PRODIS.Authoring* relies on latest software technology like the Java Platform, Enterprise Edition (JEE), the Eclipse Rich Client Platform (RCP), and the Open Standards Gateway Initiative (OSGi), to name just a few. *PRODIS.Authoring* is very actively being developed and extended, its software code comprising now more than two million lines in more than 600 Eclipse plug-ins.

The goal of this project is to develop model-based concepts and strategies to refine the product development and the software development processes. Project results are based on first-hand process experience. Results are fed-back into the product lifecycle activities. Hence, the project has an immediate positive effect on current and further product development efficiency and accompanying operations. New concepts are assessed with regards to quality enhancement and reduced work effort. The project covers several core topics, some of them are briefly introduced subsequently.

Potentials in the area of modeling and generation identifies areas for the use of modeling languages, how the present usage of modeling languages can be adapted, how the current generator can be adapted and extended.

Quality assurance mechanisms aim at the inception of strategies that lead to an even more cost-efficient quality assurance. A focus is on activities that can be automated.

Support of the system evolution in general looks into supporting system evolution through automation. Certain changes in the system require specific system evolution activities to be performed. These activities are scrutinized and strategies are being revised facilitating the leaner execution of these activities.



Database migration and persistence seeks for streamlining the current approach for executing database updates.

Harmonization of system architecture seeks-out software synergies among PRODIS.Authoring and its peer product in the automotive production and manufacturing arena: PRODIS.Automation. The project investigates approaches for unifying tooling, lifecycle activities, and software reuse.

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

G. Bürvenich, C. Herrmann, T. Kurpick, A. Lindt, M. Look, C. Pinkernell, B. Rumpe, M. Tran, M. Uzunov

J. Gräfen, T. Greifenberg, A. Hutter, W. Kluth, P. Krantz, L. Krause, M. Lang, S. Roidl, P. Ruhrländer, V. Serebro, K. Thissen, D. Wolf

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.

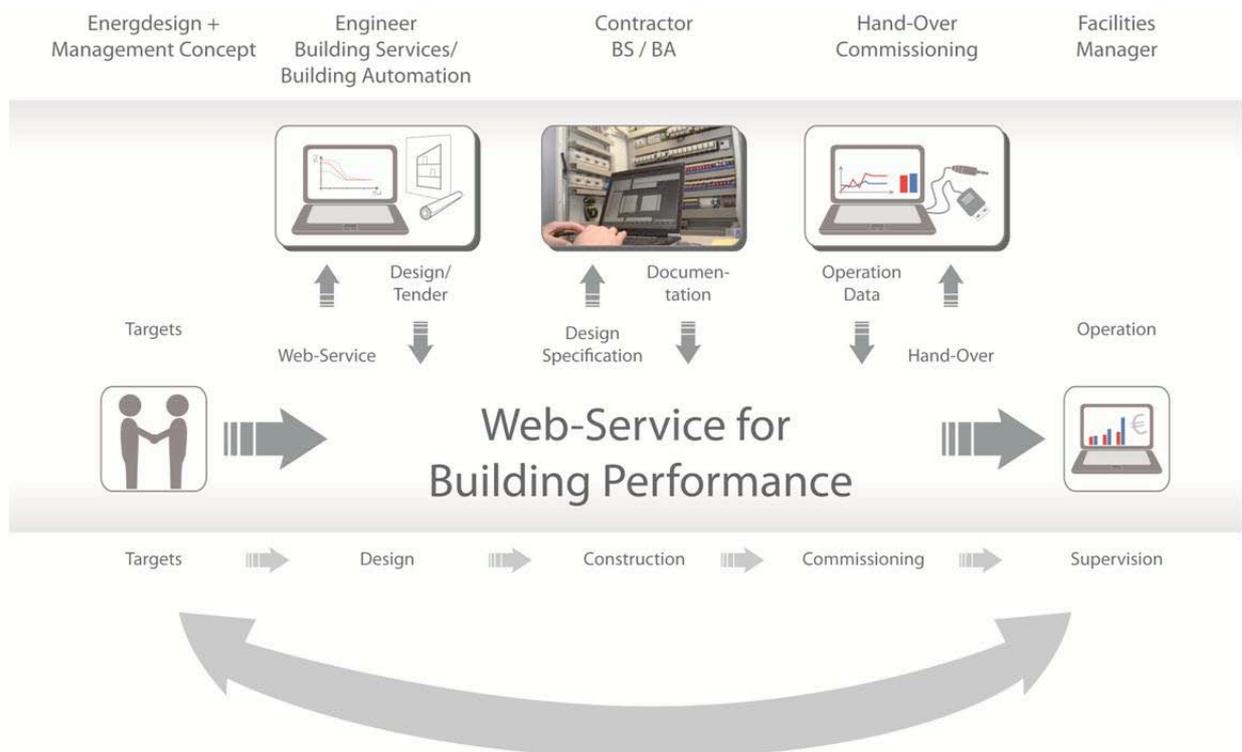


Figure 1: Quality Process based on Energie Navigator Platform

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.

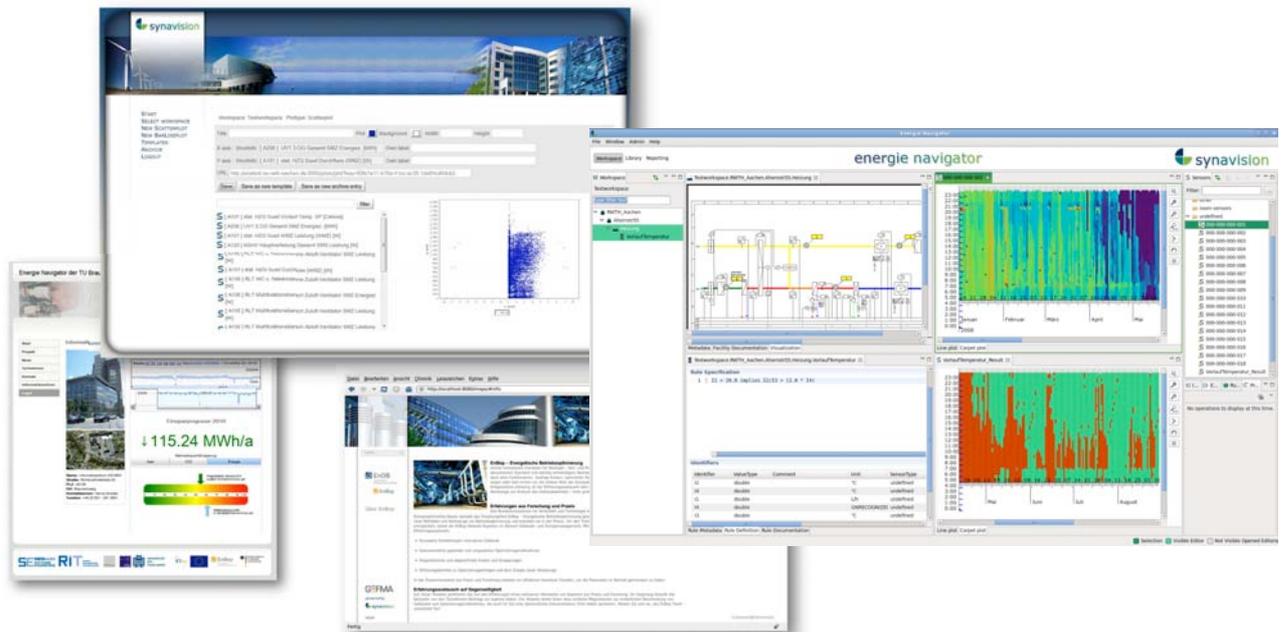


Figure 2: Expert tool and web interfaces

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 and replicated at National Theatre Prague.

A Web 2.0 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 (GloSE)

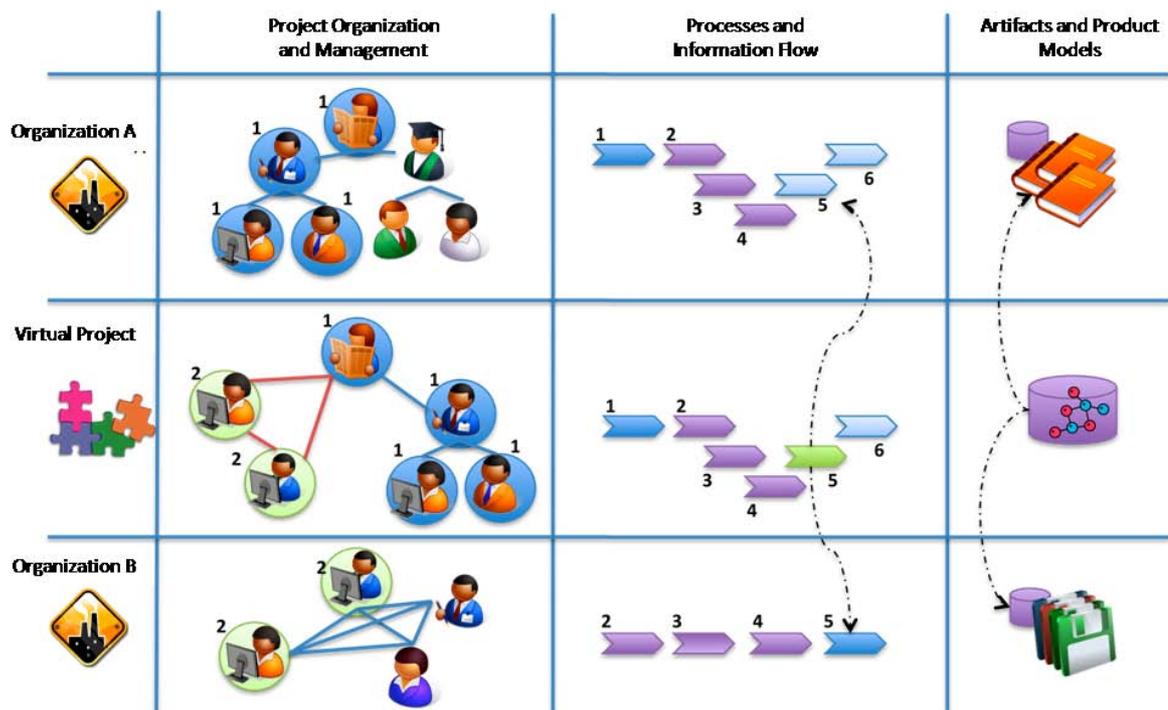
C. Herrmann, T. Kurpick and B. Rumpe

P. Chomicz, R. Eikermann and Z. Mansouri

In cooperation with:

TU München, Leibniz Universität Hannover, and TU Clausthal and several industrial partners

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. 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.



In the last year the focus has been on utilizing social networking information in distributed development projects as well as effective customer feedback, especially in cases where the customers are not co-located with the development team. Personal information that has been stored in several social networks by the members of a global software engineering project can be aggregated and used in the context of such projects to reduce the socio-cultural distance among the team members. For this reason a supporting infrastructure has been developed that allows the aggregation and usage of such information. Customer feedback is essential for a

project to be successful. In the context of the GloSE project, the effective application of feedback systems in requirements engineering and acceptance tests has been researched.

Mobile Campus Project

M. Akbari, J.O. Ringert and B. Rumpe

To ease the parking situation and the traffic flow in and around the RWTH Aachen, new services can be created to simplify the change to public transport in everyday life. By a set of mobile applications and web services, the journey and travel planning, booking of various mobility options and the navigation are enabled on and within the campus and simplified. The applications of the Mobile Campus Projects will bring sustainable benefits to the students, employees, partners and visitors of the RWTH Aachen and the city of Aachen.



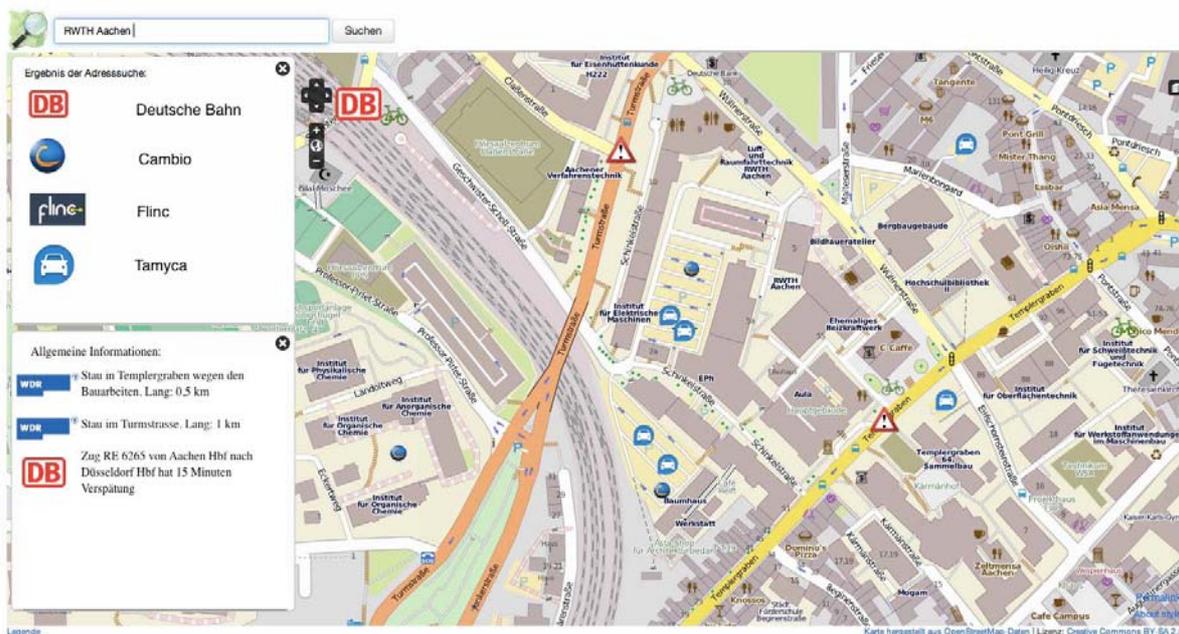
The Mobile Campus Project supports the plans at RWTH Aachen University to relax the parking situation at the various campuses. This is achieved in that the transition is simplified to alternative mobility concepts through mobile applications and web services. The results are a sustainable profit not only for the RWTH, but for the entire city of Aachen and the partners involved. The advantages are:

- RWTH Aachen University can reduce the cost of parking provision and management.
- The Job Ticket of the RWTH Aachen finds more takers among the employees of the university.
- Updated building, space infrastructure and databases for the central university administration
- The quality of services to our students is increasing with new and improved offerings.
- Guests and partners find it easier and more targeted to their appointments at the RWTH Aachen.
- Service Partners such as Cambio, Tamyca or Wabe Association consolidating their presence in Aachen and form together a model for other cities and universities.

By a set of mobile applications and web services, the journey and travel planning, booking of mobility offerings and navigate to and on campus significantly.

Such an integrated approach is unique in Germany and represents an outstanding innovation in the field of mobility for businesses and cities. Regional and national partners such as German Rail Rent, Cambio, Tamyca, the Wabe Fline Association and are therefore willing to enrich this approach with their offers and services and support.

To develop a customer-focused product over the past months students, staff and partners of the RWTH Aachen were questioned about their wishes and ideas for improving the city and university life. On this basis, the existing usage scenarios were validated and supplemented with new ideas from further interviews. This made it possible to test and evaluate various technical implementation possibilities. The result of these studies was noted in a detailed requirements document, including project and development plan.



Development of Domain Specific Languages with MontiCore

*M. Breuer, A. Haber, C. Herrmann, K. Hölldobler, A. Horst, F. Leppers,
M. Look, P. Mir Seyed Nazari, A. Navarro Pérez,
C. Pinkernell, J. O. Ringert, B. Rumpe, M. Schindler, P. Schütze,
G. Volkova, I. Weisemöller, and A. Wortmann*

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 1. 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.

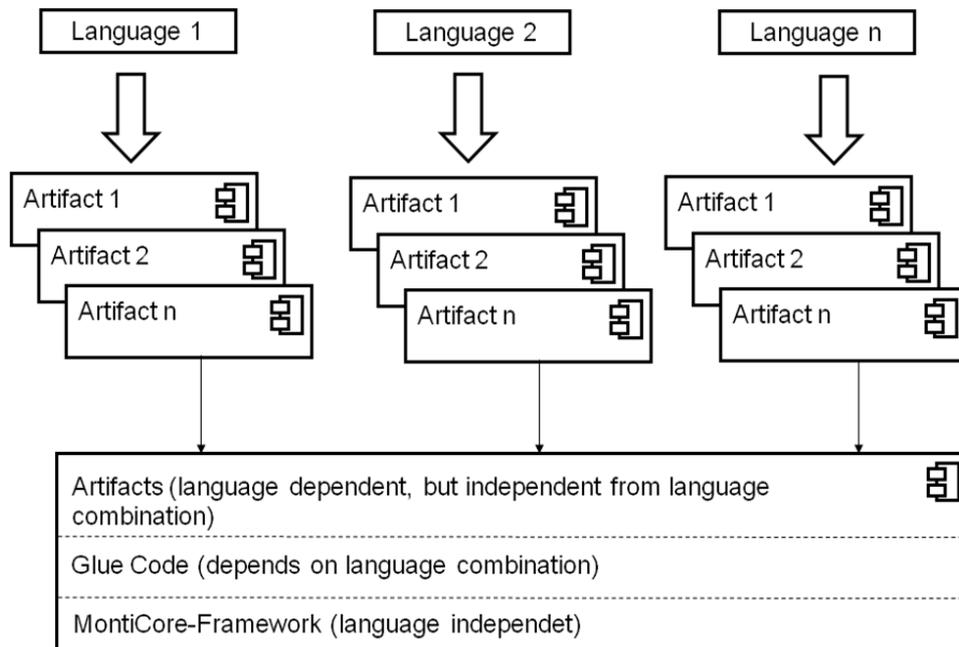


Figure 1: Compositional Development of Languages with MontiCore

MontiCore provides coherent compositionality in language development, including concrete and abstract syntax, symbol table computation, context conditions, and template-based code generation, as well as compliance to the wide spread Eclipse Modeling Framework (EMF). Furthermore a model transformation engine has been developed and integrated into

MontiCore which allows the generation of transformation languages for any defined language.

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 MontiWIS. At the time being, this set of languages developed with MontiCore contains modeling languages of general applicability such as UML/P, GPLs such as C++ and Java, and specific modeling or constraint languages, for instance languages used in automotive software engineering and commonly used languages like XML and SQL. As future work we plan to extend this library of languages and languages components.

O(SC)²ar

A. Navarro Pérez, P. Nazari, A. Roth and B. Rumpe

L. Lang and M. Mades

In cooperation with StreetScooter GmbH, Dräxlmaier GmbH, FEV GmbH, FIR e.V., Hans Hess Automotive, regio IT

The *O(SC)²ar* 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)²ar* 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)²ar* 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 car's infotainment capabilities as well as its technological capabilities, like battery management and hardware monitoring. Due to its openness, the *O(SC)²ar* infrastructure will enable third-party service providers to develop own service and car software additions and provide them for *O(SC)²ar*-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.

SensorCloud

L. Hermerschmidt, A. Navarro Pérez and B. Rumpe

M. Lüger and K. Tsolediris

In cooperation with QSC AG, University of Applied Sciences Cologne, symmedia GmbH and Dillenburger Group

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.

Software Platform Embedded Systems XT (SPES-XT)

Arne Haber, Pedram Mir Seyed Nazari and Bernhard Rumpe

In cooperation with

Siemens AG, Airbus Operations GmbH, Audi Electronics Venture GmbH, Berner & Mattner Systemtechnik GmbH, Robert Bosch GmbH, Cassidian, Daimler AG, EADS-Deutschland GmbH Innovation Works, INCHRON GmbH, Itemis AG, Liebherr Aerospace Lindenberg GmbH, Pure-Systems GmbH, Technische Universität München, Fortiss GmbH, Fraunhofer-Institut, OFFIS e.V., Technische Universität Kaiserslautern, Universität Duisburg-Essen, TU Braunschweig

The current challenges faced by industrial companies in the development of embedded systems emerge among other things from the dramatically increasing volume and increasing complexity of individual systems. Mastering the development of such systems is critical to the competition in terms of improvement of innovation potential, time-to-market and competitive costs structures. Deficiencies or material weaknesses in the design and the development process for such systems lead to significant financial losses or even threats to the physical safety of people.

Building on SPES 2020 the current project SPES-XT has the goal to expand and deepen the seamless, methodological and technical integration of modeling and analysis techniques for embedded systems.

As a subcontractor of Daimler AG, this year we worked out the state of the art techniques for variability modeling in model-based development and developed concepts for expanding the SPES meta-model.

Concepts for Variant- and Compatibility Management

Supporting Software Evolution

Arne Haber, Bernhard Rumpe, Christoph Schulze

In cooperation with DAIMLER AG

Today's automotive systems are very complex structures, which consist of many subsystems delivering different kinds of functionalities, like parking support, driving assistance, wiper control or car-theft protection.

In the automotive industry, instead of single products, large product lines and product families are established. In addition mostly every newly designed car is a further



development of an older version instead of a redesign. As the evolution of features is hard to predict, older components need to be adaptable to new interfaces or contexts to minimize the costs of further developments.

In this project the most important architecture description languages of the last decades are evaluated in context of the variability and evolution management of function components. The most promising approaches are compared based on criteria derived from context related use cases.

Productline aware Toolchain

Carsten Kolassa and Bernhard Rumpe

In cooperation with VOLKSWAGEN AG

Using modeling languages that allow modeling of product lines is a start but comes nowhere close to being able to apply it to development product lines and development lifecycle. The goal of this project is to create methodologies as well as tools that help in the implementation of a product line and that aid along the development process.



In order to achieve this, the lifecycle is divided into several phases and every phase is analyzed individually to improve its tool support focusing on product lines.

WATTALYST
Modeling and Analyzing Demand and Response Systems
EU-FP7 STREP – Grant Agreement 288322

T. Kurpick, A. Lindt, M. Look, C. Pinkernell and B. Rumpe

*In cooperation with
 AUEB, Athens (GR); EFPL, Lausanne (CH); IBM, Bangalore (IN);
 LTU, Lulea (SE); tecnia, Bilbao(ES); SAMPOL, Mallorca (ES)*

The *WATTALYST* (*WATT anALYST*) project is an international research project funded by the European Commission’s FP-7 program. The consortium consists of seven universities, research institutes and companies residing in Sweden, Greece, Spain, Switzerland, India and Germany. The project started on October 1st 2011 with a duration of three years.

The target of the project is the development of a Demand and Response (DR) infrastructure which will be used to influence and optimize energy consumption of users in private homes. The overall target is the reduction of peak loads (see Fig. 1) by homogenizing the energy consumption of city quarters. The project will produce design recommendations for DR-Systems which focus on appropriate technical infrastructures, incentive schemes for participants and overall economic models.

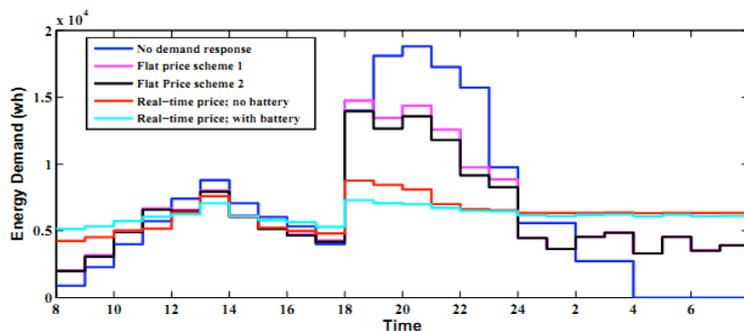


Fig. 1 - Peak loads in a daily base line profile

A DR-System requires frequent and real-time interactions with the participants. Therefore a closed loop approach is used as depicted in Fig 2.

Observe:

The premises will be equipped with sensors and intelligent meters which frequently collect dedicated energy consumption data on appliance level. This data will be uploaded to a cloud based evaluation platform. In addition to these probably fine grained sensor data, information from public available channels like weather reports, events and holidays are aggregated.



Fig. 2 - „DR-Loop

Infer:

Data-Mining techniques allow now the generation of reports including an energy consumption prediction. This will be used as input for economical models which will produce possible suggestions for shiftable loads according to the customers comfort and profile.

Inform:

These suggestions will be transferred as DR-Signals back to the end users. Electronic displays and internet applications will be used for the feedback channel.

Influence:

The private are now able to reflect and adjust their energy usage, decide on those suggestions and react to the DR-Signal. By this means regional peak loads are going to be equalized. Again, the user's reactions to the DR-Signal will be observed and used as new input to optimize the models in the DR-System. This step closes the loop.

The implemented infrastructure will be tested in field trials including several private homes in Spain and India.

In the first part of the project, the chair of Software Engineering has developed a software architecture including a design of a central cloud storage system for the sensor mass-data (see *Observe*). A overall view of the architecture is shown in Fig.3

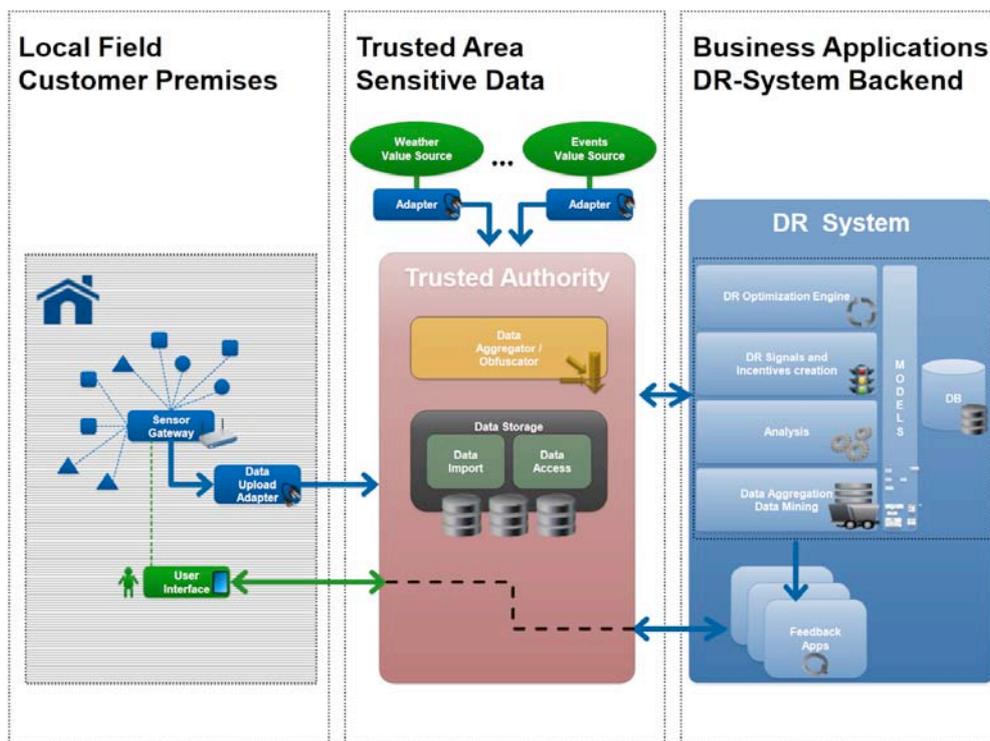


Fig. 3 - Conceptual Software Architecture

The software infrastructure consists of several layers and architecture components. On the bottom level, a communication infrastructure between the sensor nodes is established based on WiFi and IEEE 802.15.4 infrastructures. The data from these sensors will be collected locally and temporarily stored in a small gateway, which is installed within the private premises. The data will be periodically transferred into globally available cloud storages. This

raises the need for an encrypted transfer and a privacy aware, secured storage for the sensitive customer data. To this end, a trusted authority service will be implemented which manages the access to this data. The data will be processed and analyzed in the DR-System (see Fig.3). The results need to be available again for the end users. For this reason the architecture will contain a feedback channel. The available information on these feedback channels can be displayed by user Interfaces which are accessible from the private homes.

Other Activities

Software Engineering Lab



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. WATTALYST

•EnergieNavigator	The logo for Energie Navigator features the text 'ENERGIE NAVIGATOR' above a blue sky with clouds, and 'RIT' below it.
•MontiCore	The logo for MontiCore features the text 'MontiCore' in a stylized blue font with a wave-like graphic.
•MontiArc	The logo for MontiArc features the text 'MontiArc' in a stylized blue font with a wave-like graphic.
•SSE-Lab	The logo for SSE Lab features the text 'SSE LAB' in a blue font next to a blue square icon.
•Compass	The logo for Compass features a blue sky with clouds and a white airplane flying.
•Mobile Devices	The logo for Mobile Devices features a blue square icon with a grid of numbers 1-9 and 0.
•Wattalyst	The logo for Wattalyst features a blue wave-like graphic and the text 'WATTALYST'.

is a Strategic Research Project funded by the European Commission's 7th Framework Program (FP-7). The project aims to develop a prototype and implementation guidelines for Demand-Response-Systems to optimize energy consumption and distribution and to reduce CO2 emissions. To learn more about the projects at SE Lab, please see the dedicated project reports below.

Additionally 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 TestCase-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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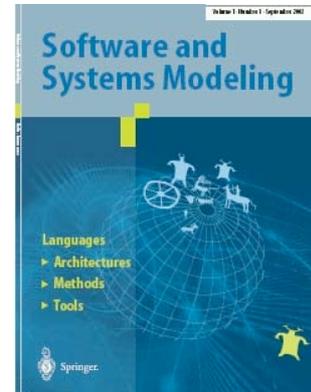
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Web sites

<http://lab.se-rwth.de>

Software and Systems Modeling (SoSyM) Journal

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



The journal is unique in its emphasis on theoretical foundations of modeling languages and techniques and on rigorous analyses of "real-world" modeling experiences. The balance of theoretical work and work based on in-depth analyses of experiences provides researchers with insights that can lead to better modeling languages and techniques and provides 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 are interested in results generated by high-quality modeling research and by rigorously analyzing modeling experiences.

GI-QFAM: Joint Interest Groups on Modeling



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

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

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

In 2012, the *Modellierung* took place as a full conference in Bamberg from March 14th to 16th. Also since 2012 Bernhard Rumpe is invited to the regular meetings of the GI Präsidium.

Conference Activities and Academic Administration

M. Nagl:

- Member of the Board of Informatics Europe
- Chair of the Department Evaluation Committee of Informatics Europe
- Vice Chair of the Accreditation Committee of EQANIE (European Quality Assurance Network for Informatics Education)
- Advisory Board of the European ULAB Project (Partners: Universidad Politecnica de Madris, TU Munich, University of Oxford, Paris Tech, Politecnico die Torino)
- Chairperson of the Audit Team of Informatics Programs Accreditation at TU Riga, Latvia (2011)
- Chairperson of the Audit Team of Informatics Study Programs' Accreditation at University of Latvia, Riga, Latvia (2011)
- Reviewers Board of the Innovation Alliance SPES of the German Minister for Research
- Member of the chair of the „Verbandsgruppe Aachen des Deutschen Hochschulverbands“
- Coach of numerous big research activities (Collaborative Research Centers, projects within the Excellence Initiative) at RWTH Aachen University
- Member of the Finding Commissions for the Professorships “Institut für Kunststoffverarbeitung” and “Production Engineering of E-Mobility Components”, both of the Mechanical Engineering Faculty at RWTH Aachen University
- Chairperson of the Audit Team of all Informatics Programs at Tartu University and Technical University of Talinn, Estonia (2012/13)
- Chairperson Team Mentoring for the First Year of Computer Science Studies at RWTH (2010 – 2012)
- Member of the Advisory Board of BMBF-Spitzencluster OWL “Intelligente Technische Systeme Ostwestfalen-Lippe“, 2012 -
- Member of the Appraisal Committee of David-Kopf-Preis 2011
- Member of the Program Committee of the Intl. Conf. on Engineering and Meta Engineering (ICEME 2011)
- Member of the Steering Committee and Member of the Applications Track Program Committee of the International Conference on Graph Transformations 2012 (ICGT 12), Bremen, Germany, September 24 – 29, 2012
- Member of the Program Committee of South African Workshop on Software Architectures SAWOSA 12
- Member of the Program Committee of European Computer Science Summit 2012, Annual Conference of Informatics Europe
- Member of the Program Committee of the Intl. Conf. on Engineering and Meta Engineering (ICEME 2012)

- Member of the Program Committee of the 18th International Conference on Reliable Software Technologies, Ada-Europe 2013, June 10-14, 2013, Berlin, Germany
- Member of the Program Committee Doktorandensymposium SE 2013
- Member of the Appraisal Committee of David-Kopf-Preis 2012

B. Rumpe:

- Member of the Präsidium der Gesellschaft für Informatik (GI)
- Member of the Program Committee of the 14th International Conference on Model Driven Engineering Languages and Systems, from 16.10.11 to 21.10.11, Wellington, New-Zealand
- Member of the Program Committee of the 4th International Workshop on Model Based Architecting and Construction of Embedded Systems, from 18.10.11 to 18.10.11, Wellington, New-Zealand
- Member of the Program Committee of The 11th Workshop on Domain-Specific Modeling, from 23.10.11 to 24.10.11, Portland, USA
- Member of the Program Committee of Complex Systems Design & Management (CSDM) 2011, from 07.12.11 to 09.12.11, Paris, France
- Member of the Program Committee of ERTS2 2012 - Embedded Real Time Software and Systems, from 01.02.12 to 03.02.12, Toulouse, France
- Member of the Program Committee of the 8. Dagstuhl-Workshop MBEES 2012 - Modellbasierte Entwicklung eingebetteter Systeme, from 06.02.12 to 08.02.12, Dagstuhl, Germany
- Member of the Program Committee of SE 2012 - Software Engineering, from 27.02.12 to 02.03.12, Berlin, Germany
- Member of the Program Committee of MOD 2012 - Modellierung 2012, from 14.03.12 to 16.03.12, Bamberg, Germany
- Member of the Program Committee of MONTEREY 2012 - 17th Monterey Workshop on Development, Operation and Management of Large-Scale Complex IT Systems, from 19.03.12 to 21.03.12, Oxford, UK
- Member of the Program Committee of the 19th Annual IEEE International Conference and Workshops on the Engineering of Computer Based Systems - ECBS 2012, from 11.04.12 to 13.04.12, Novi Sad, Serbia
- Member of the Program Committee of ICMT 2012 - 5th International Conference on Model Transformation, from 28.05.12 to 29.05.12, Prague, Czech Republic
- Chair of FormSERA2012 - Formal Methods in Software Engineering: Rigorous and Agile Approaches, from 02.06.12 to 02.06.12, Zurich, Switzerland
- Chair of MiSE 2012 - ICSE Workshop on Modeling in Software Engineering 2012, from 02.06.12 to 03.06.12, Zurich, Switzerland
- Member of the Program Committee of FMOODS-FORTE 2012 - Joint International Conference of 14th Formal Methods for Open Object-Based Distributed Systems and 32nd Formal Techniques for Networked and Distributed Systems, from 13.06.12 to 16.06.12, Stockholm, Sweden

- Member of the Program Committee of ISARCS 2012 - 3rd International ACM Sigsoft Symposium on Architecting Critical Systems, from 26.06.12 to 28.06.12, Bertinoro, Italy
- Member of the Program Committee of ECMFA-2012 - Eight European Conference on Modelling Foundations and Applications, from 02.07.12 to 05.07.12, Kgs. Lyngby, Denmark
- Member of the Program Committee of ICECCS 2012 - 17th IEEE International Conference on Engineering of Complex Computer Systems, from 18.07.12 to 20.07.12, Paris, France
- Member of the Program Committee of FOSD'12 - 4th International Workshop on Feature-Oriented Software Development, from 24.09.12 to 25.09.12, Dresden, Germany
- Member of the Program Committee of SLE 2012 - 5th International Conference on Software Language Engineering, from 25.09.12 to 28.09.12, Dresden, Germany
- Member of the Program Committee of ME 2012 - 6th International Workshop on Models and Evolution, from 30.09.12 to 30.09.12, Innsbruck, Austria
- Member of the Program Committee of ACES-MB-12 - 5th International Workshop on Model Based Architecting and Construction of Embedded Systems, from 30.09.12 to 30.09.12, Innsbruck, Austria
- Workshop Organizer of the 4th ICSE Workshop on Models in Software Engineering (MiSE), June 2-3, 2012, Zurich, Switzerland
- Workshop Organizer of Formal Methods in Software Engineering: Rigorous and Agile Approaches (FormSERA). ICSE Workshop, June 2, 2012, Zurich, Switzerland
- Workshop Organizing Chair of Software Engineering 2012 Workshop Proceedings, GI-Edition - Lecture Notes in Informatics (LNI). P-199.
- Workshop Organizer of Science and Engineering of Cyber-Physical Systems (Dagstuhl Seminar 11441), Schloss Dagstuhl - Leibniz-Zentrum für Informatik
- Vice Chair of Kommission für Lehre der FG Informatik (KfL)
- Vice Chair of Kommission für Servicelehre der FG Informatik (KfSL)
- Vice Chair of Prüfungsausschuss Informatik (PA)
- Chairperson of Querschnittsfachausschuss Modellierung (QFAM) der Gesellschaft für Informatik
- Chairperson of the committee for „Re-Akkreditierung und Modernisierung der Studiengänge Informatik Bachelor und Master“
- Chairperson of the appointments committee for the professorship "High Performance Computing" and the associated leadership of the computer center
- Chairperson of the appointments committee for the professorship "Dienstinformatik" ("E-Services")

Talks and Publications

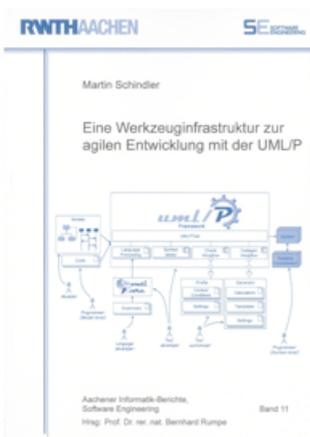
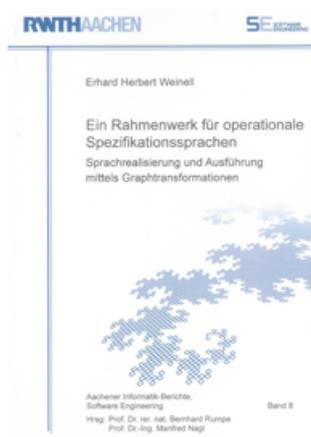
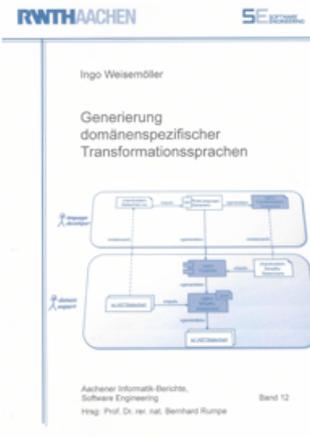
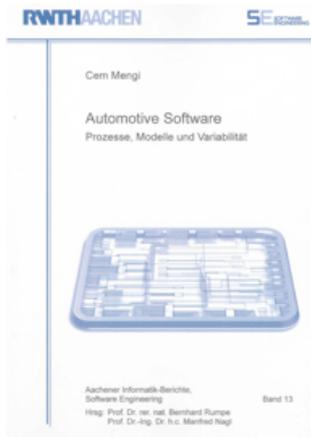
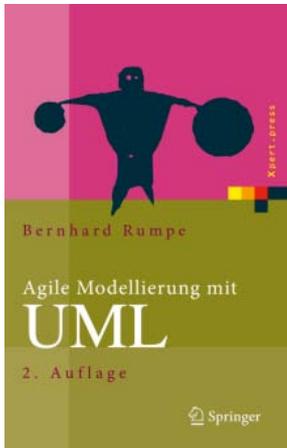
Talks

- M. N. Fisch, C. Pinkernell, S. Plesser and B. Rumpe: *The Energy Navigator – A Web-Platform for Performance Design and Management*, 7th International Conference on Energy Efficiency in Commercial Buildings (IEECB), Frankfurt a. M., Germany, April 2012.
- M. N. Fisch, M. Look, C. Pinkernell, S. Plesser and B. Rumpe: *State-Based Modeling of Buildings and Facilities*, 11th International Conference for Enhanced Building Operations (ICEBO' 11), New York City, USA, October 2011.
- C. Herrmann, T. Kurpick, B. Rumpe: *SSELab: A Plug-In-Based Framework for Web-Based Project Portals*, In: Proceedings of the 2nd International Workshop on Developing Tools as Plug-Ins (TOPI 2012) at ICSE 2012, June 3, Zurich, Switzerland, 2012.
- T. Kurpick, C. Pinkernell, B. Rumpe: *Der Energie Navigator*, Workshop des Forums Informatik: Entwicklung und Evolution von Forschungssoftware (EEFSW), Kerkrade, Netherlands, November 2011
- S. Maoz, J. O. Ringert, B. Rumpe: *Semantically Configurable Consistency Analysis for Class and Object Diagrams*, AlgoSyn annual Workshop, Rolduc, Netherlands, Nov. 17, 2011
- S. Maoz, J. O. Ringert, B. Rumpe: *Architectural Synthesis: From Partial Views to an Architecture*, AlgoSyn Presentation, RWTH Aachen, Dec. 7, 2011
- S. Maoz, J. O. Ringert, B. Rumpe: *An Interim Summary on Semantic Model Differencing, Comparison and Versioning of Software Models (CVSM 2012)*, Co-located with the 27th IEEE/ACM International Conference On Automated Software Engineering (ASE2012), Essen, Germany, Sep. 3, 2012
- S. Maoz, J. O. Ringert, B. Rumpe: *ArcV: A Formal Views Specification Language for the Structure of Component and Connector Architectures*, AlgoSyn Presentation, RWTH Aachen, Sept. 12, 2012
- C. Mengi: *Refactoring of Automotive Models to Handle the Variant Problem*, Workshop: Modellbasierte und Modellgetriebene Softwaremodernisierung (MMSM), Conference “Modellierung 2012”, March 2012
- M. Nagl/ M. Akbari: *Mentoring in der Informatik: Motivation, Probleme, Erfahrungen, Lösungsansatz, Kick-off-Veranstaltung “Aachener Mentoring Modell“*, Aachen, 26. Oktober 2011
- M. Nagl: *Continuous Professional Development Programs: Motivation, Problems, Accreditation*, Meeting of GRIN (Italian Association of Computer Science Professors), Milan, Nov. 7, 2011
- M. Nagl: *Department Evaluation: A New Initiative of Informatics Europe*, European Computer Science Conference 2011, Milan, November 9, 2011
- M. Nagl: *40 Jahre Informatik an der RWTH: Die zweite Hälfte 1992 – 2012*, Feier zum 40jährigen Bestehen der Fachgruppe Informatik und Ehrenpromotion John Mylopoulos, May 9, 2012
- B. Rumpe: *Modularity from Code for Models*, Beitrag for a panel at Models 2011. Wellington, NZ, October 2011.

B. Rumpe: *Evolving and Synthesis of Delta-oriented Software Product Line Architectures*, TU Wien, invited speech, May 15, 2012.

B. Rumpe: *Evolving Delta-oriented Software Product Line Architectures*, Monterey Workshop, Oxford, UK, March 19-21, 2012

Books



Publications

- B. Westfechtel/ M. Nagl: *Graph Transformations for Evolving Domain Knowledge*, in Ehrig, Engels, Kreowski, Rozenberg (Eds.): Proc. Intern. Conf. on Graph Transformations ICGT 2012, Lect. Notes in Computer Science 7562, 341 - 355, Sept. 2012
- M. Nagl, M. Akbari, Th. Leonhardt, M. Frickenschmidt, S. Schalthöfer: *Mentoring in der Studieneingangsphase – Erfahrungen aus der Informatik der RWTH Aachen*, 22 pp., Sept. 2012
- Th. Leonhardt, M. Akbari, M. Nagl, S. Schalthöfer, M. Frickenschmidt: *Mentoring Informatik RWTH – Auswertung einer Umfrage*, 5 pp., Sept. 2012
- MentoringTeam Informatik (M. Akbari, Th. Leonhardt, M. Nagl, M. Frickenschmidt, S. Schalthöfer): *Mentoring für die Studieneingangsphase, Programm für das erste Semester*, 26 pp., Sept. 2012
- MentoringTeam Informatik (M. Akbari, Th. Leonhardt, M. Nagl, M. Frickenschmidt, S. Schalthöfer): *Mentoring für die Studieneingangsphase, Programm für das zweite Semester*, 12 pp., Sept. 2012
- S. Maoz and Y. Sa'ar: *Two-Way Traceability and Conflict Debugging for AspectLTL Programs* In Proc. 11th Int. Conf. on Aspect Oriented Software Development (AOSD), 2012, ACM, pp. 35-46.
- A. Haber, H. Rendel, B. Rumpe, and I. Schaefer: *Evolving Delta-oriented Software Product Line Architectures*, In: Large-Scale Complex IT Systems. Development, Operation and Management, 17th Monterey Workshop 2012, Oxford, UK, March 19-21, 2012. LNCS Vol. 7539, pp. 183-208.
- O. Liskin, C. Herrmann, E. Knauss, T. Kurpick, B. Rumpe, and K. Schneider: *Supporting acceptance testing in distributed software projects with integrated feedback systems: Experiences and requirements*, In: Proceedings of 7th International Conference on Global Software Engineering (ICGSE'12), Puerto Alegre, Brazil, pp.84-93, 2012.
- B. Rumpe, I. Schaefer, G. Snelting: *20 Jahre Softwaretechnik an der TU Braunschweig*, In: H.-D. Ehrich (Hrsg.): 40 Jahre Informatik an der Technischen Universität Braunschweig 1972-2012. GI-Edition Lecture Notes in Informatics, pp.140-147, 2012.
- C. Berger, B. Rumpe: *Autonomous Driving - 5 Years after the Urban Challenge: The Anticipatory Vehicle as a Cyber-Physical System*, In: Proceedings of the 10th Workshop on Automotive Software Engineering (ASE 2012), pp. 789-798, Braunschweig, September 2012.
- C. Mengi: *Automotive Software - Prozesse, Modelle und Variabilität*, Shaker Verlag, ISBN 978-3-8440-1262-1. Aachener Informatik-Berichte, Software Engineering Band 13. 2012.
- S. Gnesi, S. Gruner, N. Plat, B. Rumpe: *Rigorous and Agile Approaches (FormSERA)*, In: Proceedings of 1st International Workshop on Formal Methods in Software Engineering, June 2, 2012, Zurich, Switzerland, 2012.
- B. Rumpe: *Agile Modellierung mit UML : Codegenerierung, Testfälle, Refactoring*, 2nd Edition, Springer Berlin, June 2012.
- J. Atlee, R. Baillargeon, R. France, G. Georg, A. Moreira, B. Rumpe, S. Zschaler: *Proceedings of 4th International Workshop on Modeling in Software Engineering (MiSE)*, June 2-3, 2012, Zurich, Switzerland, 2012.

- C. Herrmann, T. Kurpick, B. Rumpe: *SSELab: A Plug-In-Based Framework for Web-Based Project Portals*, In: Proceedings of the 2nd International Workshop on Developing Tools as Plug-Ins (TOPI 2012) at ICSE 2012, June 3, Zurich, Switzerland, 2012.
- Dirk Riehle, Carsten Kolassa, Michel A. Salim: *Developer Belief vs. Reality: The Case of the Commit Size Distribution*, Software Engineering 2012: 59-70
- M. Nagl: *40 Jahre Informatik an der RWTH Aachen: Die zweite Hälfte 1992 – 2012*, Annual Report of the Computer Science Department of RWTH Aachen University, 12 pp., May 2012
- C. Mengi, M. Nagl: *Refactoring of Automotive Models to Handle the Variant Problem*, Softwaretechnik-Trends, 32(2):2, 11-12, May 2012.
- M. N. Fisch, C. Pinkernell, S. Plesser and B. Rumpe: *The Energy Navigator – A Web-Platform for Performance Design and Management*, In: Proceedings of the 7th International Conference on Energy Efficiency in Commercial Buildings (IEECB), Frankfurt a. M., Germany, April 2012.
- M. Schindler: *Eine Werkzeuginfrastruktur zur agilen Entwicklung mit der UML/P*, Shaker Verlag, ISBN 978-3-8440-0864-7. Aachener Informatik-Berichte, Software Engineering Band 11. 2012.
- S. Maoz, Y. Sa'ar: *Two-way traceability and conflict debugging for AspectLTL programs*, In: Proceedings of the 11th International Conference on Aspect-oriented Software Development, AOSD 2012, Potsdam, Germany, March 25-30, 2012.
- D. Lo, S. Maoz: *Scenario-based and value-based specification mining: better together*, In: Automated Software Engineering, Springer Netherlands, 1-36, 2012.
- T. Gülke, B. Rumpe, M.Jansen, J. Axmann: *High-Level Requirements Management and Complexity Costs in Automotive Development Projects: A Problem Statement*, In: Requirements Engineering: Foundation for Software Quality 18th International Working Conference, Proceedings, REFSQ 2012, Essen, Germany, March 19-22, 2012.
- C. Hopp, H. Rendel, B. Rumpe, F. Wolf: *Einführung eines Produktlinienansatzes in die automotive Softwareentwicklung am Beispiel von Steuergerätesoftware*, In: Software Engineering 2012: Fachtagung des GI-Fachbereichs Softwaretechnik, 27. Februar - 2. März 2012 in Berlin. pp. 181-192, LNI 198, 2012
- A. Haber, J. O. Ringert, B. Rumpe: *MontiArc - Architectural Modeling of Interactive Distributed and Cyber-Physical Systems*, RWTH Aachen University, Technical Report. AIB-2012-03. February 2012.
- S. Jähnichen, B. Rumpe, H. Schlingloff (Eds.): *Software Engineering 2012 Workshop Proceedings*. GI-Edition - Lecture Notes in Informatics (LNI). P-199. 2012.
- H. Giese, B. Rumpe, B. Schätz, J. Sztipanovits: *Science and Engineering of Cyber-Physical Systems (Dagstuhl Seminar 11441)*, In: H. Giese, B. Rumpe, B. Schätz, J. Sztipanovits (Eds.). Dagstuhl Reports. Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, 2012.
- C. Berger, B. Rumpe: *Engineering Autonomous Driving Software*, In: C. Rouff, M. Hinchey (Eds.). Experience from the DARPA Urban Challenge. Springer, 2012.
- M. Zanin, D. Perez, D. Kolovos, R. Paige, K. Chatterjee, A. Horst and B. Rumpe: *On Demand Data Analysis and Filtering for Inaccurate Flight Trajectories*. In: Proceedings of the SESAR Innovation Days, EUROCONTROL, November 2011.
- R. Wörzberger, T. Heer: *DYPROTO – tools for dynamic business processes*, In: International Journal of Business Process Integration and Management, Vol. 5, No. 4, pp. 324-343. 2011.

- M. N. Fisch, M. Look, C. Pinkernell, S. Plesser and B. Rumpe: *State-Based Modeling of Buildings and Facilities*, In: Proceedings of the 11th International Conference for Enhanced Building Operations (ICEBO' 11), New York City, USA, October 2011.
- S. Maoz, J. O. Ringert, B. Rumpe: *Summarizing Semantic Model Differences*, In: ME 2011 - Models and Evolution, Wellington, New Zealand. Ed: B. Schätz, D. Deridder, A. Pierantonio, J. Sprinkle, D. Tamzalit, Wellington, New Zealand, Okt. 2011.
- B. Rumpe, I. Weisemöller: *A Domain Specific Transformation Language*, In: ME 2011 - Models and Evolution, Wellington, New Zealand. Ed: B. Schätz, D. Deridder, A. Pierantonio, J. Sprinkle, D. Tamzalit, Wellington, New Zealand, Okt. 2011.
- S. Maoz, J. O. Ringert, B. Rumpe: *Semantically Configurable Consistency Analysis for Class and Object Diagrams*, In: Model Driven Engineering Languages and Systems (MODELS 2011), Wellington, New Zealand. pp. 153-167, LNCS 6981, 2011. Received Best Paper Award and ACM Distinguished Paper Award at the MODELS 2011 Conference
- T. Heer: *Controlling Development Processes*, Shaker Verlag, ISBN 978-3-8440-0509-7. Aachener Informatik-Berichte, Software Engineering Band 10. 2011.
- S. Maoz, J. O. Ringert, B. Rumpe: *CD2Alloy: Class Diagrams Analysis Using Alloy Revisited*, In: Model Driven Engineering Languages and Systems (MODELS 2011), Wellington, New Zealand. pp. 592-607, LNCS 6981, 2011.
- A. Haber, T. Kutz, H. Rendel, B. Rumpe, I. Schaefer: *Towards a Family-based Analysis of Applicability Conditions in Architectural Delta Models*, In: Proceedings of VARY International Workshop affiliated with ACM/IEEE 14th International Conference on Model Driven Engineering Languages and Systems (MODELS'11), IT University Technical Report Series TR-2011-144, pp. 43-52, October 2011.

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Simona Jeners (Pricope), M.Sc.
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Dipl.-Inform. Matthias Vianden
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(NECTEC scholarship)
Tanya Sattaya-aphitan, M.Eng.
(TOT scholarship)
- **Student Researchers**
Frederic Evers
Christian Charles
Elena Pyatkova
Claude Mangan
Andrej Dyck



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.* Reference models (e.g. CMMI, SPICE) are used by organizations to improve software processes. A systematic approach is developed to decide which combinations of them are best suited for the intended improvement.
- *Interactive Use Case based Prototyping.* Since prototypes are typically created manually 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 goal of this project.
- *Architecture Evolution and Evaluation.* Software tends to evolve independently from their architecture description. We are developing an approach to monitor and evaluate the state of the architecture and to support the goal-based evolution of the software system.

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 (Metric - Documentation, Integration, and Configuration)
- MoCCa (Model Composition and Combination Vault)

In 2012 we received the Best Paper Award of EuroSPI 2012, Vienna for the paper “*Towards an Integration of Multiple Improvement Reference Models based on Automated Concept Extraction*” written by Simona Jeners, Horst Lichter and Ana Dragomir.

Teaching

We offer the following courses on graduate level:

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

Research Projects

Reusing Domain Engineered Artifacts for Code Generation

A. Ganser, H. Lichter

Model driven architecture (MDA), and model driven engineering (MDE) are promising approaches to increase reuse and to reduce development time and effort.. Both 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.

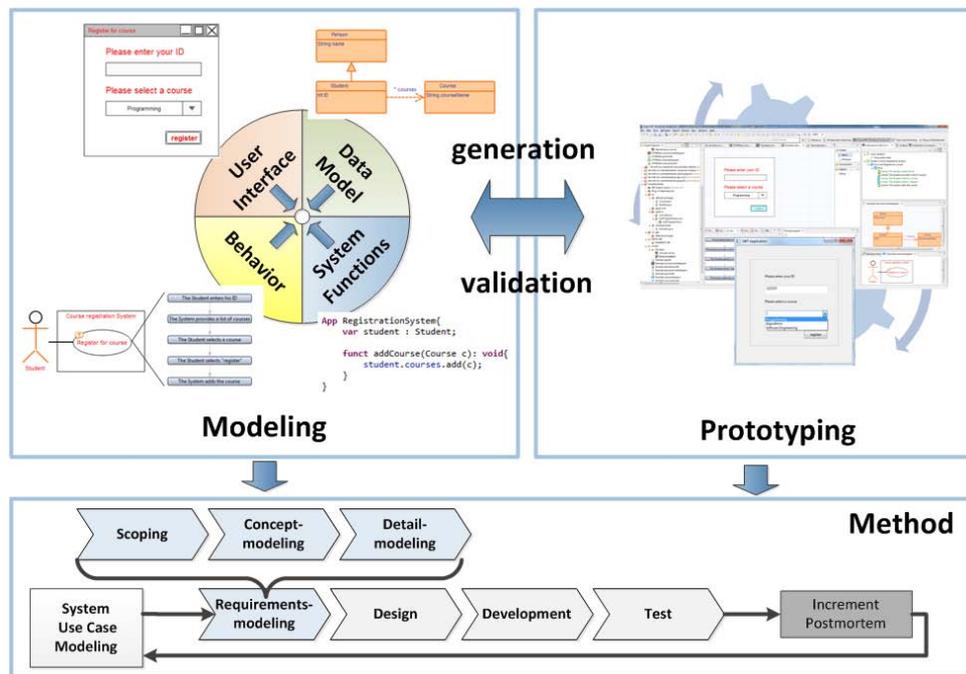
The goal of this research project is to bolster model reuse by providing interfaces attaching descriptions and providing examples and models by means of recommender systems. Furthermore, models should not be treated as in an isolated world, but related to each other, knowing not only that these models 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.

Interactive Use Case based Prototyping

V. Hoffmann, H. Lichter

Nowadays prototypes are typically created manually and they are not directly connected to other requirements specification documents. 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.

Goal-based Process Improvement

S. Jeners, H. Lichter

External cooperation: Generali Informatik Services, Aachen

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 improvement reference models (IRMs) 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 IRMs 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 IRM 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 IRMs 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 IRMs. For an efficient implementation of the IRMs, the traces between the improvement practices and their corresponding IRM' 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.

Model-based Testing of Web Applications

T. Sattaya-aphitan, H. Lichter

External cooperation: TOT Public Company Limited, Bangkok

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.

Strategic Release Management of Platform-based Architecture

M. Firdaus Harun, H. Lichter

To deliver software products on schedule, development teams struggle focusing on the build, deploy, test, and release process. In general, development teams employ ad hoc release plans or reuse release processes that are based on personnel experiences and previous projects. This practice can lead to severe problems.

As software systems and their development processes grow more complex, the release processes also become complicated. The structure of the software can be modeled by components and modules and their interdependences. Sometimes components are built from different platform for e.g. .Net, EJB, J2EE, etc. Therefore, a deep understanding of the designed architectures and the constraints of the applied software development is a must to specify and set up appropriate release processes in order to always ship the right version of components or elements into deployment environments and to release the software on time.

This research project aims to investigate what are factors and constraints that influence release processes. Finally, we want to propose a strategic and holistic approach to release management to deal with the multifaceted constraints.

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.

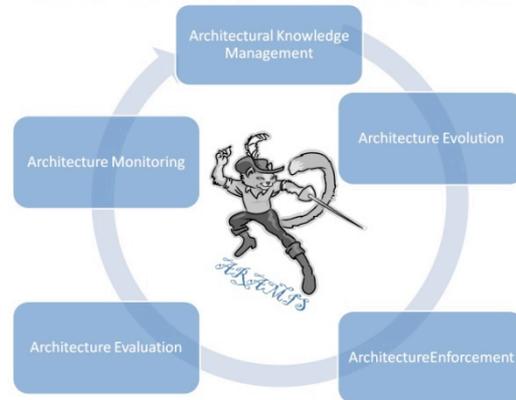
Model-based Software Architecture Evolution and Evaluation

A. Dragomir, H. Lichter

External cooperation: Generali Informatik Services, Aachen

The architecture of software systems directly influences crucial quality attributes and therefore should be considered whenever important decisions regarding their evolution must be taken. However, up-to-date descriptions that correctly reflect the static, dynamic and deployment view of the system's architecture rarely exist. On the one hand, architecture descriptions are usually elaborated at the beginning of a software project. On the other hand, after the initial version of the system has been constructed, it tends to evolve independently from its architecture description. Changes to the system are rarely documented properly and originally imposed rules are gradually violated. In extreme cases, it can become completely unclear how the software system performs its use-cases.

The ARichitecture Analysis and Monitoring InfraStructure



The aim of the ARAMIS project is to develop an approach that supports the model-based evolution and evaluation of the architecture of a software system. To achieve this, a method to continuously monitor the state of the software architecture will be employed. This will produce up-to-date architecture descriptions at various levels of abstraction and from various points of view, to support the needs of all the involved architecture stakeholders. Also, we will investigate how to enable stakeholders to easily create rules that should be imposed on the software architecture and then use these rules to periodically check if the architecture is still conformant with them. Furthermore, we will research if currently existing metrics can be used to regularly evaluate the state of the architecture, or if new ones should be developed. As a result, we plan to offer a continuous overview of the quality evolution of the architecture of the software system. Finally, we intend to develop a method for defining architecture variants and then employ the previously-mentioned metrics to analyze which of the evolution variants is better.

Other Activities

- Organization of Forum Informatik Workshop Entwicklung und Evolution von Forschungssoftware, Rolduc, November 10-11, 2012, *H. Lichter, V. Hoffmann, M. Vianden, A. Ganser.*
- Member of the international program committee, 3rd International Workshop on Formal Methods and Agile Methods, Thessaloniki, Greece, October 2, 2012, *H. Lichter*
- Member of the international program committee, 2th Annual ACM Symposium on Applied Computing, Software Engineering Track, Riva del Garda (Trento), Italy, March 26-30, 2012, *H. Lichter*
- Member of the international program committee, 6th IEEE International Conference on Software Security and Reliability (SERE), Washington D.C., June 20-22, 2012 *H. Lichter*
- Member of the program committee, Software Engineering 2012, Berlin, February 27 – March 2, 2012, *H. Lichter*
- Member of the program committee PhD Symposium at Software Engineering 2012, Berlin, *H. Lichter*
- Member of the program committee Modellierung 2012, March 14.-16, 2012, Bamberg, *H. Lichter*
- Head of program committee and organization of International Workshop on CMMI based Software Process Improvement in Small and Medium Sized Enterprises (SPISME 2011), December 11, 2011, Johor Bahru, Malaysia, *H. Lichter*
- Member of the international program committee of 5th International Malaysian Conference on Software Engineering, December 12-14, 2011, Johor Bahru, *H. Lichter*
- Panel Member of 3rd Software Engineering Postgraduates Workshop, December 12, Johor Bahru, Malaysia, *H. Lichter*
- Visiting Professor at Universiti Teknologi Malaysia, Johor Bahru, Malaysia, December 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 board of management AFST, Association for Social Technologies e.V., Aachen, *H. Lichter*
- Organization of the Universal / Specialized Preparatory Courses in Computer Science 2012, *H. Lichter, A. Ganser*
- Project lead conducting "Personalisiertes Lernen von fachlichen Grundlagen und Studientechniken in Vorkursen" (Exploratory Teaching Space), 2012, *H. Lichter, A. Ganser*

- Member of Preparatory Course Task Force, 2012, *A. Ganser*
- Member of Computer Science Faculty Committee, 2012, *A. Ganser*
- Member of RWTH Aachen University Scientific Staff Committee, 2012, *A. Ganser*
- Member of Steering Committee Computational Science Center RWTH, 2012, *A. Ganser*
- Member of Steering Committee ZLW/IMA, 2012, *A. Ganser*
- Contributor to Mentoring Program for beginners in Computer Science, 2012, *A. Ganser*
- Member of workgroup “Qualität von textuellen Anforderungen”, GI, Gesellschaft für Informatik – Fachgruppe Requirements Engineering , *V. Hoffmann*

Talks and Publications

Talks

H. Lichter: Software Processes in an Agile World. Proceedings of International Workshop on CMMI based Software Process Improvement in Small and Medium Sized Enterprises (SPISME 2011), Johor Bahru, Dec-12, 2011.

H. Lichter: Software Engineering Research and Industry Cooperations, Department Software Engineering, Chulalongkorn University, Bangkok, February 9, 2012.

S. Jeners: Towards an Integration of Multiple Improvement Reference Models based on Automated Concept Extraction. 19th EuroSPI Conference, BENA Business Base Nineteen, Vienna, Austria, 25.-27. 06. 2012.

M. Vianden: MeDIC - Eine Infrastruktur zum Verwalten, Dokumentieren und Visualisieren von Metriken. Workshop Entwicklung und Evolution von Forschungssoftware, Rolduc, November 10-11, 2012.

C. Piyabunditkul,: SPI through Process Tailoring Framework with Objective-based Scoring Metric. 19th EuroSPI Conference, BENA Business Base Nineteen, Vienna, Austria, June 25-27, 2012.

Publications

Simona Jeners, Horst Lichter, Ana Dragomir (2012): Towards an Integration of Multiple Improvement Reference Models based on Automated Concept Extraction. 19th EuroSPI Conference, BENA Business Base Nineteen, Vienna, Austria, 25.-27. 06.2012, in Winkler, Dietmar, O'Connor, Rory V., Messnarz, Richard (Eds) Systems, Software and Services Process Improvement, Communications in Computer and Information Science, vol 301, 978-3-642-31199-4, Springer Berlin Heidelberg, pp 205-216,

Tisanai Krisanathamakul, Chayakorn Piyabunditkul, Apinorn Methawachananon, Pawarat Nontasil (2012): SPI through Process Tailoring Framework with Objective-based Scoring Metric. 19th EuroSPI Conference, BENA Business Base Nineteen, Vienna, Austria, 25.-27. 06.2012, R. Messnarz et al. (Eds.), Industrial Proceedings, DELTA, Denmark, pp 11.23-11.31, ISBN 978-87-7398-154-2.

T. Thanarukvudhikorn, A. Ganser, H. Lichter, T. Anwar (2011): RIOT: Rapid, Iterative and Off-The-Shelf Tool-Evaluation, 5th Malaysian Conference on Software Engineering, MySEC 2011, 12-14 December, Johor Bahru, Malaysia, pp. 489-494, doi: 10.1109/MySEC.2011.6140722.

D. Homchuenchom, C. Piyabunditkul, H. Lichter, T. Anwar (2011): SPIALS: A light-weight Software Process Improvement Self-Assessment Tool, 5th Malaysian Conference on Software Engineering, MySEC 2011, 12-14 December, Johor Bahru, Malaysia, pp. 195-199, doi: 10.1109/MySEC.2011.6140668.

H. Lichter, T. Anwar (eds.) (2011): Proceedings of International Workshop on CMMI based Software Process Improvement in Small and Medium Sized Enterprises (SPISME 2011), Johor Bahru, Dec-12, 2011, ISBN 978-967-0194-14-1.

H. Lichter (2011): Software Processes in an Agile World. Proceedings of International Workshop on CMMI based Software Process Improvement in Small and Medium Sized Enterprises (SPISME 2011), Johor Bahru, Dec-12, 2011, ISBN 978-967-0194-14-1, pp 7-12.

Meiliana, M. Vianden, H. Lichter (2011): Variability Model towards a Metric Specification Process. International Conference on Computer Science and Information Technology (ICCSIT'2011), Pattaya Dec. 17-18, PSRC – Planetary Scientific Research Center, ISBN 978-81-922428-2-8, pp 76-79.

O. Sarkoses, M. Vianden, H. Lichter (2011): Evaluating Presentation Layer Development Frameworks for EJB Applications in J2EE Architecture. International Conference on Computer Science and Information Technology (ICCSIT'2011), Pattaya Dec. 17-18, PSRC – Planetary Scientific Research Center, ISBN 978-81-922428-2-8, pp 37-41.

Communication and Distributed Systems



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Overview

2012 has been a bit special for ComSys. This was largely due to the efforts that have gone into the final planning of the new purpose-built Computer Science building, passionately know as E3 – the new (hopefully sweet) home of ComSys. These planning efforts also included both acquiring much of the necessary funding (and paying for the rest out of our own pocket) and the design of the interior of the building down to a very high level of detail (resulting in a more than 1200 pages ‘Raumbuch’ for ComSys and C.S.). The Chair Holder and a few ‘volunteers’ put more person years into this than they would care to remember.

In addition, for quite some time the project led to a continuous emotional roller coaster – Have we got enough money? Why are we so generous with our savings and our time? Will the Rector’s or the Dean’s office provide additional funding? Will the building ever be built at all? Why are preservationist completely immune to arguments? After three years of planning hassle/hell ComSys found that it would have been better to forget about E3 and to spend the money on more useful things like teaching, research and BBQs.

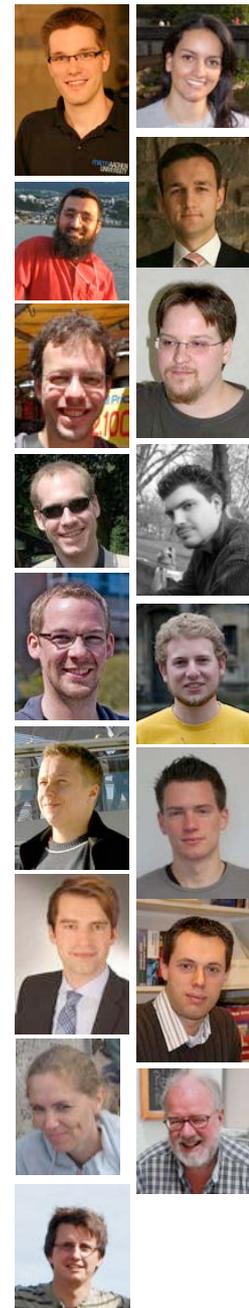
However, the noise from the construction site (and the cover photo of this report) are testimony to the fact it is nevertheless being built, so fingers crossed that the efforts, the nerves and all the hard-earned money will be well spent at the end of the day. We are now looking forward to report next year about a painful move and all the complaints we will have gotten about how on Earth one could do such a lousy planning job and waist such a lot of money. We’ll keep you updated.

For all that, parts of life went on quite normally. Research at ComSys still 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. Although next to writing unsuccessful excellence proposals and planning a building, not much time was left for research and publishing.

The range of systems considered covered complex and massively distributed Peer-to-Peer-systems, 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-Organisation 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.

Also, we are proud of 21 Bachelor, 6 Master and 9 Diploma theses that members of our staff have successfully supervised.

But it's not just about numbers. We also had some particularly successful students.

For one, Angel Tchordbadjiiski received one of the three FIF Thesis Awards for his Diploma Thesis on Liquid Democracy by FIF e.V. (Forum InformatikerInnen für Frieden und gesellschaftliche Verantwortung; Forum of Computer Scientists for Peace and Society). The award ceremony took place on 10 November at the annual FIF conference in Fulda.

Likewise, Oscar Dustmann and Mirko Stoffers were awarded were awarded KuVS prizes for the best theses in the area of Communication and Distributed Systems in Germany, Austria, and Switzerland in 2011. KuVS (Fachgruppe Kommunikation und Verteilte Systeme) is the German Computer Science Society's (GI) Special Interest Group on Communication and Distributed Systems. Oscar's Bachelor Thesis is entitled 'Scalable Symbolic Execution of Distributed Systems', the title of Mirco's Master Thesis is 'Heuristic Based Synchronisation in Parallel Discrete Event Simulations using Automatic Dependency Analysis'.

Last but definitely not least our latest alumni with a PhD:

Dr. Hamad Alizai

- Dr. Stefan Götz
- Dr. Tobias Heer
- Dr. Benjamin Schleinzer
- Dr. Alexander Zimmermann

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 cancellation. 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.

Sensor based Landslide Early Warning System / SLEWS:

Jó Ágila Bitsch Link, Klaus Wehrle

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.

Recently, we started to collaborate with wind turbine foundation companies and with the Chinese Academy of Sciences in an effort to further apply this technology in the real world.

Accurate Map-based Indoor Navigation Using Smartphones / FootPath:

Jó Ágila Bitsch Link, Klaus Wehrle

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 onto 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 We recently extended the system for use with indoor vehicles like wheelchairs and SegWays. Making use of the smartphone back camera, we derive the speed from the motion vectors produced by the video-encoding hardware.

The project is still in an early phase, but has been very well received so far in conferences (IPIN) and trade fairs (MWC) and has led to several contacts with industry (Bosch Sensortec, Software Imaging).

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

The performance of a WLAN station heavily depends on the selection of an Access Point (AP). A wrong AP selection might yield to a bad Quality of Experience (QoE) and therefore unsatisfied users. The current IEEE 802.11 association approach based the association decision on the strongest Received Signal Strength Indicator (RSSI). Since this value does not represent the real features or capacities of the APs, this decision does not lead to the selection of the most suitable AP for a specific user.

The project MetroQoE introduces QoE-based mechanisms, in order to guarantee the expected QoE when the users are accessing services and applications in Wireless Metropolitan Area Sharing Networks (WMSN).

In WMSN scenarios, the lack of a centralized management, and the existence of many administrative domains make it difficult to guarantee the QoE that users wanted. The first MetroQoE mechanism is able to enhance the association decision in WLAN through the use of additional metrics in the selection of an AP providing the best connectivity index for a specific user.

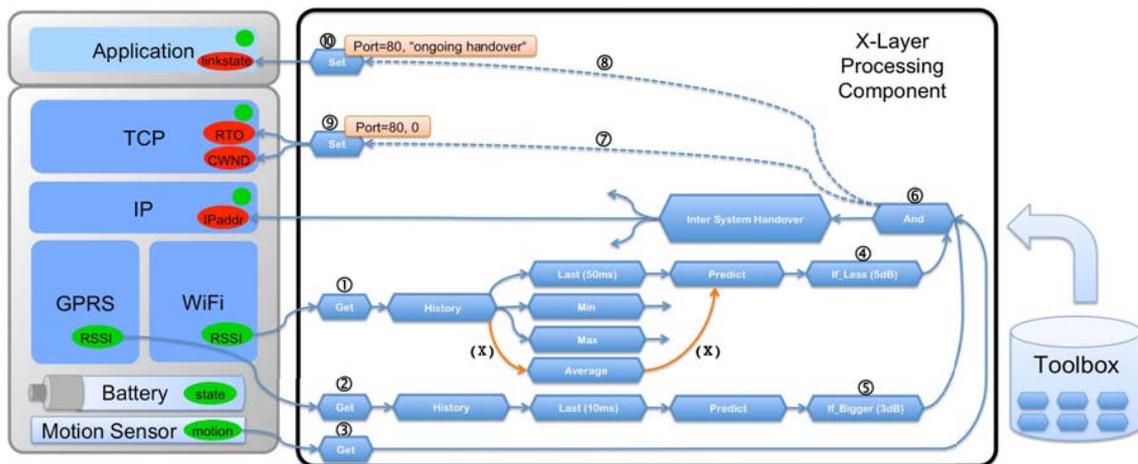
The second MetroQoE mechanism is called Gossipmule. Under the current scenario, it is not possible that a user has the whole image of the network topology and therefore of the performance of the APs. Gossipmule uses mobile crowdsensing between the wireless stations to collect and disseminate information regarding the network. The station uses this information in order to have a more assertive association decision.

The third mechanism is a QoE estimator tool. The goal of the estimator is to sense different QoE factors such as delay, packet loss, RSSI, application requests, battery consumption, among others, in order to estimate a QoE value that reflects the user satisfaction. Additionally, the tool is able to make a customized estimation since it takes into account the user preferences using a Facial Expression Recognition component to evaluate the user satisfaction.

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

Ismet Aktas, Klaus Wehrle

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

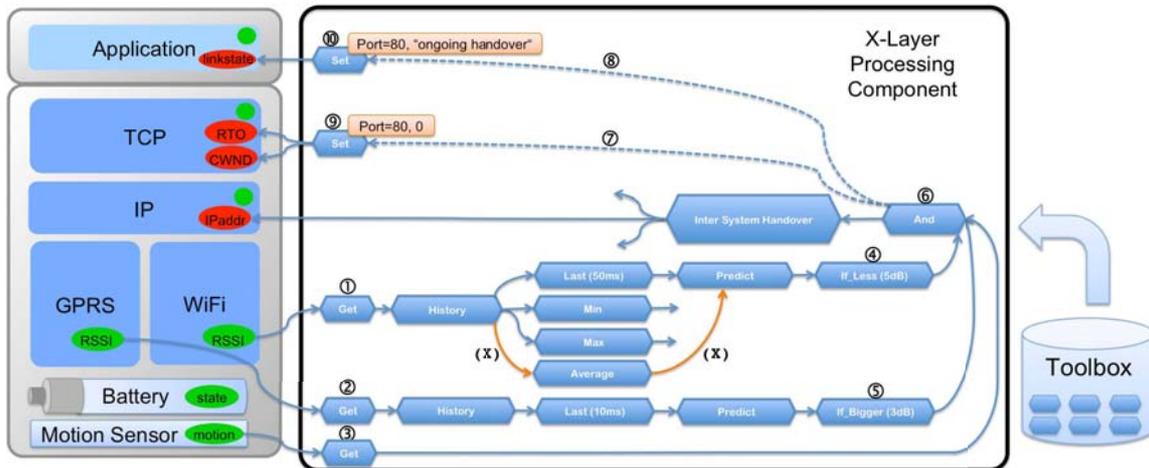


As a result of this observation, the aim of this project is the development of a framework that enables flexible and versatile adaptation of protocols and communication sub-systems to the dynamic requirements and applications that wireless environments demand. Therefore, two major enhancements compared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

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TinyWifi – Making Network Protocol Evaluation Portable Across Multiple PHY-Link Layers

Muhammad Hamad Alizai, Klaus Wehrle

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.

On-Demand Rate Adaptation For No-Ack Traffic

Florian Schmidt, Oscar Puñal, James Gross, Klaus Wehrle

Rate adaptation is one of vital parts of a wireless communication system. To adapt to ever-changing channel conditions, the sender has to make a tradeoff between high data rates and robustness.

In 802.11 (WLAN), these algorithms almost invariably depend on acknowledgments sent by the receiver to inform the sender about the correct reception. This means that unacknowledged traffic cannot be used with these rate adaptation systems, which renders them nearly useless. On the other hand, unacknowledged traffic has high potential for increases in throughput for error-tolerant or very time-critical traffic, in which retransmissions (and therefore acknowledgments) are of little use.

In this project, we focus on developing and investigating solutions to implement a rate adaptation algorithm that will work without acknowledgments, and facilitate the use of unacknowledged traffic in 802.11 networks.

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

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

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.

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

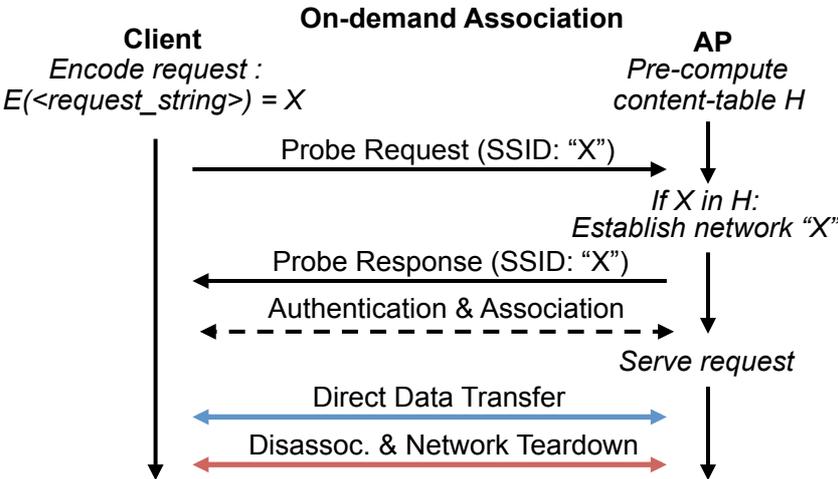
René Hummen, Tobias Heer, Klaus Wehrle

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

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.

On-demand Content-centric Wireless Networking
Hanno Wirtz, Klaus Wehrle
 B-IT Research School

Typical scenarios in the city or on campus, show a high proliferation of wireless communication devices such as smart-phones, laptops or netbooks. Wireless 802.11 networks between these devices allow for a spontaneous exchange of content or provision of services without the need for infrastructure-based services. However, the above mentioned proliferation of devices and therefore large number of networks hinders users in identifying and selecting the network that serves a specific request. Furthermore, visible information about networks and the users, content and services available in the network is restricted to space-constrained identifiers such as SSID fields and, if supported, 802.11 Information Elements. These identifiers thereby only allow expressing very limited information about the network, hardly supporting users in identifying a network that serves a given request.



We propose an approach to client-driven content-centric wireless networking in which the user specifically signals his request for a user, content item or service via 802.11 management frames. Upon reception of these frames, wireless devices that serve this request establish a dedicated wireless network on-demand. Our approach seamlessly integrates into the 802.11 association process and therefore provides support for unmodified wireless devices. Furthermore, by leveraging the wireless broadcast medium, we achieve pervasive service and peer discovery without the overhead of iterating through existing networks or running a traditional service discovery protocol.

Mobile Access: Wi-Fi based user Localization

Nicolai Viol, Klaus Wehrle

The ability to dynamically adapt information and content 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.

3D Propagation Model-based Wi-Fi localization

Klaus Wehrle, Nicolai Viol

funded by COMSYS

The high interest in location aware services and autonomous mobile systems require accurate and ubiquitous localization systems. While GPS is the most establish localization system for outdoor scenarios accuracy gets critical in dense urban areas and is not functional in most indoor environments. Hence, additional and alternative technologies are of need.

Wi-Fi systems provide an inexpensive platform to establish accurate localization in GPS denying environments. Wi-Fi Infrastructure and coverage is almost ubiquitous in many public buildings and urban environments and modern mobile devices are already equipped with Wi-Fi technology. Many approaches in Wi-Fi based localization have shown good to excellent accuracy for many environments. A main problem with Wi-Fi based localization systems is the high calibration and maintaining effort necessary to archive localization accuracy of about 2 meters or better and thus it makes such systems unattractive for productive and real-world deployments.

In our approach we use 3D Wi-Fi signal propagation models that are able to simulate the real-world signal propagation with high accuracy. The use of propagation models significantly reduces the calibration effort compared to the existing solutions, because they are easy to adapt to environmental changes or relocation of access points.

Furthermore, based on the available propagation models and the 3D models of the environment we developed a probabilistic path-matching algorithm using a Hidden Markov Models, able to improve localization accuracy especially in indoor environments. Therefore we combine the information of the propagation models with a motion model of the user and a

transition model of the particular environment to compute the most probable path of a user with respect to the Wi-Fi measurements of the users mobile device.

We established a working prototype in a large office environment that achieves accuracy better than 2m in average. Our algorithm, the concept of the prototype, and the evaluation results have been published at the IPIN 2012 conference.

Live-migration of application context between heterogeneous systems

Uta Christoph, Klaus Wehrle

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.

In the year of 2012 we have extended SliceTime to support the analysis of BitTorrent software. For this purpose we have developed a BitTorrent simulation model for ns-3 that can be applied for emulation purposes and that is fully interoperable with SliceTime.

Integration Testing of Protocol Implementations using Symbolic Distributed Execution

Raimondas Sasnauskas, Klaus Wehrle

Automatism and high-coverage are the core challenges in testing communication protocols in their early development phase. Ideally, the testing process should cope with a large input space, several sources of non-determinism, and heterogeneous operating environments to effectively explore the emerging execution paths. In practice, however, the missing tool support imposes a huge amount of manual effort to perform integrated conformance and interoperability testing of protocol implementations.

In this project, we designed SymNet, an integrated testing environment which targets the latter limitations using state-of-the-art symbolic execution techniques. Our approach is to interconnect several virtual machines, execute each of them using selective symbolic execution, and centrally coordinate the emerging distributed execution paths. The key challenges are the synchronization of distributed constraints, detection of false positives, and pruning of redundant execution states. We implemented a prototype of SymNet and applied it to the Linux implementation of Host Identity Protocol (HIP). Our early experiments demonstrate the applicability of the approach to real-world 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 developed for a number of courses. Each such unit (and the associated material) were dedicated to a specific Computer Science topic. The underlying idea was that each of these topics 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's distributed file systems can be classified into two different approaches: Firstly we have clients accessing resources on a server and secondly we have peers in a Peer-to-Peer network that are used to store our files. My work concentrates on Peer-to-Peer based file systems, as topology changes in mesh-networks due to the fluctuation of network users calls for a flexible solution. Client-server based approaches do not offer this kind of flexibility. The goal of the project is to show that unique requirements exist 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.

COrporate Standardisation Management in the ICt Sector (COSMICS)

Kai Jakobs

Co-funded by CIGREF Foundation

The project aims at finding out whether or not there is a link between an organisation's 'success' in standardisation, its internal standardisation management, and the 'behaviour' of its individual WG members. Based on this, the project will develop initial recommendations for organisations ('best practice') on how to improve their success in standards setting.

To this end, the project will first undertake a literature study, covering aspects like, among others, standardisation strategies, organisational standardisation management, and organisational communication.

Subsequently, four to six exploratory case studies will be conducted. Specifically, the goal is to do one 'major' case study that will cover three major standardisation activities in which the case company has recently been involved. Standards managers, standards setters, and external members of the relevant standards working groups will be interviewed. This study will be complemented by three to five 'minor' case studies.

Privacy in Lighting Systems

Jan Henrik Ziegeldorf, Oscar Garcia Morchon, Klaus Wehrle

joint work with Philips Research, Eindhoven, the Netherlands

The Internet of Things (IoT) paradigm envisions the pervasive interconnection and cooperation of smart things over the current and future Internet infrastructure. The IoT is, thus, the evolution of the Internet to cover the real world, enabling many new services such as smarter buildings and cities. Advanced lighting solutions will be a key driver for the IoT in these areas. Reliable privacy protection is a mandatory requirement to gain acceptance among users and comply with current and forthcoming legislation.

The project is conducted jointly with Philips Research, Eindhoven, a global leader on lighting systems pioneering in the IoT. Though the project has a concrete focus on lighting networks, it also considers their integration with other systems, such as Building Management Systems or Smart City services in a system-of-systems architecture.

The guiding principle of the project is to fully embrace privacy-enhancing technology (PET) as an enabler for advanced IoT services in the intersection of user expectations, legal boundaries and sustainable business models. Concrete project goals are, but not limited to:

- Categorization and identification of rising privacy issues in lighting networks within the general scope of the IoT evolution

- Investigation of legal and user requirements
- Design, development and evaluation of PETs and privacy-aware architectures
- Distillation of best practices and standard solutions

SoulMigration: User-centric context migration between heterogeneous systems

Sebastian Jansen, Klaus Wehrle

funded by UMIC cluster of excellence

With a focus on device mobility in the recent years of mobility research, current technologies sufficiently provide roaming and mobility for all kind of devices, using various combinations of WiFi and cellular access models. With a growing number of smaller, more powerful mobile devices per single user, this leads to an increasing number of device changes per day due to the fact that a user is now able to switch devices based on his current task and setting instead of being bound to a single device per location. However, changing between devices also means losing the current working context, as settings, views, and data remains on the source device and must be transferred to / re-established on the new device manually.

Our aim with SoulMigration is to overcome this drawback, enabling seamless migration of application context between heterogeneous applications and devices, allowing the user to switch between different devices smoothly. The project covers ways of extracting application context out of running applications, modelling and transferring this information in a device and application independent way. Concentrating on context instead of migrating whole applications not only requires less computation power and transfer bandwidth, and supports device independence, but also opens more possibilities, e.g. for context adjustment concerning privacy issues or distributing several context elements to different available platforms fully utilizing available capabilities (e.g. executing computing-intensive parts on a PC while using a smartphone as I/O device). A prototype framework for context extraction and transfer for different platforms has been developed to prove general feasibility of our approach. This framework is being extended and improved in the course of the project.

SensorCloud

René Hummen, Martin Henze, Dirk Thissen, Klaus Wehrle

joint work with QSC AG, Cologne University of Applied Sciences, symmedia GmbH

funded by the Federal Ministry of Economics and Technology (BMWi)

SensorCloud is a joined project with several partners from academia and industry. Within RWTH Aachen University we closely cooperate with the chair of *Software Engineering* and the chair of *Sociology of Technology and Organization*. This project is a research effort that tries to provide synergies for two recent trends in networking: the Internet of Things and Cloud Computing.

A key motivation for *SensorCloud* is the availability of sensed data. Today's applications of sensor networks often implement isolated networks. It is oftentimes neither possible to reuse information for different application scenarios nor to combine information from different networks in order to gain higher-value information. In stark contrast to such restricted data availability, the central and highly scalable platform of *SensorCloud* could make information accessible across application and network boundaries. Hence, *SensorCloud* would allow to reuse sensed information for different kinds of applications and to correlate sensor data independent from the sensor location.

Sensed data may contain highly personal or otherwise critical information (especially in company settings). Hence, the Chair of *Communication and Distributed Systems* is responsible for addressing the security implications when interconnecting sensor networks with the Cloud. We observe that this scenario typically involves a gateway in the trusted domain of the sensor data provider. While this gateway commonly provides connectivity with the Internet, we elevate it to a trust point of the *SensorCloud* architecture. Specifically, a trust point encrypts sensed data before sending it to the Cloud and gives the Cloud instructions for secure data access authorization. This ensures that the data provider remains in control over her data. Besides the actual design of the trust point-based architecture, *SensorCloud* research topics include transport and object security, efficient multi-party encryption and integrity protection, key management, authorization management, and mechanisms to reveal privacy implications to users and Cloud providers.

IN2RES: Wireless Sensor Networks into the Real World

Matteo Ceriotti, and Klaus Wehrle

Funded by Alexander von Humboldt Foundation

Some time ago, the research community envisioned a world pervaded by tiny smart devices able to monitor the environment and change it. However, after a decade of work, only few are

the successful deployments of operational systems. We argue that this is connected to the impact of real world environment characteristics on the technology. In the exceptional cases where the installation is successful, the resources are allocated and designed with a single application scenario in mind. This prevents the exploitation of the deployment effort, increasing the cost of the application development as well as its maintenance if application requirements change.

This project targets Infrastructures of Interconnected Resources, where sensing, storing and actuating capabilities are provided by wireless battery-powered embedded devices. By tackling the interplay between the environment and these infrastructures, we will develop methodologies and protocols to make the deployment of such systems easy, scalable, and applicable to multiple application scenarios.

In In2Res we are developing a software layer, able to guide the placement and configuration of the resources in the field according to application requirements, e.g., sampling rates and system lifetime. During system operation, In2Res will face the impact of environment dynamics on communication, energy consumption, and other infrastructure properties, by monitoring the resources and supporting the execution of manual and automatic maintenance tasks. The result will be a concrete tool available to both research and industry, shifting the attention to the application layer and fostering the deployment of the technology at the concrete benefit of the end user.

Other Activities

Klaus Wehrle

PC member of the

- 7th IEEE International Workshop on Self Managing Database Systems (SMDB2012)
- 4th ICST International Workshop on OMNeT++ (OMNeT++ Workshop'12)
- 3rd ACM/IEEE International Workshop on Software Engineering for Sensor Network Applications (SESENA'12)
- IEEE GlobeCom Next Generation Networking and Internet Symposium (NGNI'12)
- 37th IEEE Conference on Local Computer Networks (LCN'12)
- 7th IEEE International Workshop on Practical Issues in Building Sensor Network Applications (SenseApp 2012)
- 10th European Conference on Wireless Sensor Networks (EWSN'13)

Dirk Thißen

PC member of the

- 8th Int. Conf. on International Conference on Web Information Systems 2011,
- 9th Int. Conf. on International Conference on Web Information Systems 2012,
- 11th Int. Conf. on WWW/Internet 2011,

Kai Jakobs

Editor-in-Chief of the

- International Journal of IT Standards & Standardization Research,
- 'Advances in IT Standards & Standardization Research' book series,
- 'EURAS Contribution to Standardisation 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

- ITU Kaleidoscope conferences (PC Chair),
- Internet Technologies & Society 2012
- Web Information Systems 2011 and 2012
- WWW/Internet 2011
- Standardisation and Innovation in IT 2011
- Quality of Information and Communications Technology
- Int. Conf. of the European Academy for Standardisation 2012

Reviewer for

- Technology Analysis & Strategic Management,

- Technovation,
- IEEE Communication Magazine,
- IEEE Transactions on Engineering Management,
- Technological Forecasting & Social Change,
- Business Process Management Journal
- Organization Studies.

Evaluator for

- The Autonomous Province of Bozen
- Enterprise Estonia

Mónica Alejandra Lora

- Member of Qualinet – COST IC 1003, European Network on Quality of Experience in Multimedia Systems and Services.

Publications

Alizai, M.A.; Vaegs, T.; Landsiedel, O.; Götz, S.; Bitsch Link, J.A.; Wehrle, K.: Probabilistic Addressing: Stable Addresses in Unstable Wireless Networks. Proceedings of the 10th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN 2011), Chicago, IL, USA.

Alizai, M.H.; Kirchen, B.; Bitsch Link, J.A.; Wirtz, H.; Wehrle, K.: Poster Abstract: TinyOS Meets Wireless Mesh Networks. Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems (SenSys 2010), Zurich, Switzerland , page 429-430. ACM, USA.

Alizai, M.H.; Wirtz, H.; Kirchen, B.; Vaegs, T.; Gnawali, O.; Wehrle, K.: TinyWifi: Making Network Protocol Evaluation Portable Across Multiple Phy-Link Layers. Proceedings of the Sixth ACM International Workshop on Wireless Network Testbeds, Experimental evaluation and Characterization (WiNTECH), Las Vegas, NV, USA.

Alizai, M.H.; Wirtz, H.; Kunz, G.; Grap, B.; Wehrle, K.: Efficient Online Estimation of Bursty Wireless Links. 16th IEEE Symposium on Computers and Communications (ISCC), Kerkyra, Greece.

Bitsch Link, J.A.; Schmitz, D.; Wehrle, K.: geoDTN: Geographic Routing in Disruption Tolerant Networks. IEEE GLOBECOM 2011 - Next Generation Networking Symposium (GC'11 - NGN), Houston, Texas, USA , page 1 - 5.

Bitsch Link, J.A.; Smith, P.; Viol, N.; Wehrle, K.: FootPath: Accurate Map-based Indoor Navigation Using Smartphones. Proceedings of the 2011 International Conference on Indoor Positioning and Indoor Navigation (IPIN), Guimaraes, Portugal , page 1-8.

Bitsch Link, J.A.; Smith, P.; Wehrle, K.: FootPath: Accurate Map-based Indoor Navigation Using Smartphones (short paper). Proceedings of the 2011 International Conference on Indoor Positioning and Indoor Navigation (IPIN), Guimaraes, Portugal , page 1-4.

Bitsch Link, J.A.; Wollgarten, C.; Schupp, S.; Wehrle, K.: Perfect Difference Sets for Neighbor Discovery. Proceedings of the 3rd Extreme Conference of Communication (ExtremeCom 2011), Manaus, Brazil.

Fomin, V.; Jakobs, K. (eds): Standards for Development. Proceedings of the 16th EURAS Conference. EURAS contributions to standardisation research, vol. 5. EURAS, ISBN 978-3861306298. 2011.

Heer, H.; Varjonen, S.: Host Identity Protocol Certificates. Document number: draft-ietf-hip-cert-09.txt. Internet Engineering Task Force.

Heer, H.; Varjonen, S.: Host Identity Protocol Certificates. Document number: draft-ietf-hip-cert-06.txt. Internet Engineering Task Force.

Heer, H.; Varjonen, S.: Host Identity Protocol Certificates. Document number: draft-ietf-hip-cert-05.txt. Internet Engineering Task Force.

Heer, H.; Varjonen, S.: Host Identity Protocol Certificates. Request For Comments (Experimental Standard). Document number: rfc6253. Internet Engineering Task Force.

Heer, T.; Garcia-Morchon, O.; Hummen, R.; Keoh, S.; Kumar, S.; Wehrle, K.: Security Challenges in the IP-based Internet of Things. Springer Wireless Personal Communications Journal, :1-16.

Hummen, R.; Heer, T.; Wehrle, K.: A Security Protocol Adaptation Layer for the IP-based Internet of Things (Position Paper). Interconnecting Smart Objects with the Internet Workshop.

Hummen, R.; Wirtz, H.; Viol, V.; Heer, T.; Wehrle, K.: PISA-SA - Security and Mobility in a Collaborative Muni-Fi (Demo Abstract). Proceedings of the fourth ACM Conference on Wireless Network Security.

Jakobs, K.; Blind, K. (eds): Proceedings of the 7th International Conference on Standardisation & Innovation in Information Technology (SIIT 2011). IEEE Press; ISBN 978-1-4577-2020-8.

Jakobs, K.; Blind, K.: ICT Standardisation Policy in Europe – Recent Past, Presence, and Future(?). Proc. SIIT 2011, IEEE.

Jakobs, K.; Blind, K.: The European ICT Standardisation Policy – Recent Developments, Current Situation, and a Brief Outlook. Proceedings of the 16th EURAS Conference. EURAS contributions to standardisation research, vol. 5, 2011.

Jakobs, K.; Blind, K.: Towards a New European ICT Standardisation Policy – Current Status and a Glimpse Into the Future. Proc. Technical Symposium at ITU Telecom World 2011, IEEE.

Jakobs, K.; Gerst, M.: Information Technology Standardisation – A Snapshot of the Global Environment. To be published in: Proc. 11th IAMB Conference, San Francisco, 2011.

Jakobs, K.; Wagner, T.; Reimers, K.: Project Report: Standardising the Internet of Things – What the Experts Think. Int. J. on IT Standards & Standardisation Research, vol.9, no.1. IGI Global.

Jakobs, K.; Wagner, T.; Reimers, K.: Project Report: Standardising the Internet of Things – What the Experts Think. Int. J. on IT Standards & Standardisation Research, 9(1)

Jakobs, K.: Improving the Links Between Research and Standardisation – A European Perspective. Standards Engineering, vol. 63, no.3, 2011.

Jakobs, K.: Koordination und Kooperation in der ICT Standardisierung. Praxis der Informations- und Kommunikationstechnik, 34(11).

Jakobs, K.: Web Information Systems and Technologies. In: Joaquim Filipe, José Cordeiro, (eds): How People and Stakeholders Shape Standards – The Case of IEEE 802.11. LNBIP, Springer.

Karuppayah, S.; Samad, F.: CAD+: Detecting Colluding Nodes in Gray Hole Attacks. Lecture Notes in Informatics GI-Edition, S-10(Informatiktage 2011):279-282.

Krebs, M.; Stein, A.; Lora Girón M.A.: Topology Stability-Based Clustering for Wireless Mesh Networks. Proceedings of the IEEE Global Telecommunications Conference GLOBECOM 2010, Miami, USA Volume 1 , page 1-5.

Krebs, M.; Stein, A.; Lora Girón, M.A.: Topology Stability-Based Clustering for Wireless Mesh Networks. Proceedings of the IEEE Global Telecommunications Conference GLOBECOM 2010, Miami, USA Volume 1 , page 1-5.

Kunz, G.; Stoffers, M.; James Gross, J.; Wehrle, K.: Runtime Efficient Event Scheduling in Multi-threaded Network Simulation. Proceedings of the 4th International Workshop on OMNeT++, Barcelona, Spain, page 1-8.

Kunz, G.; Tenbusch, S.; Gross, G.; Wehrle, K.: Predicting Runtime Performance Bounds of Expanded Parallel Discrete Event Simulations. Proceedings of the 19th Annual Meeting of the IEEE International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems.

Lora Girón, M.A.: Experience Level Agreements in Wireless Metropolitan Area Sharing Networks. Proceedings of the ACM CoNEXT 2010 Student Workshop, Philadelphia, USA Volume 1.

Lora Girón, M.A.: Experience Level Agreements in Wireless Metropolitan Area Sharing Networks. Proceedings of the ACM CoNEXT 2010 Student Workshop, Philadelphia, USA Volume 1. ACM, USA.

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

Moskowitz, R.; Jokela, P.; Henderson, T.R.; Heer, T.: Host Identity Protocol Version 2. Document number: draft-ietf-hip-rfc5201-bis-04.txt. Internet Engineering Task Force.

Moskowitz, R.; Jokela, P.; Henderson, T.R.; Heer, T.: Host Identity Protocol Version 2. Document number: draft-ietf-hip-rfc5201-bis-03.txt. Internet Engineering Task Force.

Österlind, F.; Sasnauskas, R.; Dunkels, A.; Dustmann, O.S.∞ Wehrle, K.: Demo Abstract: Integrating Symbolic Execution with Sensornet Simulation for Efficient Bug Finding. Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems (SenSys 2010), Zurich, Switzerland , page 383-384.

Ott, J.; Hyytiä, E.; Lassila, P.; Vaegs, T.; Kangasharju, J.: Floating Content: Information Sharing in Urban Areas. Proceedings of the 9th IEEE International Conference on Pervasive Computing and Communications (PerCom 2011).

Samad, F.; Makram, S.A.: Adaptive Security Established on the Requirements and Resource Abilities of Network Nodes. The 10th IEEE Wireless Local Networks(WLN 2010) in the 35th IEEE Local Computer Networks (LCN 2010), Denver, Colorado, U.S.A. Volume 1 , page 752-755.

Sasnauskas, R.; Dustmann, O.S.; Kaminski, B.L.; Weise, K.; Kowalewski, S.; Wehrle, K.: Scalable Symbolic Execution of Distributed Systems. Proceedings of the 31st IEEE Int'l Conference on Distributed Computing Systems, (ICDCS 2011), June 20-24, Minneapolis, Minnesota, USA.

Schleinzer, B.; Samsel, C.; Inden, N.: Leistungsbewertungswerkzeuge für Applikationen in Drahtlosen Mesh Netzwerken. To be published in: Praxis der Informations-verarbeitung und Kommunikation, Special Issue, vol. 35.

Schleinzer, B.; Samsel, C.; Inden, N.: Netgrind – Ein Leistungsbewertungs-werkzeug für Applikationen in Wireless Mesh Netzwerken. Proceedings of the 6. GI / ITG-Workshop on Leistungs-, Zuverlässigkeits- und Verlässlichkeitsbewertung von Kommunika-tionsnetzen und verteilten Systemen

Schleinzer, B.; Yoshioka, N.: A Security Pattern for Data Integrity in P2P Systems. PLoP 2010, Reno, NV, USA.

Schmidt, F.; Alizai, M.H.; Aktas, I.; Wehrle, K.: Refector: Heuristic Header Error Recovery for Error-Tolerant Transmissions. Proceedings of the 7th International Conference on emerging Networking EXperiments and Technologies (CoNEXT), Tokyo, Japan , page 1-12.

Vaegs, T.; Alizai, M.A.; Bitsch Link, J.A.; Wehrle, K.: Efficient Power Management Using Out-of-Band Signaling. Proceedings of the 10th GI/ITG KuVS Fachgespräch Drahtlose Sensornetze (FGSN), page 77-80.

Varjonen, S.; Heer, T.; Rimey, K.; Gurtov, A.: Secure Resolution of End-Host Identifiers for Mobile Clients. IEEE GLOBECOM 2011 - Next Generation Networking Symposium (GC'11 - NGN).

vom Lehn, H.; Bitsch Link, J.A.; Wehrle, K.: Work in Progress: Uncovering the Privacy Implications of Web Usage [Poster].

Weingaertner, E.; Schmidt, F.; vom Lehn, H.; Heer, T.; Wehrle, K.: SliceTime: A platform for scalable and accurate network emulation. Proceedings of the 8th USENIX Symposium on Networked Systems Design and Implementation (NSDI '11).

Weingaertner, E.; vom Lehn, H.; Wehrle, K.: Device-driver enabled Wireless Network Emulation. Proceedings of the 4th International ICST Conference on Simulation Tools and Techniques (SIMUTools 2011).

Williams, R.; Graham, I.; Jakobs, K.; Lyytinen, K.: China and Global ICT standardisation and innovation. Technology Analysis & Strategic Management, vol. 23, no. 7, pp. 715-724, 2011.

Wirtz, H.; Backhaus, R.; Hummen, R.; Wehrle, K.: Demo: Establishing Mobile Ad-Hoc Networks in 802.11 Infrastructure Mode. Proceedings of the Sixth ACM International Workshop on Wireless Network Testbeds, Experimental evaluation and Characterization (WiNTECH 2011), Las Vegas, NV, USA.

Wirtz, H.; Heer, T.; Klaus Wehrle, K.: A Generic Service Overlay for Wireless Mesh Networks. 3rd GI/ITG KuVS Fachgespräch on NG SDPs. Berlin, Germany.

Wirtz, H.; Heer, T.; Backhaus, R.; Klaus Wehrle, K.: 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.

Wirtz, H.; Hummen, R.; Viol, N.; Heer, T.; Girón, M.L.; Wehrle, K.: Cooperative Wi-Fi-Sharing: Encouraging Fair Play. Proceedings of the ITU-T Kaleidoscope Event 2011, Cape Town, South Africa.

Zimmermann, A.; Hannemann, A.; Schleiner, B.: IP address assignment in wireless mesh networks.. Wireless Communications and Mobile Computing, 11(3):321-337.

Mobile Network Performance Group

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- **Associated Members**
Dipl. Inform. Georg Kunz
- **External Assistants**
Neda Petreska, M.Sc.
- **Student Assistants**
Simon Tenbusch
Daniel Schemmel



Overview

The Mobile Network Performance Group was a junior research group 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). As of November 15th 2012, Prof. James Gross is establishing a new group on Machine-to-Machine communications at KTH Stockholm. However, the Mobile Network Performance group will continue its research efforts in the chair of Communication System of Prof. Klaus Wehrle for the next two years (until all PhD students have finished). The research profile of the group consists of the following areas:

- Design & performance of 80 MHz future wireless local area networks
- Interference coordination and performance modelling of LTE cellular networks
- Parallel network simulation for wireless systems and networks
- Ultra-high reliability of wireless local area networks for industrial applications
- Clustering, channel usage and routing in cognitive ad-hoc wireless networks
- Queuing-theoretic analysis of wireless networks and systems
- Jamming and rate-adaptation in vehicular 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 nine PhD students (Oscar Puñal, Christian Dombrowski, Donald Parruca, Di Li, Georg Kunz, Yulin Hu, Marco Weyres, Neda Petreska and Mirko Stoffers), 5 student research assistants and four diploma/master thesis candidates.

Highlights of this year comprise:

1. A call for Prof. James Gross from KTH Stockholm.
2. A newly established industry project described below.
3. Two more PhD students which joined our group (Mirko Stoffers, Neda Petreska)
4. Mirko Stoffers being awarded the Gi KuVS prize for the best master thesis in Germany.
5. An invitation of Prof. James Gross to give a research seminar at Bangkok University of Technology in August 2012.

Research Projects

In the following we provide some more information on our research projects:

Industry Project ‘Parallel Network Simulation’

In co-operation with Huawei Technologies Ltd.

Network simulation becomes ever more complex due to more and more requirements from the physical layer to model the instantaneous signal propagation circumstances as detailed as possible. For the development of various technical advances, this is meanwhile imperative. Unfortunately, this requires more and more computational power as network models of interest also become bigger in terms of terminals and base stations to be simulated. In this industry project, we are advising several departments of Huawei on different parallelization techniques for discrete-event simulation with a particular emphasis on the applicability of these schemes for wireless network simulation. The project contains close cooperation with frequent travels to the main development site at Chengdu (where this report has been written also). The cooperation will continue until January 2014 and will focus in quite cutting-edge parallelization principles not established so far in commercial network simulators.

Project 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

Joint project together with Georg Kunz and Klaus Wehrle

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

Simulation models of wireless networks typically require a considerably more detailed modeling of the lower network layers than models of wired networks. In particular, the wireless channel and the physical layer demand precise models to capture the subtle effects

and interactions of advanced wireless communication technologies such as MIMO transmissions or successive interference cancellation. 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, “Interference Coordination for LTE Networks”, The Sirindhorn International Thai-German Graduate School of Engineering (TGGS), King Mongkut’s University of Technology North Bangkok, Thailand, August 2012 (invited presentation).
- J. Gross, “Some Recent Results on the Effective Service Capacity Modeling of Wireless Networks”, *VDE/ITG 5.2.4 Workshop on Modeling Mobile Networks*, Nokia Siemens Networks Research Lab Ulm, Januar 2012.
- J. Gross, “Performance Models for OFDMA Cellular Networks”, Universität von Porto, Porto, Portugal, Dezember 2011.(Eingeladener Vortrag).

Publications

- Y. Hu und J. Gross, “On the Outage Probability and Effective Capacity of Multiple Decode-and-forward Relay System“, akzeptiert zur *IFIP Wireless Days 2012*, Dublin, Ireland, November 2012.
- D. Li and J. Gross, “Distributed TV Spectrum Allocation for Cognitive Cellular Network under Game Theoretical Framework“, In *Proc. of the IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks 2012 (DySPAN 2012)*, Washington, USA, Oktober 2012.
- J. Gross, M. Weyres und A. Wolisz, “Effective Service Capacity Analysis of Opportunistic Multi-Carrier OFDMA Systems“, In *Proc. of the ACM International Symposium on QoS and Security for Wireless and Mobile Networks (ACM Q2SWinet 2012)*, Paphos, Zypern, Oktober 2012.
- F. Schmidt, A. Hithnawi, O. Puñal, J. Gross und K. Wehrle, “A Receiver based 802.11 Rate Adaptation Scheme with On-Demand Feedback“, In *Proc. of the IEEE International Symposium on Personal, Indoor and Mobile Radio Communications 2012 (PIMRC 2012)*, Sydney, Australien, September 2012.
- O. Puñal, A. Aguiar und J. Gross, “In VANeTs we Trust? Characterizing RF Jamming in Vehicular Networks“, In *Proc. of the 9th ACM Workshop on VehiculAr Inter-NETworking, Systems and Applications 2012 (ACM VANET 2012)*, Low Wood Bay, England, Juni 2012.
- J. Gross, “Scheduling with Outdated CSI: Effective Service Capacities of Optimistic vs. Pessimistic Policies“, In *Proc. of the 20th IEEE/ACM Workshop on Quality of Service 2012 (IWQoS 2012)*, Coimbra, Portugal, Juni 2012.
- G. Kunz, D. Schemmel, J. Gross und K. Wehrle, “Multi-Level Parallelism for Time- and Cost-efficient Parallel Discrete-Event Simulation on GPUs“, In *Proc. of the 26th ACM/IEEE Workshop on Principles of Advanced and Distributed Simulation 2012 (PADS 2012)*, Zhangjiajie, China, Juli 2012.
- O. Puñal und J. Gross, “Power Loading: Candidate for Future WLANs?“, In *Proc. of the 13th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2012 (WoWMoM 2012)*, San Francisco, USA, Juni 2012.
- G. Kunz, M. Stoffers, J. Gross und K. Wehrle, “Know Thy Simulation Model: Analyzing Event Interactions for Probabilistic Synchronization in Parallel Simulations“, In *Proc. of the 5th International ICST Conference on Simulation Tools and Techniques 2012 (SIMUTools 2012)*, Desenzano, Italien, März 2012.

G. Kunz, S. Tenbusch, J. Gross und K. Wehrle, “Extending the OMNeT++ Sequence Chart for Supporting Parallel Simulations in Horizon”, In *Proc. of the 5th International ICST Conference on Simulation Tools and Techniques 2012 (SimuTools 2012)*, präsentiert auf dem *International Workshop on OMNeT++*, Desenzano, Italien, März 2012.

Informatik 5

Information Systems



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Aachener Strassenbahn- und Energieversorgung AG, ABB, aiXtrusion GmbH, Allgäuer Überlandwerke GmbH, atmosfair GmbH, Apache Rave, Cantamen GmbH, Cyntelix, Deutsche Bahn AG, DSW24, EADS Deutschland GmbH, Energieversorgung Sylt GmbH, Ericsson Eurolabs, European Schoolnet, FIR e.V., flinc AG, Hacon GmbH, HCIC, Helmut Hund GmbH, HUBJECT GmbH, Humance AG, IAEW, IFHT, IKA, imc AG, Inform GmbH, InnoZ GmbH, INSTICC, ISEA, IVU Traffic Technologies, mr.net mbH, MSR-Office, Nettropolis GmbH, Nokia Siemens Networks, region iT GmbH, Siemens AG, Software AG, Solopan GmbH, Stadtwerke Aachen, Stadtwerke Duisburg AG, Stadtwerke Leipzig, Stadtwerke Osnabrück, Stadtwerke Trier, strophe.js, SURFnet, Thinking Networks AG, TWT GmbH, PSI AG, Universitätsklinikum Düsseldorf, VDV, VRR, 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 2011-2012, the group's third-party funding again reached close to 3 m€. Large newly acquired projects include the eConnect project by the German Ministry of Economy (BMWi) in which six RWTH research groups collaborate with a consortium of regional energy providers on the ICT infrastructure for smart grids in eMobility. The German Federal Government named eConnect its "lighthouse project in ICT for electromobility". At the end of the reporting period, a new EU Integrated Project LAYERS in technology-enhanced learning was also approved with a large participation by our group

Members of i5 again took leading roles in the organization and program chairing of international conferences. Yiweh Cao and Ralf Klamma were program co-chairs at ICWL 2011 and ICWL 2012, Milos Kravcik organized the JTEL Summer School, Matthias Jarke a Dagstuhl Seminar on Requirements Management, and several team members led workshops at important national and international conferences. As in the previous year, Dr. Krempels co-organized the 2012 Informatics Summer party, and Dr. Quix the Computer Science-internal championship InfoCup. Another highly visible internal events organized by i5 were the celebration of the 40th Anniversary of Computer Science studies at RWTH Aachen, combined with the award of an honorary doctoral degree to our long-standing cooperation partner Joh Mylopoulos (University of Trento). Last not least, the Informatics department held a colloquium in honor of the 60th birthday of Prof. Matthias Jarke. All in all, a truly party-intensive year!

The personnel at Informatik 5 remains highly international, representing almost 20 different nationalities. Doctoral theses were defended by Yiweh Cao, Jessica Huster, and Xiang Li, the latter with distinction. Congratulations are also due to Michael Derntl and Milos Kravcik who received best paper awards at two of the four internationally leading eLearning conferences within a couple of weeks. On the occasion of his birthday, Prof. Jarke received the Fraunhofer Medal in recognition of his outstanding services within the Fraunhofer Society of Applied Research which also re-elected him for a second period as Chairman of the Fraunhofer ICT group (Europe's largest applied research organization in IT) and member of the Fraunhofer Presidential Board. Moreover, he was appointed as one of the two new Fellows of the GI German Informatics Society elected in 2012.

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. More than 20 institutions at RWTH Aachen participate in UMIC, aiming at interdisciplinary design of ultra high-speed mobile information and communication systems. Informatik 5 works closely together with many institutes of electrical engineering, mechanical engineering, architecture, and computer science in two subprojects in the research area of “Mobile Applications and Services”.

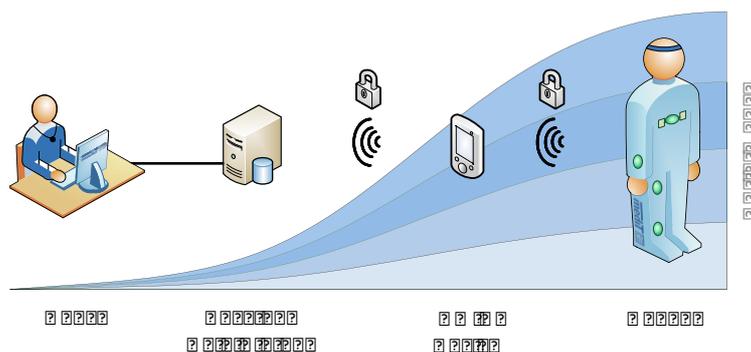
Model Management and Data Integration Research

Mobile and Wearable P2P Information Management in Health Net Applications

M. Jarke, C. Quix, S. Geisler, X. Li, J. Döring, S. Weber, T. Yu, S. Kim (MedIT), M. Hassani (Informatik 9), T. Quadflieg (ITA), U. Meyer, J. Barnickel (IT Security)

Informatik 5 cooperates with the institute for textile technology (ITA), the Philips Chair for Medical Information Technology (MedIT), Informatik 9 (Data Management and Exploration) and the UMIC research group IT Security. The aim is to develop a P2P network in which patients, doctors, nursing staff, and emergency services have full access to information and services in their mobile work environment. Data about the health status of a patient is collected by a network of sensors integrated in the textile clothes. The data can be reviewed by doctors to consult the patients online, or by the emergency service to improve the diagnosis in an emergency situation.

After a first successful demonstration of the prototype at the Lousberglauf 2011, the team continued the development of the prototype, focusing especially on the quality of the collected data. Several studies have been performed to improve the quality of the ECG signal which is measured by several textile-integrated sensors. The sensor data is sent to a mobile device and can be shared in a peer-to-peer network. Thereby, remote monitoring of the state of runners and more complex data analysis on backend servers is enabled. The work of Informatik 5 focuses on mobile data integration, exchange and visualization. The software has been developed on the Android platform.



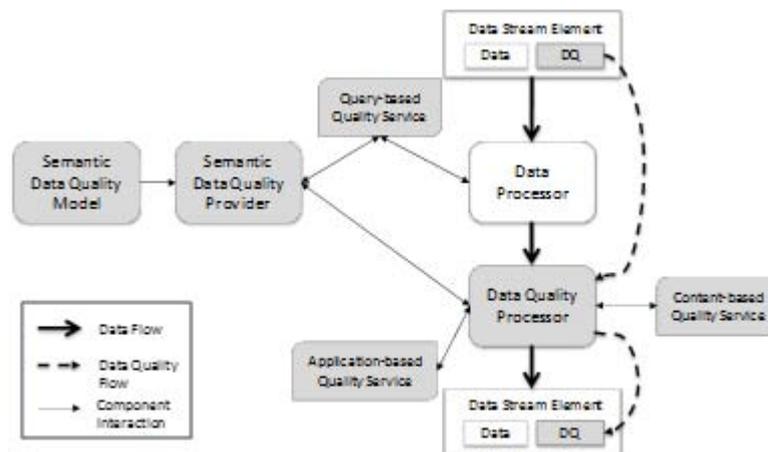
Furthermore, Informatik 5 organized the International Workshop on Information Management in Mobile Applications (IMMoA) at the International Conference on Very Large Databases (VLDB) in Istanbul, Turkey. Daniela Nicklas from the University of Oldenburg gave an inspiring keynote talk on context modelling and its integration into mobile applications.

Cooperative Cars – CoCar

M. Jarke, C. Quix, S. Geisler, S. Schiffer (Knowledge-based Systems Group), J. Döring, S. Weber

The Cooperative Cars (CoCar) project, supported by the German Federal Ministry for Research and Education and Ericsson EuroLabs, 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. Several partners from telecommunications and automobile industry identified which traffic management and driver assistance applications are suitable for use of this technology.

Informatik 5 cooperated with Ericsson in Aachen and Fraunhofer FIT and develops data models, algorithms and systems for the data processing of CoCar applications. The main focus was on investigating data stream management systems as the core component for data processing in traffic information systems to realize multiple traffic applications. Furthermore, the group studies data (stream) mining algorithms for traffic applications. In 2012, the data stream-based evaluation framework has been extended by a data quality component which enables a continuous monitoring of multiple data quality measures during data processing. This allows not only to produce new traffic information such as queue-end warnings, but also to add a reliability value for this information. Furthermore, countermeasures can be activated if the data quality drops below a certain threshold. For example, if there is not a sufficient number of CoCars to produce reliable traffic messages, additional sources, such as floating phone data or road-side units can be taken into account.



Architecture of the Ontology-Based Data Quality Framework

ConceptBase - A deductive object manager for meta databases

M. Jarke, C. Quix, F. Kastrati, 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 2011/12, the group focused on continuous improvement of the system and removed several bugs.

Model Management

M. Jarke, C. Quix, S. Geisler, F. Kastrati, X. Li, D. Yankov

Research in model management focuses on the formal definition of structures and operators for the management of complex data models to support applications dealing with the integration, maintenance, and evolution of data models. Based on the generic role-based meta model *GeRoMe*, the group developed the generic model management *GeRoMeSuite* which includes support for model management operations such as schema matching, composition of mappings, schema integration, and model transformation.

In 2012, the group worked especially on information extraction methods to extract structured data from unstructured documents. This work is done in the context of the dataspace framework which 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 way enabling a semantic search over heterogeneous sources. The system is domain independent, and utilizes an open-source knowledge base for extracting semantic classes for the extracted 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.

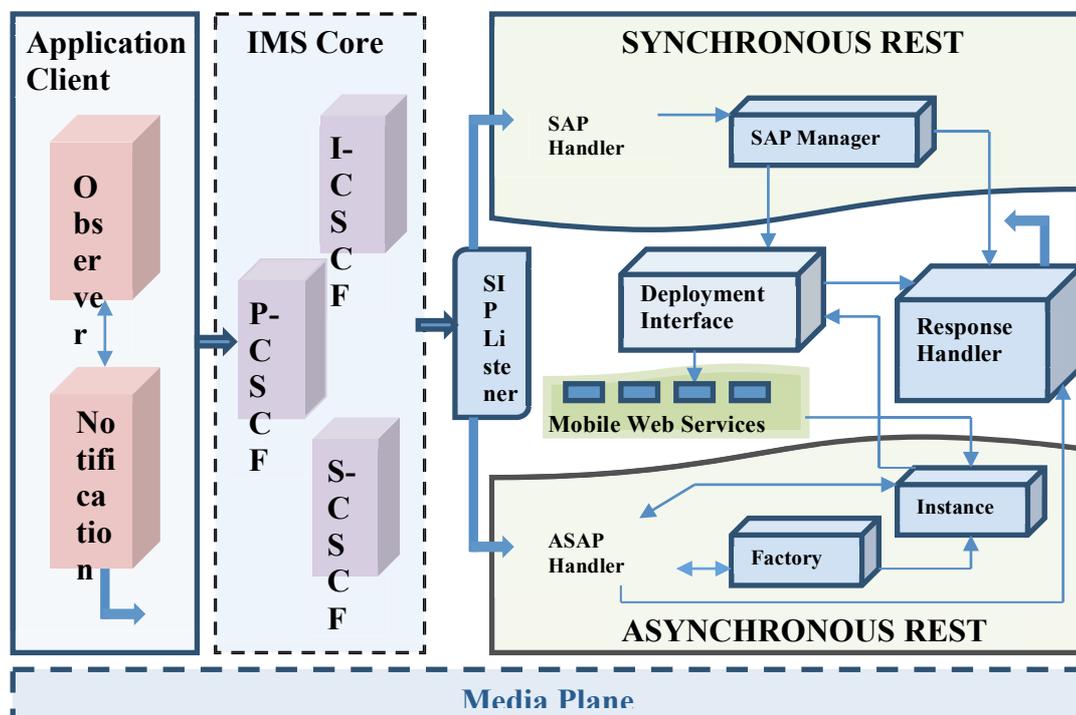
Mobile Community Information Systems Research and Development

B-IT Research School: Mobile to Mobile (M2M) multimedia service provisioning in future mobile networks

M. Jarke, A. C. Muzzamil

Multimedia applications are bandwidth-hungry whereas mobile networks are bandwidth-constrained. Enabling high quality multimedia services over mobile networks is not straight forward. has always been a great concern in this scenario. This dissertation project investigates a fundamental platform for Mobile-to-Mobile (M2M) service networks, where each subscriber device serves high quality multimedia services to other devices on the network with guaranteed Quality of Service (QoS). The proposed mobile platform is envisaged to host future M2M services 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.

In 2012, along with multiple architectural enhancements, the mobile platform has been extensively tested with the state-of-the-art Ericsson IMS and Fraunhofer OpenIMS testbeds. Thus, the existing platform is now been able to host and serve multiple M2M multimedia services over the future LTE-Evolved Packet System (EPS).



econnect Germany – Stadtwerke machen mobil

K.-H. Krempels, C. Terwelp, P. Heinz, C. Samsel

Within econnect Germany specialized R&D groups are developing applications for sustainable mobility based on electric energy. The objectives of the project are approaches for: smart grids for renewable energy, mobility concepts for urban areas, smart parking for vehicle to grid scenarios, information systems for public transportations, and finally, smart charging for electric vehicles. Informatik 5 coordinates the project activities of the seven participating institutes of RWTH Aachen University. In four scientific workshops with academic and industrial participants, we focused on knowledge acquisition, requirements engineering, and conceptual modelling for mobility concepts in urban and rural areas. In the development process for a new mobility concept for the City of Osnabrück the current public transport situation was analyzed and the city master plan was consulted to detect actual conceptual drawbacks and system operation bottlenecks. Furthermore, near and medium term objectives for urban mobility were defined to improve the public transport infrastructure and mobility efficiency supported by electric vehicles. As the new mobility concept for the City of Osnabrück is based on a higher integration of mobile transport systems, e.g. trains, busses, shared e-bikes, shared e-cars, and redesigned mobility points, e.g. integrated bus, e-bike and e-car station, there is high need to reduce the usage complexity of the new public transportation system. Therefore, representative mobility scenarios were used for use case deduction, requirements analysis for planning and navigation in the new system, and finally, the technical specification of an intuitive smartphone application supporting the user in pre- and on-trip planning and navigation. econnect Germany was awarded as a light house project for electric mobility by the German Federal Ministry of Economics and Technology.

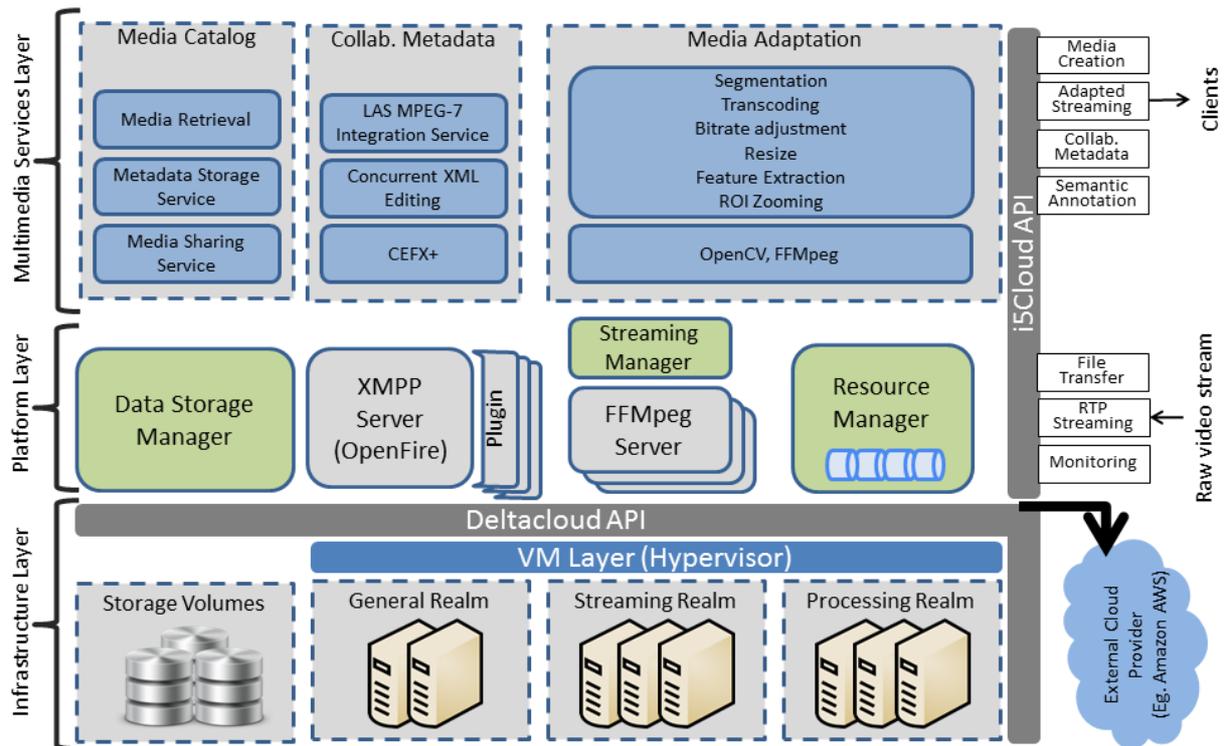
Future Mobile Internet Services: Virtual Campfire

*M. Jarke, R. Klamma, Y. Cao, D. Kovachev, M. Jansen (Sbg), G. Toubekis (Sbg),
P. Nicolaescu, G. Aksakalli, A. Belur, M. Hackstein, S. Javaid, A. Rafique*

Virtual Campfire aims to provide professional communities such as researchers' communities for cultural heritage management an advanced framework to create, search, and share multimedia artifacts with context awareness easily and fast. Virtual Campfire has established a research framework for mobile multimedia management with metadata standards and hybrid tagging approaches, cloud computing for mobile multimedia processing and mobile communities, convergence research on mobile and Web 2.0, social network analysis for mobile communities, and prototyping of complex community information systems.

In 2012, Virtual Campfire has been further developed by: 1) a framework and infrastructure for mobile cloud computing, 2) distributed user interfaces on different mobile devices, and 3)

social network analysis methods for mobile community exploration. Within the context of this project, Yiweh Cao completed and successfully defended her dissertation.



B-IT Research School: Multimedia Cloud Computing

M. Jarke, R. Klamma, D. Kovachev, G. Aksakalli

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.

BIT Research School: Community-centered Semantics for the Detection of Faked Multimedia

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

The dissertation project by Khaled Rashed investigates the possibility of combining the power of Web 2.0 techniques and community approaches with capabilities of content-based similarity search and retrieval with the 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. During the year 2012, an algorithm called MHITS to rank users' expertise in online web-based collaborative fake media detection systems has been developed. We integrate SumUp, a Sybil-resilient algorithm; into MHITS algorithm as a robust ranking strategy. This work is supported in part by the B-IT Research School.

Research in Technology-Enhanced Learning

EU Network of Excellence GALA: Games and Learning Alliance

M. Jarke, R. Klamma, M. Derntl, M. Kravcik, A. Hannemann

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.

During the second year of the project, i5 had four major work items. First, the collaboration in the Technical Committees and Special Interest Groups carried fruits, and findings were submitted and published at different conferences (e.g. AIIDE 2012, VS-GAMES 2012) and journals in collaboration with consortium partners. Second, results of the 2nd GaLA Alignment School in Carcavelos, Portugal, workshop track on “Interactive Storytelling” will be used as input to GaLA’s new Serious Games MSc curriculum. Third, in collaboration with GaLA partner Cyntelix we co-chaired a highly successful workshop on “Pedagogically Driven Serious Games” (PDSG 2012) at the 7th European Conference on Technology Enhanced Learning (EC-TEL 2012) in Saarbrücken, Germany. Fourth, we made “Serious Games” the main theme of our High-tech Entrepreneurship and New Media lab for computer science master students in winter term 2011/12 at RWTH Aachen University. In this lab course our GaLA partner Cyntelix co-supervised one student team in a Serious Game development project.

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

*M. Jarke, R. Klamma, M. Derntl, M. Kravcik,
S. Erdtmann, K. Hoxha, L. Dohmen, R. Uppal, A. Peash*

With a 10-year horizon, TEL-MAP 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. 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 second year of the project (October 2011 – September 2012) i5 produced several key contributions to the project:

- We conceived, developed, deployed, and evaluated an embeddable dashboard on <http://learningfrontiers.eu> for supporting roadmapping activities by different stakeholders (e.g. policy makers, observers, authors) by providing flexible and personalized visualizations of data indexed in our Mediabase.
- We extended i5’s AERCS system with a conference and journal series analysis tool, as well as a series comparison tool. These tools enable stakeholders to view, analyze, compare, and benchmark the development and status of conference and journal author communities based on social network measures.
- All Mediabase data sources were significantly extended with new data from blogs, EU funded projects, and papers. We published several papers at international conferences and journals on results of social network analyses in these data sources. Also, we automatically extract and publish a daily digest of “hot blog posts” from the TEL blogosphere indexed in the Mediabase.

LD-Grid: Learning Design Grid

M. Derntl

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 project was successfully completed in May 2012. The main outcomes are:

- A comprehensive mapping of representations of design knowledge in TEL and reviews of existing banks of learning design resources and tools, <http://ld-grid.org>
- Several workshops including Art and Science of Learning Design (ASLD 2011), Theory and Practice of Learning Design at Online Educa 2011 (TPDL 2011) and at Designs for Learning Conference (TPDL 2012), and a workshop to be held at the 2013 Alpine Rendezvous called “Teacher-led Inquiry and Learning Design: The Virtuous Circle”. In addition, several papers were published.
- A follow-up project called METIS, in which i5 is a consortium member, and which is funded by the European Commission in the Lifelong Learning Programme. METIS will commence in November 2012 and will last for 28 months.

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

M. Jarke, R. Klamma, Y. Cao, M. C. Pham, R. Vuorikari (European Schoolnet), A. Sahib

The EU Life Long Learning Project TeLLNet supports the development of European Schoolnet (www.etwinning.net) in cooperation with the European Schoolnet, Open University of the Netherlands, and Institute for Prospective Technological Studies (IPTS) as one of European Commission Joint Research Centers. Social Network Analysis (SNA) helps the project investigate patterns of teacher communication, cooperation, and other kinds of interaction taking place in business, organizations and the World Wide Web.

In 2012, we finished the dynamic analysis of eTwinning communication, to identify social roles in the learning network on the member level, on the sub-network structures, and on the network level. A dynamic data flow automatically triggers the re-computation of roles and structures over time, based on the previously established data warehouse. Time series analyses observe the evolution of the teachers’ professional development. We have proposed a model to analyze the development of eTwinning community based on different kinds of interaction between eTwinners (teachers). We focus on two problems. Concerning the

development of eTwinning, we analyze the development patterns of the community. To assess social capital in eTwinning, we measure both individual and group social capital. The results are useful for policy-makers, members and central support service of the eTwinning network, 35 National Support Services and the eTwinning Steering Committee, to understand the underlying mechanisms for the transfer of good practices and innovation.

EU Integrating Project ROLE: Responsive Open Learning Environments

M. Jarke, R. Klamma, M. Kravcik, Z. Petrushyna, D. Renzel, A. Hannemann, A. Guth, P. De Lange

ROLE is an EU-funded large-scale integrated project in the domain of technology enhanced learning (TEL). ROLE 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 mash-up) new components and functionalities, adapted by collaborating learners to enhance the effectiveness of their learning. As vice coordinator, I5 is technical leader and community facilitator.

We coordinated development, hosted and maintained the project development infrastructure, released four versions of the ROLE Software Development Kit and are hosting the ROLE Sandbox. Building on earlier results and ongoing efforts we further elaborated the idea of Social Requirements Engineering and the ROLE Requirements Bazaar, resulting in a prototypical implementation and a further publication at EC-TEL 2012. Another focus was on real-time communication and collaboration in widget-based Web applications using the XMPP protocol, in particular Inter-widget Communication. We actively contribute to several well-known OS projects and standardization bodies such as Strophe.js, Apache Rave and the XMPP Community. The dissemination activities included also co-organization of two workshops at the ICALT and UMAP conferences, focusing on investigation of self-regulated learning (S-ROLE) and personalization approaches in learning environments (PALE). Our achievements have been presented at the most relevant e-learning conferences like ICALT, EC-TEL, and ICWL, where our contribution received the Best Paper Award.

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 was to design context adaptive systems for knowledge processes. The Informatik 5 subproject “Traceable Cooperative Requirements Engineering for Communities-of-practice” extended 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. A model for community-oriented requirements engineering, developed within CONTici, was applied and verified in three large-scale open-source projects of bioinformatics (“Soziale Interaktion in Open-Source-Communitys”, Praxis der Wirtschaftsinformatik). Further, a widget-based platform, which incorporates the previously developed storytelling platform and bubble annotator, was realized and evaluated within community-oriented lab “High-tech Entrepreneurship and new Media”.

Life Science Informatics

SEKT - Spezifische Detektion von einzelnen Keimen in Rein- und Trinkwasser

T. Berlage, J. Bornemeier

SEKT was newly established in 2012. The overall goal of the project is to detect bacteria in drinking water by filtering the water and microscopically analyzing the filter surface for a small number of bacteria. The intention of EADS as a partner is to use this technology in various security scenarios and in regular aircraft maintenance. Helmut Hund GmbH is responsible for the optical detection hardware.

The work of RWTH is focused on image analysis, the recognition and discrimination of bacteria, which are labeled with fluorescent antibodies. We will develop a suitable strategy for scanning the filter surface, including content-based autofocus. We will work on different methods for the recognition of suitable objects and for discrimination between bacteria and other material. We will support the validation of the technology by performing analysis on both sparse and high filter loads, on both synthetic as well as real-world samples.

B-IT Research School, DFG KFO-217: 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. The new methods was compared to manual analysis in various experiments and the robustness of the method could be established. A new and more general approach does not need structural recognition of the membranes, which often is a specialized image analysis procedure. Instead, probabilistic sampling of the toponomic area combined with an improved selection strategy allows us to tackle more general tissue structures. The new approach was validated to be substantially equivalent to the previous, more specific methods.

The results were presented to a high-level board of reviewers. As a result, a second project period was granted. In this period we will focus on tissue-level structures to ensure that the fields-of-view analyzed from a large slide can be automatically selected via image analysis. This will provide a less biased and more automated analysis of whole slides.

Virtual Microscopy in Geoscience

T. Berlage, J. Bornemeier

In collaboration with Fraunhofer FIT, an automated scanning microscope has been developed that is able to scan thin sections of rock automatically in multiple polarization angles. The purpose of the project is to develop a new method to represent these data sets in a more space-efficient manner. For this purpose, changes of a pixel over polarization angles are fitted with a cosine function if possible, as this is what pure crystals embedded in the rock will show. This representation will be suitable both for virtual microscopy (reduced bandwidth) and image processing (natural distinction of differently oriented crystals in contrast to non-polarizing material). The software will be tested in a teaching environment. For this purpose, an interdisciplinary ETS grant with the geo-sciences has been approved.

Other Research Projects

Forum Informatik: Deployment of a Multi-Agent Simulation Platform for Interdisciplinary Research and Teaching

M. Jarke, R. Klamma, M. Brettel (WIN), T. Kron (Institut für Soziologie)

Following up the successfully finished OBIP project we are creating a virtual center for multi-agent simulation together with colleagues from the institutes of engineering and sociology. Goal of the project is the creation and dissemination of knowledge about the multi-agent simulation system Repast within the wider RWTH Aachen University research and teaching community. For this purpose, we are setting up a repository of already existing models and a documentation wiki for the communication of modelling, implementation, and teaching knowledge. In 2012 we also performed a workshop with the help of the ZLW. In the workshop we explored new teaching methods and disseminated first results of the project. Within the workshop two interdisciplinary theses were finished. A master thesis dealt with the multi-agent simulation of entrepreneurial decision making processes (causal vs. effectual) based on different network topologies of the entrepreneurial networks. A bachelor thesis was simulating the effects of ethno-nationalist conflicts in the Balkan wars in the 90s.

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.

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

M. Jarke, D. Renzel, 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.

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.

Other Activities

Service

Thomas Berlage served as a reviewer for the french Agence Nationale de Recherche for their excellence initiative "investissements d'avenir" in the 2011 Bioinformatics call.

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

Michael Derntl served as external reviewer for the “Veni” grants, Netherlands Organization for Scientific Research (NWO). He also served as reviewer for the Promotion Committee at School of Computing and Information Systems at Athabasca University, Canada. He was member of the Doctoral Consortium at the 7th European Conference on Technology Enhanced Learning (EC-TEL 2012). He also coordinates the thesis seminar series at i5.

Matthias Jarke’s major service activities in 2011-2012 included

- 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 Speaker, B-IT Research School
- Inaugural Dean, Applied Information Technology, German University of Technology in Oman (GUtech)
- 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
- Member, CeBIT-Messeausschuss
- Member, Industrie 4.0 Working Group of BMBF and BMWi Germany
- Member, Working Group on Reference Data Set, Wissenschaftsrat Germany
- Jury, Wissenschaftspreis Stifterverband der Deutschen Wirtschaft
- Chairman, ASIIN review group for University of Potsdam and Hasso-Plattner-Institute

Within the RWTH Future Concept “RWTH-2020”, Prof. Jarke was so-responsible for the activity “International Recruiting”.

Nils Jeners is member of the executive committee of the Fachgruppe CSCW (Computer-Supported Cooperative Work) der GI (Gesellschaft für Informatik).

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. In WS 11/12 he held a guest professorship at Universidad Carlos III de

Madrid, Spain. He founding member of the European Association on Technology Enhanced Learning (EATEL). He served as external reviewer for a PhD at UPM, Madrid, Spain.

Wolfgang Prinz is member of the executive committee of the Fachgruppe CSCW (Computer-Supported Cooperative Work) der GI (Gesellschaft für Informatik).

Wolfgang Prinz is Editor of *i-com Zeitschrift für interaktive und kooperative Medien*, Oldenbourg Verlag.

Wolfgang Prinz is Editor of the CSCW Journal, Springer.

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 continued to be manager of the *i** Wiki.

Thomas Rose acted as reviewer for funded EU projects on “ICT for Energy and Water Efficiency” for the European Commission after serving as evaluation expert for EU Project Proposals on "ICT for Energy and Water Efficiency in Public Housing" in 2010/11.

Editorial Boards

Michael Derntl served as an executive reviewer for the following journals: *Educational Technology & Society*. He also served as a peer reviewer for the *IEEE Transactions on Learning Technologies*, *Educational Technology Research & Development*, and the *Journal of Research and Practice in Information Technology*.

Sandra Geisler is a member of the editorial board of the *International Journal of e-Healthcare Information Systems (IJe-HIS)*.

Matthias Jarke serves on the editorial boards of the following journals: *ACM Transactions on Management Information Systems (ACM-TMIS)*, *Decision Support Systems*, *Group Decision and Negotiation*, *Information Systems Modeling and Design*, *Wirtschaftsinformatik/ Business Information Systems Engineering*, *Journal of Intelligent Information Systems*, *Requirements Engineering Journal*, *Journal of Universal Computer Science (J. UCS, co-editor in chief)*.

Ralf Klamma serves as associate editor for *IEEE Transactions on Learning Technologies (TLT)*, *Springer Journal on Social Network Analysis and Mining (SNAM)*, and *IJTEL*. 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 special issues for *IJTEL* and for *ComSIS Journal*. 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 *World Wide Web Journal (WWWJ)*, *IEEE Transactions on Learning Technologies (TLT)*, *Multimedia Tools and Applications (MTAP)*, *Journal of Networks and Applications (JNCA)*, *Journal of Universal Computer Science (JUCS)*, *Information Systems Frontiers (ISF)*, *Künstliche Intelligenz (KI)*, *Educational Technology & Society (IFETS)*, *ACM Journal on Computers and Cultural Heritage (JOCCH)*, *Journal of Computer Science and Technology (JCST)*, and *International Journal on Cooperative Information Systems (IJCIS)*.

Milos Kravcik serves on the editorial board of the *International Journal of Technology Enhanced Learning*. He is executive peer-reviewer of the *Journal of Educational Technology & Society* and reviewed also submissions for two books (*Serious Games for Healthcare*,

Technological and Social Environments for Interactive Learning) and four journals (Educational Technology Research and Development, IEEE Transactions on Learning Technologies, Transactions on the Web, Journal on Computing and Cultural Heritage).

Zinayida Petrushyna becomes an editor of the special issue on “Learning Analytics” for the International Journal of Technology Enhanced Learning.

Christoph Quix served as a reviewer for Data & Knowledge Engineering, the Journal of Web Semantics, the Journal of Web Engineering, and the World Wide Web Journal.

Dominik Renzel continued to serve as reviewer for the International Journal on Multimedia Tools and Applications (MTAP).

Thomas Rose has been Programme Committee member of the workshop for "IT-support of rescue forces", GI conference 2012, Braunschweig and a Programme Committee member of the workshop for "Standard Operating Procedures for Health Care", GI conference 2012, Braunschweig.

Conference Organization

Yiwei Cao was panel co-chair of 11th International Conference on Web-based Learning (ICWL'12). She was program committee member of 8th International Workshop on MOBILE and NETWORKING Technologies for social applications (MONET'12), COMPLEX'12, CONTENT'12, ICST'12, CTUW'12, DEXA'12, IMCIC'12, Mobile Learning'11 (ML'12), and IEEE Mobile Cloud 2013. Yiwei Cao was also reviewer for International Journal on Multimedia Tools and Applications (MTAP), CSCS Journal, Elsevier Journal of Pervasive and Mobile Computing (JPMC), Elsevier Journal of Systems and Software (JSS), ACM Intelligent Tutoring and Coaching Systems (TIST), and Elsevier Journal of Tourism Management (JTMA).

Michael Derntl was programme committee member of the following conferences: 7th European Conference on Technology Enhanced Learning (EC-TEL 2012), 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), 4th IEEE International Conference on Technology for Education (T4E 2012), 4th International Conference on Games and Virtual Worlds for Serious Applications (VS-Games 2012), 11th International Conference on Web-Based Learning (ICWL 2012), the Doctoral Consortium of EC-TEL 2012, and 20th International Conference on Computers in Education (ICCE 2012). He co-organized a workshop at the JTEL Summer School 2012.

Sandra Geisler and Christoph Quix organized the International Workshop on Information Management in Mobile Applications (IMMoA) at the International Conference on Very Large Databases (VLDB) in Istanbul, Turkey.

Matthias Jarke was co-organizer of the Dagstuhl Seminar “Requirements Management – New Challenges and Approaches”. He was also program committee member of the following conferences: SE 2012 (Berlin) and SE 2013 (Aachen), CAiSE 2012 (Gdansk), REFSQ 2012 (Essen), ER 2012 (Florence)

Nils Jeners co-chaired the 3rd Workshop „Kollaboratives Arbeiten an Interaktiven Displays – Gestaltung, Bedienung und Anwendungsfelder“ of the Mensch & Computer 2012.

Nils Jeners served on the program committee of the 1st International Workshop on Socially Intelligent Computing (SINCOM 2012) of the OnTheMove OTM Federated Conferences and Workshops.

Ralf Klamma was PC co-chair of the following events: International Conference on Web-based Learning (ICWL'12), Sinaia, Romania, tutorial chair for the 2012 International Conference on Advances in Social Network Analysis and Mining (ASONAM 2012), PhD advisory chair at the JTEL Summer School in Technology Enhanced Learning, Estoril, Portugal, May 2011, and PC co-chair of the International Workshop on Pedagogically Driven Serious Games (PDSG'12), Saarbrücken, Germany, September 2012. He served as program committee member / reviewer for the following conferences: ACM Symposium on Applied Computing (SAC'12), Designing Interactive Systems (DIS'12), IFIP Conference on Open and Social Technologies for Networked Learning (OST'12) 11th IEEE International Conference on Advanced Learning Technologies (ICALT'12), IEEE - Engineering Education (EDUCON'12), IEEE American Control Conference (ACC'12), IEEE/FTRA International Conference on Multimedia and Ubiquitous Engineering (MUE'12), Wirtschaftsinformatik'13, International Symposium on Collaborative Technologies and Systems (CTS'12), Communities & Technologies'13, International Conference on Web-based Learning (ICWL'12), European Conference on Technology Enhanced Learning (EC-TEL'12), International Conference on Ambient Systems, Networks and Technologies (ANT'12), IEEE Conference on Decision and Control and European Control Conference (IEEE CDC-ECC'12), IEEE International Conference on Technology for Education (T4E'12), International Conference on Signal Image Technology & Internet Based Systems (ACM/IEEE SITIS'12), GI-Workshop Digital Social Networks (GI-DSN'12), International Conference on Social Computing and its Applications (SCA'12), Conference on Learning Analytics & Knowledge (LAK'12), International Conference on MultiMedia Modeling (MMM'12), Workshop Business Process Management and Social Software (BPMS2'12), Interactive Computer Aided Learning (ICL'12), Simposio Internacional de Informática Educativa (SIIE'12), I-KNOW'12, CRIWG Conference on Collaboration and Technology (CRIWG'12), Workshop Computer-based Knowledge & Skill Assessment and Feedback in Learning Settings (CAF'12), Workshop on Text Information Retrieval (TIR'12), International Workshop on Social Knowledge Discovery and Utilization (SKDU'12), Workshop on Personalization Approaches in Learning Environments (PALE'12), Workshop on Socially Intelligent Computing (SINCOM'12), International Workshop on Social Computing, Network, and Services (SocialComNet'12), Workshop on Business Applications of Social Network Analysis (BASNA'12), International Workshop on evidenced-based Technology Enhanced Learning (ebTEL'12), Workshop on Bootstrapping Learning Analytics (BLA'12), International Workshop on Enabling Successful Self-Regulation in Open Learning Environments (S-ROLE'12), Workshop on Semantic Models for Adaptive Interactive Systems (SEMAIS'12), Workshop on Data Management in the Cloud (DMC'13).

Milos Kravcik co-organized 8th Joint European Summer School on Technology Enhanced Learning (JTEL 2012), International Workshop on Enabling Successful Self-Regulation in Open Learning Environments (S-ROLE 2012 at ICALT), and 2nd Workshop Personalization Approaches in Learning Environments (PALE 2012 at UMAP). He was programme committee member of the following conferences and workshops: 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), IFIP Conference Open and Social Technologies for Networked Learning (OST 2012), 20th conference on User Modeling, Adaptation and Personalization (UMAP 2012), 11th International Conference on Web-based Learning (ICWL 2012), 7th European Conference on Technology Enhanced Learning (EC-TEL 2012) and its Doctoral Consortium, International Conference in Games and Virtual Worlds for Serious Applications (VS-Games 2012), 39th International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM 2013), 4th International Workshop on Social and Personal Computing for Web-Supported Learning Communities (SPeL 2011), 1st International Workshop on Pedagogically-driven Serious

Games, and 2nd Workshop on Awareness and Reflection in Technology-Enhanced Learning (ARTEL 2012) at EC-TEL 2012.

Karl-Heinz Krempels was program chair of the 8th International Conference on Web-Information Systems and Technologies (WEBIST'12). He was program committee member of 7th International Joint Conference on Computational Intelligence (ECTA'12)

Zinayida Petrushyna was a program committee member of the 7th European Conference on Technology Enhanced Learning (EC-TEL 2012) and IADIS e-Learning 2012. She organized the Workshop "Presentation Skills" during the 8th Joint European Summer School on Technology Enhanced Learning (JTEL 12).

Wolfgang Prinz co-chaired the 1st International Workshop on Socially Intelligent Computing (SINCOM 2012) of the OnTheMove OTM Federated Conferences and Workshops. He is currently is Program chair of the 6th International Conference on Communities and Technologies 2013, Munich.

Christoph Quix was a member of the program committee of the 31st International Conference on Conceptual Modeling (ER 2012), of the 28th International Conference on Data Engineering (ICDE 2012), and of the 11th International Conference on Ontologies, DataBases, and Applications of Semantics (ODBASE 2012).

Dominik Renzel organized the Workshops "How to Build & Develop Responsive Open Learning Environments with the ROLE SDK" during the 8th Joint European Summer School on Technology Enhanced Learning (JTEL 12) and the Dev8eD 2012 conference. He also co-chaired the third ROLE Developer Camp 2011 in Leuven, Belgium.

Thomas Rose organized as workshop co-chair the workshop on "Standard Operating Procedures for Health Care", GI conference 2012, Braunschweig.

Christoph Terwelp served as a reviewer the 8th International Conference on Web-Information Systems and Technologies (WEBIST'12).

Software Demonstrations

ROLE Interwidget Communication. 3rd ROLE Developer Camp, November 29, 2011, Leuven, Belgium

Interwidget Communication with XMPP. FOSDEM 2012, Jabber/XMPP DevRoom, February 4, 2012, Brussels, Belgium

ROLE Technologies – A possible contribution to Apache Rave? Apache Rave Meetup NL, June 13, 2012, Utrecht, NL.

YouTell, 2st GaLA Alignment School, Carcavelos, Portugal, June 25, 2012

Virtual Campfire, UMIC Day 2011, Aachen, Germany, October 19, 2011

Talks and Publications

Talks

Y. Cao: Learning Analytics for Learning Blogospheres. ICWL 2012, Sinaia, Romania, September 2, 2012.

Y. Cao: Learning Analytics - Social Network Analysis for Learning Communities. CELSTEC Learning Networks Seminar Series, Heerlen, the Netherlands, April 17, 2012.

Y. Cao: Opening Speech. ICWL 2011, Hong Kong, China, December 8, 2011.

M. A. Chaudhary: Mobile-to-Mobile multimedia streaming using REST-based mobile services. International Conference on Multimedia Computing and Systems (ICMCS), 2012, Tangier Morocco, May 11, 2012

M. Derntl: *The European TEL Projects Community from a Social Network Analysis Perspective*. 7th European Conference on Technology Enhanced Learning (EC-TEL 2012), Saarbrücken, Germany, September 20, 2012

M. Derntl: *An embeddable dashboard for widget-based visual analytics on scientific communities*. 12th International Conference on Knowledge Management and Knowledge Technologies (I-KNOW 2012), Graz, Austria, September 5, 2012

M. Derntl: *Interactions for Learning as Expressed in an IMS LD Runtime Environment*. 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), Rome, Italy, July 5, 2012

M. Derntl: *Social Network Analysis of European Project Consortia to Reveal Impact of Technology-Enhanced Learning Projects*. 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), Rome, Italy, July 5, 2012

M. Derntl: *Interactive Storytelling*. 2nd GaLA Alignment School, Carcavelos, Portugal, June 25, 2012

M. Derntl: *The European Technology Enhanced Learning Landscape*. 8th Joint European Summer School on Technology Enhanced Learning, Estoril, Portugal, May 22, 2012

M. Derntl: *Basics of Paper Writing and Publishing in Technology Enhanced Learning*. 8th Joint European Summer School on Technology Enhanced Learning, Estoril, Portugal, May 22, 2012

S. Geisler: An Ontology-based Data Quality Framework for Data Stream Applications. 16th International Conference on Information Quality, November 2011, Adelaide, Australia.

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

M. Jarke: *From ICT Research to Innovation and Back*. Australian-German CSIRO-Fraunhofer Workshop, Berlin, 12.3.2012; also German-Korean Workshop, Birlinghoven Castle, 26.3.2012

N. Jeners, Analyzing Tie-Strength across Different Media. Workshop “Workshop on Socially Intelligent Computing (SINCOM 2012)”, Rome, August 14, 2012

R. Klamma: *Learning Analytics in a Mobile World*, Invited Talk, Leganes, Spain, e-Madrid Seminar, March 16, 2012

- R. Klamma: *The Social Requirements Engineering (SRE) Approach to Developing a Large-scale Personal Learning Environment Infrastructure*, Saarbrücken, Germany, EC-TEL 2012, September 21, 2012
- R. Klamma: *Community Analytics – An Information Systems Perspective*, Keynote, Raesfeld, Germany, CRIWG 2012, September 17, 2012
- M. Kravcik: *Adaptive Mobile Micro-Learning Analytics*. DFG Meeting, Darmstadt, Germany, June 11, 2012
- M. Kravcik: *ROLE Project*. 2nd GaLA Alignment School, Carcavelos, Portugal, June 27, 2012
- M. Kravcik: *Supporting Self-Regulation by Personal Learning Environments*. 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), Rome, Italy, July 6, 2012
- M. Kravcik: *Supporting Self-Reflection in Personal Learning Environments Through User Feedback*. 2nd International Workshop on Personalization Approaches in Learning Environments (PALE), held in conjunction with the 20th International Conference on User Modeling, Adaptation, and Personalization (UMAP2012), Montreal, Canada, July 17, 2012
- D. Kovachev, Cuong Manh Pham: *Enhancing Academic Event Participation with Context-aware and Social Recommendations*. ASONAM 2012, Istanbul, Turkey, August 28, 2012.
- D. Kovachev: *Learn-as-you-go: New Ways of Cloud-based Micro-learning for the Mobile Web*. ICWL 2011, Hong Kong, December 8, 2011.
- D. Kovachev: *Adaptive Computation Offloading from Mobile Devices into the Cloud*. MUE 2012, Madrid, Spain, July 11, 2012.
- D. Kovachev: *Beyond the Client-Server Architectures: A Survey of Mobile Cloud Techniques*. IEEE ICC 2012, Beijing, China, August 15, 2012.
- M.C. Pham: *Learning Analytics in a Teachers' Social Network*. Eighth International Conference on Networked Learning (NLC 2012), Maastricht, the Netherlands, April 2-4, 2012
- C. Quix: GeRoMe: Ein generischer Ansatz zur Verwaltung von komplexen, heterogenen Datenmodellen. Informatik-Kolloquium, RWTH Aachen University, April 20, 2012.
- X.Li: *Merging Relational Views: A Minimization Approach*. 30th Int. Conference on Conceptual Modeling (ER 2011), Brussels, Belgium, Oct 31-Nov 3, 2011
- W. Prinz, Trends im Mobile Entertainment, ECO Mobile Games Conference, 7.12.11, Cologne
- W. Prinz, Key Note "Soziale Medien und ihre Wirkung auf den Arbeitsplatz von morgen", CISCO CIO Roundtable, 22.3.12, Hannover
- W. Prinz, Zukunft der Arbeit: Social Media im Unternehmen, eLearning Conference Tour 2012, 2.5.12, Cologne
- W. Prinz, Grundprinzipien von Social Media und ihre Rolle in der internen Unternehmenskooperation, Riffelalper Managementtage, 29.8.2012, Zermatt
- W. Prinz, From Groupware to Social Media - A Comparison of Conceptual Models. PRO-VE, 13th IFIP Working Conference on Virtual Enterprises, 3.10.2012, Bournemouth

W. Prinz, Next Generation Workplace Media, Wirtschaftswoche Konferenz, Enterprise Collaboration & Communication, 26.11.12, Frankfurt

D. Renzel: *Interwidget Communication with XMPP*. FOSDEM 2012, Jabber/XMPP DevRoom, Brussels, Belgium, February 4, 2012

D. Renzel: *ROLE Technologies – A possible contribution to Apache Rave?* Apache Rave Meetup, Utrecht, NL, June 13, 2012

T. Rose has presented to the City Council of Rösrath the “IT-Vision for Multiple Use of School Facilities”

T. Rose: The Myth of Business Process Modelling for Emergency Management Planning, 9th ISCRAM, Vancouver, BC, April 2012

T. Rose: Cross-organizational Preplanning in Emergency Management with IT-supported Smart Checklists, Future Security 2012, Bonn, September 2012

Publications

Books and Edited Volumes

Dina Barner, Shirley Beul, Uta Christoph, Eva-Maria Jakobs, Karl-Heinz Krempels (eds.): Context Aware Intermodal Routing. Nutzerzentrierte Entwicklung eines mobilen Fahrgastinformationssystems. Apprimus Wissenschaftsverlag, 2011.

Stefano Bocconi, Ralf Klamma, Yulia Bachvarova (eds.): Proceedings of the 1st International Workshop on Pedagogically-driven Serious Games (PDSG 2012), Saarbrücken, Germany, September 18, 2012, vol. 898, CEUR Workshop Proceedings (2012)

Yiwei Cao: Uncertainty Handling in Mobile Community Information Systems, Dissertation, RWTH Aachen University, 2012

Jessica Huster: Prozessanalyse und Ontologieevolution in kreativen, dynamischen Domänen. Dissertation, RWTH Aachen University 2012 (Shaker-Verlag, Informatik Series)

Karl-Heinz Krempels, José Cordeiro (eds.): WEBIST 2012 - Proceedings of the 8th International Conference on Web Information Systems and Technologies, Porto, Portugal, 18 - 21 April, 2012. SciTePress 2012.

Howard Leung, Elvira Popescu, Yiwei Cao, Rynson Lau, Wolfgang Nejdl (eds.): Advances in Web-Based Learning - ICWL 2011, Proceedings of 10th International Conference on Web-Based Learning, Hong Kong, December 2011, Springer LNCS 7048.

Xiang Li: Constraint-driven schema integration. Dissertation, RWTH Aachen University, 2012

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

Elvira Popescu, Ling Qi, Ralf Klamma, Howard Leung, Marcus Specht (eds.): Advances in Web-based Learning - ICWL 2012, Proceedings 11th International Conference, Sinaia, Romania, September 2-4, 2012, Springer LNCS 7558

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, CEUR-WS.org/Vol-732/

Journal Articles

Buchholz, Hagen; Prinz, Wolfgang: Der Digitale Untersetzer – Änderung des Trinkverhaltens durch Reflexion, i-com Zeitschrift für interaktive und kooperative Medien, Themenschwerpunkt Persuasive Technologies, 2, 2012

Mohamed Chatti, Ulrik Schroeder, Matthias Jarke: LaaN – Convergence of Knowledge Management and Technology-Enhanced Learning. IEEE Transactions on Technology-Enhanced Learning 5, 2 (2012): 177-189

Michael Derntl, Ralf Klamma: A Mediabase for Technology Enhanced Learning in Europe. IEEE Learning Technology Newsletter, 14 (3):2-5 (2012)

Michael Derntl, Susanne Neumann, David Griffiths, Petra Oberhuemer: The Conceptual Structure of IMS Learning Design Does Not Impede Its Use for Authoring. IEEE Transactions on Learning Technologies, 5(1):74-86 (2012)

Sandra Geisler, Christoph Quix, Stefan Schiffer, Matthias Jarke: An Evaluation Framework for Traffic Information Systems Based on Data Streams. Transportation Research Part C, Special Issue on Data Management in Vehicular Networks, vol. 23, August 2012, 29–55.

Anna Hannemann, Ralf Klamma, Matthias Jarke: Soziale Interaktion in Open-Source-Communitys. Open Source - Konzepte, Risiken, Trends, Praxis der Wirtschaftsinformatik, HMD 283, 49. Jahrgang (2012)

Manh Cuong Pham, Michael Derntl, Ralf Klamma: Development Patterns of Scientific Communities in Technology Enhanced Learning. Educational Technology & Society, 15(3): 323-335 (2012)

Dejan Kovachev, Yiwei Cao, Ralf Klamma: Building Mobile Multimedia Services: A Hybrid Cloud Computing Approach. Journal of Multimedia Tools and Applications, Special issue on Multimedia on the Web, Springer (2012)

Wolfgang Prinz, Sabine Kolvenbach: From Groupware to Social Media – Extending an Existing Shared Workplace System with Social Media Features, it – Information Technology, 5, 2013, 228-234

Khaled Rashed, Dominik Renzel, Ralf Klamma, Matthias Jarke: Community and trust-aware fake media detection. Journal of Multimedia Tools and Applications, Special issue on Multimedia on the Web, Springer (2012)

Katrien Verbert, Xavier Ochoa, Michael Derntl, Martin Wolpers, Abelardo Pardo, Erik Duval: Semi-automatic assembly of learning resources. Computers & Education, 59(4), 1257-1272 (2012)

Conference, Book Contributions, Patents

M. A. Chaudhary: Mobile-to-Mobile multimedia streaming using REST-based mobile services. International Conference on Multimedia Computing and Systems (ICMCS), 2012, Tangier Morocco, May 11, 2012

Michael Derntl, Ralf Klamma: Social Network Analysis of European Project Consortia to Reveal Impact of Technology-Enhanced Learning Projects. Proceedings of 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), European Projects Track, Rome, Italy, pp. 746-747 (2012)

Michael Derntl, Susanne Neumann, Petra Oberhuemer: Interactions for Learning as Expressed in an IMS LD Runtime Environment. Proceedings of 12th IEEE International

Conference on Advanced Learning Technologies (ICALT 2012), Rome, Italy, pp. 383-387 (2012)

Michael Derntl, Ralf Klamma: The European TEL Projects Community from a Social Network Analysis Perspective. In A. Ravenscroft et al. (Eds.): 21st Century Learning for 21st Century Skills - 7th European Conference of Technology Enhanced Learning, EC-TEL 2012, Saarbrücken, Germany, LNCS vol. 7563, pp. 51-64, Springer Verlag (2012)

Michael Derntl, Stephan Erdtmann, Ralf Klamma: An Embeddable Dashboard for Widget-Based Visual Analytics on Scientific Communities. Proceedings of 12th International Conference on Knowledge Management and Knowledge Technologies, I-KNOW '12. ACM Press (2012)

Michael Derntl, Susanne Neumann, Petra Oberhuemer: Opportunities and Challenges of Formal Instructional Modeling for Web-based Learning. Advances in Web-Based Learning - ICWL 2011, Proceedings of 10th International Conference, Lecture Notes in Computer Science, vol. 7048, pp. 253-262, Springer Verlag (2011)

Mateusz Dolata, Ibrahim Cakir, Kashyap Todi, and Nils Jeners: From heavyweight framework to lightweight patchwork. In Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work Companion (CSCW '12). ACM, New York, NY, USA, 67-70

Sebastian Franken, Nils Jeners: SurgeryNet - Eine Kooperationsplattform zur individuellen Aus- und Weiterbildung in der Chirurgie. 11. Jahrestagung der Deutschen Gesellschaft für Computer- und Roboterassistierte Chirurgie. CURAC 2012

Sandra Geisler, Sven Weber, Christoph Quix: Ontology-based Data Quality Framework for Data Stream Applications. Proc. of the 16th International Conference on Information Quality, November 2011, Adelaide, Australia.

Nils Jeners, Wolfgang Prinz: From Groupware to Social Media - A Comparison of Conceptual Models. In: Camarinha-Matos, L.M., Xu, L., and Afsarmanesh, H. (eds.) Collaborative Networks in the Internet of Services. pp. 416-423. Springer 2012

Nils Jeners, Petru Nicolaescu, Wolfgang Prinz: Analyzing Tie-Strength across Different Media. In: Herrero, P., Panetto, H., Meersman, R., and Dillon, T. (eds.) On the Move to Meaningful Internet Systems: OTM 2012 Workshops. pp. 554-563. Springer (2012)

Roland Klemke, Milos Kravcik: Open 3D Environments for Competitive and Collaborative Educational Games. Proceedings of the 1st International Workshop on Pedagogically-driven Serious Games (PDSG 2012) in conjunction with the Seventh European Conference on Technology Enhanced Learning (EC-TEL 2012), Saarbrücken (Germany), September 2012

Florian Klomp maker, Karsten Nebe, Nils Jeners: Kollaboratives Arbeiten an Interaktiven Displays – Gestaltung, Bedienung und Anwendungsfelder , Workshop, M&C 2012, Konstanz

Dejan Kovachev, Yiwei Cao, Ralf Klamma, Matthias Jarke: Learn-as-you-go: New Ways of Cloud-based Micro-learning for the Mobile Web. Advances in Web-Based Learning - ICWL 2011, Proceedings of 10th International Conference, Lecture Notes in Computer Science, Hong Kong, LNCS vol. 7048, pp. 51-61, Springer Verlag (2011)

Dejan Kovachev, Tian Yu, Ralf Klamma: Adaptive Computation Offloading from Mobile Devices into the Cloud. Proceedings of the 6th International Conference on Multimedia and Ubiquitous Engineering (MUE 2012), Madrid, Spain, IEEE (2012)

Dejan Kovachev, Ralf Klamma: Beyond the Client-Server Architectures: A Survey of Mobile Cloud Techniques. Proceedings of the 2012 IEEE Workshop on Mobile Cloud Computing

(MobiCC'12) held in conjunction with the 1st IEEE International Conference on Communications in China (ICCC'12), Beijing, China, IEEE (2012)

Milos Kravcik, Ralf Klamma: Supporting Self-Regulation by Personal Learning Environments. Proceedings of the 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), Rome, Italy, 710-711, IEEE Computer Society

Milos Kravcik, Olga C. Santos, Jesus G. Boticario, Diana Perez-Marin: Proceedings of the 2nd International Workshop on Personalization Approaches in Learning Environments (PALE), held in conjunction with the 20th International Conference on User Modeling, Adaptation, and Personalization (UMAP 2012), Montreal, Canada, July 17th, 2012. CEUR Workshop Proceedings (2012)

Effie L-C. Law, Arunangsu Chatterjee, Dominik Renzel, Ralf Klamma: The Social Requirements Engineering (SRE) Approach to Developing a Large-Scale Personal Learning Environment Infrastructure. In A. Ravenscroft et al. (Eds.): 21st Century Learning for 21st Century Skills - 7th European Conference of Technology Enhanced Learning, EC-TEL 2012, Saarbrücken, Germany, Springer LNCS 7563, 194-207

Xiang Li, Christoph Quix: Merging Relational Views: A Minimization Approach. Proc. 30th Int. Conference on Conceptual Modeling (ER 2011), Brussels, Belgium, November 2011.

Alexander Nussbaumer, Milos Kravcik, Dietrich Albert: Supporting Self-Reflection in Personal Learning Environments Through User Feedback. In M. Kravcik, O.C. Santos, J.G. Boticario, D. Perez-Marin (Eds.) Proc. 2nd International Workshop on Personalization Approaches in Learning Environments (PALE), held in conjunction with UMAP2012, Montreal, Canada, July 2012. CEUR Workshop Proceedings (2012)

Alexander Nussbaumer, Marcel Berthold, Daniel Dahrendorf, Hans-Christian Schmitz, Milos Kravcik, Dietrich Albert: A Mashup Recommender for Creating Personal Learning Environments. In E. Popescu et al. (Eds.): ICWL 2012, Springer LNCS 7558, 79–88, 2012

Alexander Nussbaumer, Maren Scheffel, Katja Niemann, Milos Kravcik, Dietrich Albert: Detecting and Reflecting Learning Activities in Personal Learning Environments. Proceedings of the 2nd Workshop on Awareness and Reflection in Technology-Enhanced Learning (#artel12) held in conjunction with EC-TEL 2012, Saarbrücken, Germany, (2012)

Sarah Leon Rojas, Nils Jeners, Uwe Kirschenmann: Analyse sozialer Beziehungen anhand nonverbaler Signale im IM-Chat. In: Reiterer, H. and Deussen, O. (eds.) Mensch & Computer. pp. 103–112. Oldenbourg Verlag (2012)

G. Peinel, T. Rose, A. Wollert (2012). The Myth of Business Process Modelling for Emergency Management Planning, *Proc. 9th ISCRAM Conference*, Vancouver, BC.

G. Peinel, T. Rose, A. Wollert (2012). Cross-organizational Preplanning in Emergency Management with IT-supported Smart Checklists. In N. Aschenbruck et al. (Eds.): *Future Security 2012, CCIS 318*, Springer-Verlag, 497-508.

Manh Cuong Pham, Michael Derntl, Yiwei Cao, Ralf Klamma: Learning Analytics for Learning Blogospheres. E. Popescu et al. (Eds.): ICWL 2012, Springer LNCS 7558, 255–264

Manh Cuong Pham, Dejan Kovachev, Yiwei Cao, Ralf Klamma: Enhancing Academic Event Participation with Context-aware and Social Recommendations. Proceeding of the 2012 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM 2012), 26-29 August, 2012, Kadir Has University, Istanbul, Turkey. 457-464

Manh Cuong Pham, Yiwei Cao, Zinayida Petrushyna, Ralf Klamma: Learning Analytics in a Teachers' Social Network. In Hodgson, et al. (eds.): Proceedings of the Eighth International Conference on Networked Learning (NLC 2012), Maastricht/NL 2012, 414 – 421

Khaled Rashed, Cristina Balasoiu, Ralf Klamma: Robust Expert Ranking in Online Communities – Fighting Sybil Attacks. Proceedings of the 8th IEEE International Conference on Collaborative Computing: Networking, Applications and Worksharing, CollaborateCom2012, Pittsburgh, Pennsylvania, USA, October 14-17

Khaled Rashed, Dominik Renzel, Ralf Klamma: Trust-aware Media Quality Profiles in Fake Multimedia Detection. Proceedings of the International Workshop on Multimedia on the Web, in conjunction with i-Know and i-Semantics 2011, 7–9 September, Graz, Austria, pp. 27-32, IEEE Computer Society (2011)

Olga C. Santos, Milos Kravcik, Diana Perez-Marin: Personalization Approaches in Learning Environments. In L. Ardisson and T. Kuflik (Eds.): UMAP 2011 Workshops, LNCS 7138, pp. 117–121. Springer Verlag (2012)

Ioana Andreea Stanescu, Antoniu Stefan, Milos Kravcik, Theo Lim, Rafael Bidarra: Interoperability Strategies for Serious Games Development. In: Leveraging Technology for Learning, Proceedings of the 8th International Scientific Conference "eLearning and Software for Education", Bucharest, April 26 - 27, (2012)

Wolfgang Thomas, Matthias Jarke: Die Informatik und ihre beiden Kulturen. In H. Müller, F. Eßer (eds.): Wissenskulturen – Bedingungen wissenschaftlicher Innovation. Kassel University Press, 116-126 (2012)

Riina Vuorikari, Adriana Berlanga, Romina Cachia, Yiwei Cao, Sibren Fetter, Anne Gilleran, Ralf Klamma, Yves Punie, Santi Scimeca, Peter Sloep, Zinayida Petrushyna: *ICT-Based School Collaboration, Teachers' Networks and their Opportunities for Teachers' Professional Development - A Case Study on eTwinning*. Advances in Web-Based Learning - ICWL 2011, Proceedings 10th Intl. Conf., Hong Kong, 2011, Springer LNCS 7048, 112-121

Other Publications

Arunangsu Chatterjee, Effie Law (eds.), Dominik Renzel, Sten Govaerts, Evgeny Bogdanov, Na Li, Freddy Limpens, Daniel Dahrendorf, Dianna Dikke, Manuel Schmidt, Matthias Palmer, Erik Isaksson, Felix Mödritscher, Alexander Nussbaumer, Marcel Berthold, Alexander Mikroyannidis: Revised Functional and Non-Functional Requirements Analysis and Specifications. ROLE Deliverable D1.5/1.6, January 2012.

Sten Govaerts, Felix Mödritscher, Hans-Christian Schmitz (eds.), Erik Issakson, Freddy Limpens, Matthias Palmér, Dominik Renzel, José Luis Santos, Kerstin Schmidt: Testing and conformance recommendations and tools that support integration and development of new services. ROLE Deliverable D3.5/2.5, January 2012.

Felix Mödritscher (ed.), Dominik Renzel, Erik Isaksson, Matthias Palmer, Alexander Mikroyannidis, Denis Gillet, Na Li, Carsten Ullrich, Kerstin Schmidt, Sten Govaerts, Daniel Dahrendorf, Diana Dikke: Reference implementation of mash-up personal learning environments to foster the broad community uptake. ROLE Deliverable 4.5/7.4, January 2012.

Gabriela Thomasova, Maren Scheffel (eds.), Diana Dikke, Nils Faltin, Sylvana Kroop, Paul Lefrère, Ilse Marschalek, Alexander Mikroannidis, Stefi Moiszi, Alexander Nussbaumer, Dominik Renzel, Hans-Christian Schmitz, Johannes Simon, Martin Wolpers: Promotion

activity of PLS Bundle and Prototype of a Mash-up PLE. ROLE Deliverable D8.4, January 2012.

Freitag, K. (ed.), Derntl, M., Cooper, A., Messagi-Kaya, M.: TEL-Map Portal Analyses and Survey Tools. TEL-Map Deliverable D6.4a, September 2012.

Ebner, H., Naeve, A. (eds.), Derntl, M., Millwood, R., Olivier, B., Pirkkalainen, H.: Supporting Roadmapping in TEL – Core Technical Infrastructure. TEL-Map Deliverable D2.4, July 2012.

Hoel, T. (ed.), Cooper, A., Derntl, M., Freitag, K., Lefrere, P., Giorgini, F., Naeve, A., Stergioulas, L., Wild, F.: Report on engagement, dissemination & awareness results. TEL-Map Deliverable D7.2b, April 2012.

Pirkkalainen, H., Naeve, A. (eds.), Pawlowski, J., Ebner, H., Lefrere, P., Garduno, J.L., Derntl, M.: Supporting Discourse Management for TEL-Map Stakeholders. TEL-Map Deliverable D2.3, October 2011.

Manh Cuong Pham, Yiwei Cao, Ralf Klamma: Social Network Analysis Methods for Lifelong Learning Communities. TELLNET Deliverable D2.2, May 2012.

Awards

M. Derntl: Best full paper award at the 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012) for the paper “Interactions for Learning as Expressed in an IMS LD Runtime Environment” (external co-authors: S. Neumann, P. Oberhuemer)

M. Kravcik: Best paper award at the 11th International Conference on Web-based Learning (ICWL 2012) for the paper “A Mashup Recommender for Creating Personal Learning Environments” (external co-authors: A. Nussbaumer, M. Berthold, D. Dahrendorf, H.-Ch. Schmitz, D. Albert)

Knowledge-Based Systems & Cognitive Robotics Group



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Gavin Rens, CSIR Meraka Institute
(September 2011 – September 2012)

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 recently finished project, funded by the German Science Foundation (DFG) and in collaboration with the University of Freiburg, we investigated the integration of Golog with state-of-the-art planning systems. In collaboration with Prof. Wagner from Biology with funding from AFR (Luxemburg) we are developing biologically inspired methods sound-source localization suitable for mobile robots. Moreover, we just started work on two new projects in the context of the DFG Research Unit FOR 1513 Hybrid Reasoning for Intelligent Systems, with seven partners from five universities headed by our group. The two projects are concerned with the verification of non-terminating action programs and planning and action control under uncertainty for mobile manipulation tasks, respectively.

Research Projects

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 funding from the German National Science Foundation (DFG) in the Priority Program “Cooperative multi-robot teams in highly dynamic domains” and the Ministry for Science of North-Rhine Westphalia, Germany (MSWF) we developed five robots and participate in RoboCup Championships with these robots for several years now. RoboCup is an international research initiative to foster research and education in the field of artificial intelligence and robotics. The common problem is to develop autonomous soccer playing robots (www.robocup.org).

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

The “AllemaniACs” RoboCup Team 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 homelike 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.

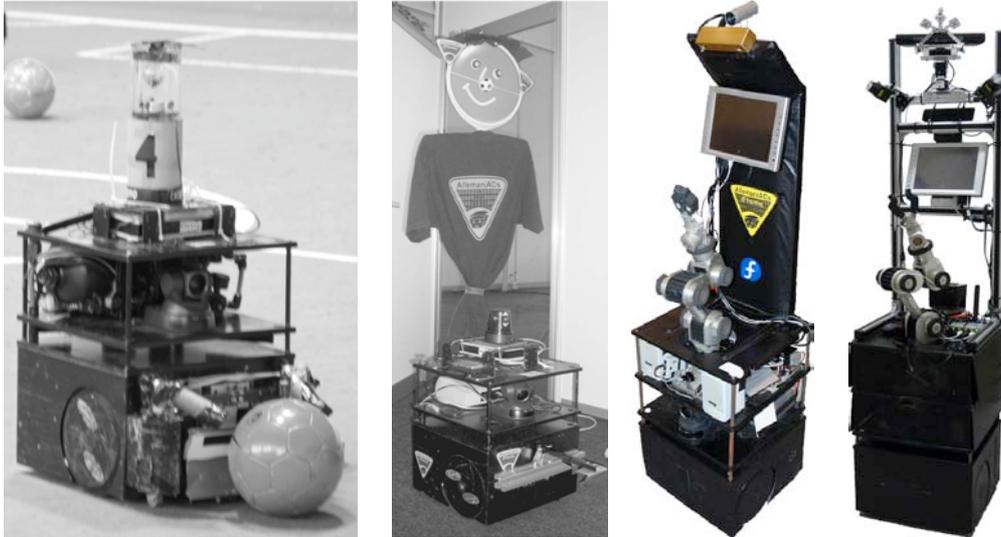


Figure 1: The pictures above illustrate the adaptation of the former soccer robot (left) to the requirements of the @Home league (center, 2006, and right, 2009 and 2011).

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.

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.

Towards a sound localization unit for service robots

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

The goal of my project is to improve localization in acoustically cluttered environments, and to isolate speech from other signals.

During the second year of the project, we were able to complete some of the work units that were started in the course of the first year. We submitted a first version of our article on side peak suppression as a function of different spectral compositions of the input signal. The reviewers suggested to compare the results to an additional, more analytical approach to side peak suppression, which we are currently working on in cooperation with the institute of mathematics 1. We have completely restructured and rewritten most of the article and added new data. The cooperation also yielded a number of interesting predictions about the scaling behavior of side peaks suppression and half-width. The article will be resubmitted in the near future.

Two diploma theses investigated a gammatone filter bank and speech detection, respectively. As a benefit of the implementation of our localization system on a GPU we are now able to not only segregate the input signal into an arbitrary number of frequency bands, but also to keep the computational costs of the vastly increased complexity of our system at bay. The number of parallel computations are only restricted by the graphics hardware. In our case, we are able to process 64 frequency bands in parallel and in real time. With our current localization algorithm we were, however, not able to vastly improve the accuracy of our system despite the interaural time difference computation in several frequency bands. This segregation process is, however, necessary for our interaural level difference detection that we are planning to implement in the third phase of the project. In addition to that we also have several ideas how to improve our interaural time difference detection by changing the way the frequency specific cues are merged. The goal will be to further reduce the influence of noise and sound reflections.

The second thesis dealt with speech detection and was based on an open source speech recognition framework developed by the computer science department 6 of the RWTH university. It allowed us to combine several well established techniques in speech recognition to build a simple and efficient speech detection algorithm. The role of a speech detector is to decide whether a certain time frame of the input signal contains speech. The goal of our localization system is to improve the localization of people that try to interact with the service robot. In order to achieve this, the system has to be able to distinguish between speech signals and any other sound sources. Based on mel frequency cepstral coefficients the detector is able to perform this decision process and allows the system to ignore any other signals, and thus to save processing power that may be required for other

processes of the mobile agent. Our system is not speaker specific and, for best results, should be trained with signals that are recorded in the environment of the mobile agent. Results showed that the system was slightly too sensitive to speech as it had a certain amount of false positives. This, however, can be further reduced by optimizing the thresholds of the decision process and by delivering more extensive training databases. Additionally, we have implemented a simple speech detector based on entropy filtering that will be more extensively tested in the coming months. Although less specific for speech signals, it can be employed without any previous training sessions for quick tests in new environments.

Recently we have also acquired a new microphone mount that allows us to perform quick localization tests without the use of the whole mobile robot. With this mount we are planning to extensively test and optimize the current algorithm and future additions.

At the ARO meeting in San Diego we presented the current architecture of our sound localization system on a poster. In addition, we supervised the practical course in animal physiology.

PLATAS – Planning Techniques and Action Languages

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

Although there is a common origin, research on automated planning on the one hand and action logics on the other hand developed rather independently over the last three decades. This is mainly due to the fact that work on action languages was concerned with formalisms of high expressiveness, whereas for planning methods, the focus had to lie on computational efficiency, yielding input languages with less expressive possibilities. However, one can observe that during the last 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 still including 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 appeared in a special issue (volume 26, number 1) of the German AI journal “Kuenstliche Intelligenz” in 2012.

Cooperative Groups of Robots in the RoboCup Logistics League Sponsored by Festo

*Tim Niemuller, Gerhard Lakemeyer, Alexander Ferrein¹, Daniel Ewert², Sebastian Reuter²,
Sabina Jeschke²*

¹ (FH Aachen) ² (IMA/ZLW & IFU, RWTH Aachen University)

In 2012 the Logistics League Sponsored by Festo (LLSF) was officially founded. The general intention is to create a simplified and abstracted factory automation scenario. Teams of up to three robots operate in a fenced area of about 5.6 m × 5.6 m as shown in Figure 2. The task is to complete a production chain by carrying a (semi-finished) product (a puck in the game) along different machines (signal lights on the playing field). Points are awarded for intermediate and completed products.

We cooperate with the IMA/ZLW & IFU of RWTH’s Mechanical Engineering Department, and with the Electrical Engineering Department of the FH Aachen to form the Carologistics RoboCup team to participate in this competition. It provides an interesting benchmark for a robotic supply chain problem. Besides typical robot tasks like self-localization, perception, locomotion, and collision avoidance it poses challenges in planning and dealing with incomplete knowledge and uncertainty. The task may be optimized on multiple levels. A single robot can, for example, minimize the distances to travel and thus production costs. More interesting is the problem when multiple robots need to cooperate and optimize globally for a high production throughput with minimal costs, and possibly time constraints.

This year, we built the foundation and participated in RoboCup 2012 in Mexico City. We will continue our cooperation and tackle the problems of efficient multi-robot action planning and global optimization.

Logic-based Learning Agents

Daniel Beck, Gerhard Lakemeyer

The agent programming language GOLOG allows the specification of so-called partial programs. That means the programmer doesn’t have to provide a completely specified program but might leave certain choices on how to proceed with the program open to the

agent. The objective, then, is to find an execution trace of the partial program that is legal and optimal wrt. an optimization theory in the current situation.

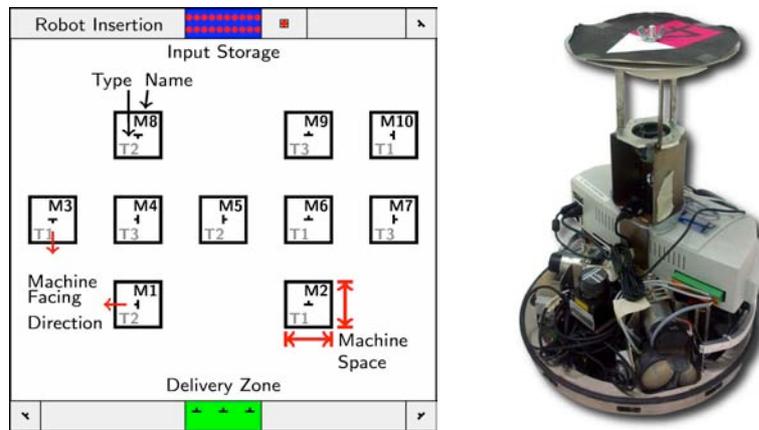


Figure 2: The left figure depicts the LLSF playing field, the right the modified Robotino robot of the Carolistics RoboCup team.

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.

In case the complete model is given the same abstraction techniques we used for reinforcement learning can be employed to compute an optimal plan for a nondeterministic program. 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.

The abstraction techniques referred to in the previous paragraphs basically group ground states which have certain similarities regarding the execution of the remaining program. In particular these groups of ground states are described by first-order formulas which can be derived for any program. For programs containing loops we discovered that in certain cases there is a pattern describing what these formulas look like for n , $n + 1$, $n + 2$, ... iterations through the loop. In our ECAI-paper we presented a new, recurrent data structure that explicitly represents those patterns and thus allows a concise representation of the abstract states—even for programs with loops with arbitrary many iterations through the loop. Previously the maximal number of loop iterations had to be limited.

The Computability of Projection in Dynamic Knowledge Bases

Vaishak Belle, Gerhard Lakemeyer

The problem of projection has been identified as a fundamental reasoning concern in dynamical domains, where we are to determine whether or not some conditions will hold after a sequence of actions has been performed starting in some initial state. Solving the problem requires, at the very least, effectively reasoning about how actions transform the world, and inferring the logical consequences of the initial knowledge base (KB). For various reasons, tractability one of them, applications often make the closed-world assumption, thereby limiting the scope of these systems for the real world.

In this project, using the language of the situation calculus, we investigate the computational properties of a number of unsolved reasoning tasks in the context of projection with incomplete information. We first look at inherently incomplete KBs, where the information provided to the agent may not determine every fact about the world. Projection, then, may involve reasoning about what is believed and also, about what is not believed. We then look at physical agents with unreliable hardware, as a result of which actions lead to certain kinds of incomplete knowledge. Intuitively, beliefs should be (periodically) synchronized with this noise. Finally, we consider the presence of other agents in the environment, whose beliefs may differ arbitrarily, and the formalism should incorporate what others sense and learn during actions.

To enable a precise mathematical treatment of incomplete KBs, we appeal to a seminal proposal by Levesque, called *only knowing*. Building on existing work, we investigate projection wrt extensions to the situation calculus for *only knowing*, noisy hardware and multiple agents. Our central contribution will be to show that, in spite of the additional expressivity, reasoning about knowledge and action reduces to non-epistemic non-dynamic reasoning about the initial KB. More precisely, we show that when the initial KB is an arbitrary first-order theory, we are able to identify conditions under which projection can be solved by progressing the KB to a sentence reflecting the changes due to actions that have already occurred. Moreover, when effectors are unreliable, we allow the system to maintain probabilistic beliefs and then show how projection can be addressed by means of updating these beliefs. Finally, when there are many agents in the picture, we show that queries about the future can be resolved by regressing the query backwards to a formula about the initial KB. *Only knowing* comes with a significant result that allows us to reduce queries about knowledge to first-order theorem-proving tasks, which is then made use of when solving projection.

Projection in Active Knowledge Bases with Incomplete Information

Vaishak Belle, Gerhard Lakemeyer

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HYBRIS: Hybrid Reasoning for Intelligent Systems

*Franz Baader, Gerhard Brewka, Wolfram Burgard, Gerhard Lakemeyer, Bernhard Nebel,
Torsten Schaub, Michael Schroeder*

In February 2012, the German Science Foundation approved the new Research Unit FOR 1513 “Hybrid Reasoning for Intelligent Systems.” The partners of this Research Unit are RWTH Aachen (Prof. Gerhard Lakemeyer, Speaker), TU Dresden (Prof. Franz Baader, Prof. Michael Schroeder), Freiburg University (Prof. Wolfram Burgard, Prof. Bernhard Nebel), Leipzig University (Prof. Gerhard Brewka), and Potsdam University (Prof. Torsten Schaub).

The work to be carried out is motivated by the fact that, to date, most Knowledge Representation and Reasoning (KR&R) approaches have focused on qualitative representations, while many application domains require that quantitative information be processed as well. Examples of such quantitative aspects are time, probabilistic uncertainty, multi-criteria optimization, or resources like mass.

The aim of this research unit is to integrate both qualitative and quantitative forms of reasoning, resulting in hybrid reasoning formalisms. The work will build on the results from the previous DFG-funded project cluster “Logic-Based Knowledge Representation”, where some of the most successful qualitative KR&R formalisms were combined with a focus on reasoning about actions. To increase the practical impact and relevance of the proposed research, experts from two carefully selected application areas, Robotics and Bioinformatics, will be part of the consortium, and both foundational and application-driven projects will be carried out. In the long run, the research unit will take a big step towards widening the use of KR&R technology as part of large, complex intelligent systems.

More information about the Research Unit can be found at www.hybrid-reasoning.org.

HYBRIS A1: Verification of Non-Terminating Action Programs

Jens Claßen and Gerhard Lakemeyer

The action language GOLOG has been used, among other things, for the specification of the behaviour of mobile robots. Since the task of such autonomous systems is typically open-ended, their GOLOG programs are usually non-terminating. To ensure that the program will let the robot exhibit the intended behaviour, it is often desirable to be able to formally specify and then verify the desired properties, which are often of a temporal nature. This task has been studied within our preliminary work from two perspectives: On the one hand, the problem was tackled for very expressive specification and action program formalisms, but without the goal of achieving decidability, i.e. the developed verification methods were not guaranteed to terminate. On the other hand, the verification problem was studied for action

formalisms based on decidable description logics and very limited means of specifying admissible sequences of actions, which allowed us to show decidability and complexity results for the verification problem. The purpose of this project is to combine the advantages of both approaches by, on one hand, developing verification methods for GOLOG programs that are effective and practically feasible and, on the other hand, going beyond the formalisms with very limited expressiveness to enhance their usefulness. Among other things, both qualitative and quantitative temporal program properties will be addressed.

This project is done in cooperation with Prof. Dr.-Ing. Franz Baader from TU Dresden.

HYBRIS C1: Planning and Action Control under Uncertainty for Mobile Manipulation Tasks

Tim Niemueller and Gerhard Lakemeyer

Mobile robots that are deployed, for instance, for domestic tasks, need to fulfill them even if they do not have complete information about the domain beforehand. Consider, for example, the task of fetching an object from a specific room. Consider further that the robot has a map of the environment and that it can plan a path to the living room. However, only when reaching the door of the living room, it will know whether or not the door is open. Moreover, it might not be known where in the living room the object is located such that the robot needs to make a plan how to find it. Next, a plan for grabbing the object in a safe way is required. This includes taking camera shots from different angles and finding an appropriate location to grab the object. Basically, the action control of the robot continuously needs to combine active perception and high-level planning with action execution. The robot has to deal with qualitative action and world descriptions as well as with uncertainty and quantitative data from sensors and actuators. The objective of this project is to develop methods for solving tasks like the above in an intelligent way by combining perception, high-level planning and action execution. An evaluation of the developed methods will be conducted on existing mobile robotic platforms.

Partners in this project are Prof. Dr. Wolfram Burgard and Prof. Dr. Bernhard Nebel from Albert-Ludwigs-Universität Freiburg.

Robust Reliable Robotic Systems

Tim Niemueller, 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.

Multi-Agent Plan Recognition

Christoph Schwering, Gerhard Lakemeyer

In autonomous multi-agent systems it is often desirable for an agent to know what the other agents are doing and/or going to do. For example, cars are expected to first drive autonomously in rather simple situations; but in complicated situations the driver should be in control. The autonomous car should recognize critical situations in advance so that control can be handed over to the driver early enough. For that, the system needs to recognize what the surrounding drivers are doing right now and then extrapolate this knowledge to predict future situations.

We developed a new model-based approach to plan recognition whose most recent state we have presented at CogRob-2012 and KI-2012. This model is comprised of a logical definition of actions and programs which represent typical agent behavior. The environment is observed periodically which, in the case of the car example, generates a sequence of global position coordinates at which the various vehicles have been seen. Then the programs from the model are executed in simulation and matched with the observations if possible.

The situation calculus equips us with a logical formalism to capture concepts such as continuous time and incomplete knowledge. The action language Golog and its existing dialects serve as foundation for our new action language that is particularly suited for plan recognition tasks. As such, our dialect of Golog is able to handle multiple agents acting in parallel and interacting with each other and with a continuous, physics-oriented world like the traffic domain. Furthermore we have built in means that allow us to execute a program incrementally and thus carry out plan recognition online, that is, we can check whether certain behavior explains what we observe while the observations come in. Another important issue in many real domains in general and the car domain in particular is robustness: the model is a rather idealized view of what happens in reality. For example, an intuitive model of a car driving straight on a lane is a straight line, yet a human certainly will not drive exactly along this line but oscillate around it. We use actions with nondeterministic effects to deal with this issue and compute confidence values of how well the model matches the observations. These confidence values provide a more detailed information about how well a hypothesis explains the observations than logic's yes/no truth values.

We also investigate on alternative and more robust ways of modelling traffic for plan recognition. The problem is to deal with cars' distances and relations to each other in a flexible yet expressive manner. Further questions in the area are, for example, how to deal with incomplete knowledge and how portions of the model can be learned using machine learning techniques. The ultimate goal of this project is to extrapolate recognized plans to predict future situations.

Ready-ROS: Integrating the High-level Control Language Readylog into the Robot Operating System

Alexander Ferrein, Tim Niemueller, 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

Committees

Gerhard Lakemeyer was a Program Committee (PC) member of a number of international conferences, including KR 2012 and ECAI 2012. In August 2012, he was elected as a member of the European Coordinating Committee for Artificial Intelligence (ECCAI). He is an Associate Editor of Artificial Intelligence and Computational Intelligence, and a member of the Editorial Board of the Journal of Applied Logic. In December 2011, he finished his term as a member of the Advisory Board of the Journal of Artificial Intelligence Research.

Stefan Schiffer was a PC member of the RoboCup Symposium and of the Poster and Demo Session at the 35th German Conference on Artificial Intelligence (KI-2012). He is an honorary member of the Technical Committee in the RoboCup@Home league after serving as a regular member for three years.

Tim Niemueller was appointed to the Technical Committee of the RoboCup Logistics League Sponsored by Festo.

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

- In March 2012, Prof. Gerhard Lakemeyer visited Prof. Maurice Pagnucco at University of New South Wales, Australia and Prof. Hector Levesque at University of Toronto, Canada.
- In September 2012, Prof. Gerhard Lakemeyer again visited Prof. Hector Levesque at University of Toronto, Canada.
- From September 2010 to December 2012, 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.
- In July and October Tim Niemueller was admitted to and participated in the 4th and 5th Research Camp of the project "Best Practice in Robotics" funded as part of the EU 7th Framework Programme. The tasks were to analyze common robot architectures to condense a best practice view and to facilitate the integration of a demonstration scenario based on the Kuka YouBot in the RoboCup@Work scenario determining the suitability of existing robot software components.

SRI International. From January to November 2011 Tim Niemueller was 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 involved robot behavior design and developing a self-diagnosis software to detect, analyze, and report or recover from typical error conditions.

Tournaments and Competitions

RoboCup 2012. In June 2012, the Carologistics joint team of the IMA/ZLW/IFU, RWTH Aachen University, the KBSG, RWTH Aachen University, and the Electrical Engineering Department, FH Aachen, participated in the Logistics League Sponsored by Festo in the international RoboCup competition which took place in Mexico City.

Demonstrations and Events

Open House Night. Jointly with Informatik 5, the KBSG had its open house night in November 2011. To give an insight on what is happening behind our doors we presented the different projects and we gave brief talks on which areas we cover in our research. Visitors also had the chance to get their hands on real robots, for example in trying to use them to play soccer. The open house night was well received and we had interesting discussions with people throughout the evening.

Demo at ICIRA 2011. The KBSG demonstrated its domestic service robot Caesar and a Robotino robot from Festo at the International Conference on Intelligent Robotics and Applications. Caesar showed its capabilities in finding tables at the venue and in picking up items from those tables. Bystanders were involved in the demo in that they could choose the item to be picked up by engaging in human-robot interaction and by simply pointing to the item to select it. Apart from this demo we also presented the outcome of a lab course where conference visitors could remote-control the Robotino and Caesar would autonomously detect and follow it around the venue.

Robotino Hackathon. In May 2012 the IMA/ZLW/IFU, RWTH Aachen University, the KBSG, RWTH Aachen University, and the Electrical Engineering Department, FH Aachen hosted a Hackathon event, where more than 20 students worked in groups on typical robot software components advised from research assistants and professors from all three institutions. From the participating students a group of four was selected which joined the Carologistics RoboCup Team for participation in the RoboCup 2012 competition.

Talks and Publications

Talks

Stefan Schiffer: Kinect in Domestic Service Robotics, REGINA Management Treffen 04/2012, Kinect Die Maschine versteht dich! National Instruments, Aachen, Germany, April 2012.

Publications

Daniel Beck, Gerhard Lakemeyer: Representing Value Functions with Recurrent Binary Decision Diagrams, Proceedings of the 20th European Conference on Artificial Intelligence (ECAI-2012), Montpellier, 2012

Jens Claßen, Gabriele Roeger, Gerhard Lakemeyer, Bernhard Nebel: PLATAS – Integrating Planning and the Action Language Golog, KI – Kuenstliche Intelligenz, vol. 26, 2012

Sandra Geisler, Christoph Quix, Stefan Schiffer, Matthias Jarke: An evaluation framework for traffic information systems based on data streams, Transportation Research Part C: Emerging Technologies, 2012

Gerhard Lakemeyer, Hector J. Levesque: Only-Knowing Meets Nonmonotonic Modal Logic, Principles of Knowledge Representation and Reasoning: Proceedings of the Thirteenth International Conference (KR-2012), Rome, Italy, June 10-14, 2012

Gerhard Lakemeyer, Yves Lespérance: Efficient Reasoning in Multiagent Epistemic Logics, Proceedings of the 20th European Conference on Artificial Intelligence (ECAI-2012), Montpellier, 2012

Hector J. Levesque, Gerhard Lakemeyer: The Truth about Defaults, Correct Reasoning – Essays on Logic-Based AI in Honour of Vladimir Lifschitz, Springer, 2012

Tim Niemueller, Stefan Schiffer, Albert Hellgrath, Safoura Rezapour Lakani, Gerhard Lakemeyer: BendIT – An Interactive Game with two Robots, Poster and Demo Session at the 35th German Conference on Artificial Intelligence (KI-2012), Saarbruecken, 2012

Tim Niemueller, Gerhard Lakemeyer, Siddhartha Srinivasa: A Generic Robot Database and its Application in Fault Analysis and Performance Evaluation, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS-2012), Vilamoura, Portugal, 2012

Stefan Schiffer, Tobias Baumgartner, Daniel Beck, Bahram Maleki-Fard, Tim Niemueller, Christoph Schwering, Gerhard Lakemeyer: robOCD: Robotic Order Cups Demo – An Interactive Domestic Service Robotics Demo, Poster and Demo Session at the 35th German Conference on Artificial Intelligence (KI-2012), Saarbruecken, 2012

Stefan Schiffer, Niklas Hoppe, Gerhard Lakemeyer: Flexible Command Interpretation on an Interactive Domestic Service Robot, Proceedings of the 4th International Conference on Agents and Artificial Intelligence (ICAART-2012), Vilamoura, Portugal, 2012 Best Student Paper Award

Stefan Schiffer, Alexander Ferrein, Gerhard Lakemeyer: Caesar: An Intelligent Domestic Service Robot, Journal of Intelligent Service Robotics, Special Issue on Artificial Intelligence Techniques in Robotics, 2012

Stefan Schiffer, Tobias Baumgartner, Gerhard Lakemeyer: A Modular Approach to Gesture Recognition for Interaction with a Domestic Service Robot, Proceedings of the 4th

International Conference on Intelligent Robotics and Applications (ICIRA-2011), Aachen, Germany, 2011

Stefan Schiffer, Alexander Ferrein, Gerhard Lakemeyer: Fuzzy Representations and Control for Domestic Service Robots in Golog, Proceedings of the 4th International Conference on Intelligent Robotics and Applications (ICIRA-2011), Aachen, Germany, 2011

Stefan Schiffer, Alexander Ferrein, Gerhard Lakemeyer: Reasoning with Qualitative Positional Information for Domestic Domains in the Situation Calculus, In Journal of Intelligent and Robotic Systems. Special Issue on Domestic Service Robots in the Real World, 2012

Christoph Schwering, Daniel Beck, Stefan Schiffer, Gerhard Lakemeyer: Plan Recognition by Program Execution in Continuous Temporal Domains, Proceedings of the 8th International Cognitive Robotics Workshop (CogRob-2012), Toronto, Canada, 2012

Christoph Schwering, Daniel Beck, Stefan Schiffer, Gerhard Lakemeyer: Plan Recognition by Program Execution in Continuous Temporal Domains, Proceedings of the 35th German Conference on Artificial Intelligence (KI-2012), 2012

Siddhartha Srinivasa, Dmitry Berenson, Maya Cakmak, Alvaro Collet Romea, Mehmet Dogar, Anca Dragan, Ross Alan Knepper, Tim Niemueller, Kyle Strabala, J. Michael Vandeweghe, Julius Ziegler: HERB 2.0: Lessons Learned From Developing a Mobile Manipulator for the Home, Proceedings of the IEEE, vol. 100, no. 8, pp. 2410–2428, 2012

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:

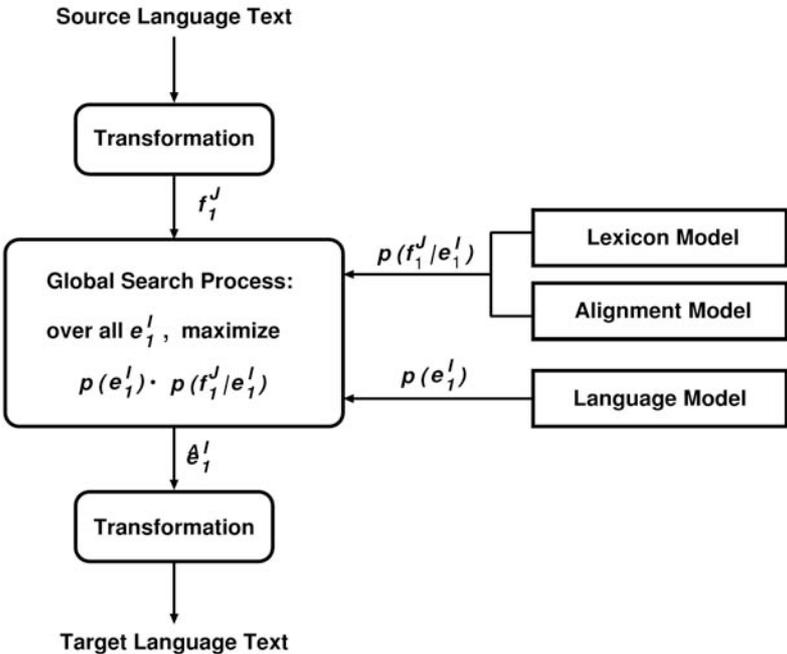
- speech recognition
 - large vocabulary recognition
 - multi-lingual speech recognition
 - speaker independent and adaptive speech recognition
 - robust speech recognition
- machine translation of spoken and written language
- natural language processing
 - document classification
 - language understanding
 - 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.



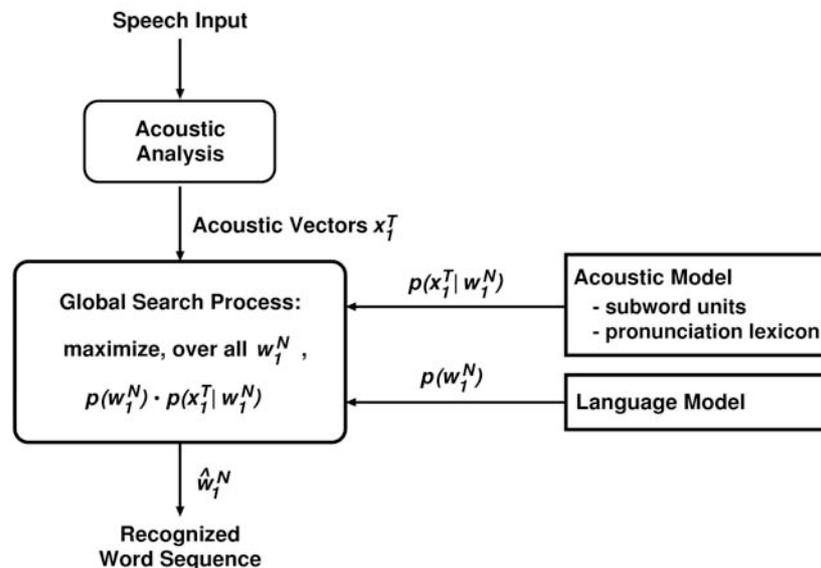
Architecture of a Statistical Machine Translation System

At ‘Lehrstuhl für Informatik 6’, the following research directions related to the main topics of machine translation were pursued in 2012:

- 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 like syntax or dependency models have been 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

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 2011:

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, Portugues, Dutch, Danish, Finnish,

Swedish, Czech, Hungarian, Polish, Slovakian and is based on corresponding TV broadcasts and internet publications.

- Methods for unsupervised training were improved to take advantage of completely untranscribed speech.
- The cooperation with the Dalle Molle Institute for Perceptual Artificial Intelligence (IDIAP), Martigny, Switzerland, on data-driven methods to extract acoustic features using neural networks was continued. Hierarchical phoneme posterior features and further approaches to combine systems based on different acoustic features were investigated.
- Speaker adaptive training was further investigated w.r.t. projection transforms, shift-only transforms, and the application of advanced training criteria.
- Log-linear, discriminative transforms of speech features were developed.
- For Arabic speech recognition, a morphological decomposition of the recognition vocabulary was investigated to reduce the considerable vocabulary sizes needed to obtain a good coverage of Arabic.
- In pronunciation modelling, methods for automatic phonetic transcription were further developed and applied to the detection and recognition of out-of-vocabulary words.
- Word graph based system combination methods and their relation to Bayes decision rule were investigated, and a simplified to confusion network construction was developed.
- Methods for log-linear modeling and discriminative training were investigated. Especially, initialization of log-linear acoustic models without using previous Gaussian mixture distributions was investigated. In addition, discriminative training criteria for ASR were generalized to include a margin term and regularization, and a close relation to support vector machines was shown.
- Refinements of Bayes decision rule using a word error based cost function were investigated with special focus on analytic simplifications and reduction of complexity.

Natural Language Processing

The goal of natural language processing is to design and build computer systems that are able to analyze natural languages like German or English, and that generate their outputs in a natural language, too. Typical applications of natural language processing are language understanding, dialogue systems and text annotation.

The development of statistical approaches for these applications is one of the research activities at the 'Lehrstuhl für Informatik 6'.

In natural language understanding, the objective is to extract the meaning of an input sentence or an input text. Usually, the meaning is represented in a suitable formal representation language so that it can be processed by a computer. Hand-crafted grammars are used in order to parse input sentences and map them onto a formal representation. The language understanding systems developed at the 'Lehrstuhl für Informatik 6' are based on statistical machine translation and learn dependencies between source and target representations automatically from annotated texts. Because the usage of hand-crafted grammars is reduced, the systems can be easily ported to other domains.

We developed a spoken dialogue system for the domain of a telephone directory assistance. A large vocabulary continuous real-time speech recognition component as well as a natural

language understanding unit and a dialogue manager are integral parts of the system. The implementation of the dialogue system is independent from the application's domain.

In part-of-speech tagging, each word is labeled with its word class (noun, verb, adjective, etc.). More generally, tagging is the task of labeling each word in a sentence with its appropriate tag; "appropriate" being defined by the task.

We developed a tagger using the maximum entropy framework which has been successfully evaluated on different tasks, like named entity recognition, part-of-speech tagging, shallow parsing, true casing and natural language understanding. The obtained results show a state-of-the-art performance.

Sign Language and Gesture Recognition

Automatic sign language and gesture recognition is similar to automatic speech recognition. Our aim is to build a robust, person independent system to recognize continuous sign language sentences. Additionally, our vision-based approach does not require special data acquisition devices, e.g. expensive data gloves which restrict the natural way of signing.

As a baseline system we propose to use appearance-based image features, i.e. thumbnails of video sequence frames. They serve as a good basic feature for many image recognition problems, and are already successfully used for gesture recognition. Further features, which are inspired by linguistic research in sign language, are extracted using hand- and head-tracking methods.

In 2008, we have furthermore shown that many of the principles from automatic speech recognition can be directly transferred to the new domain of continuous automatic sign language recognition and that great improvements are possible by adopting the experiences from automatic speech recognition to problems in video-analysis.

We achieved very promising results on publicly available benchmark by combining different data sources, suitable language modelling, temporal contexts, and model combination.

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



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

Handwriting Recognition

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

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

All proposed methods were evaluated on the IFN/ENIT Arabic handwriting database. In particular, and to the best of our knowledge, the presented results could outperform all error rates reported in the literature. The approach presented in TOCITE-ICDAR-DT ranked third at the ICDAR 2011 Arabic Handwriting Recognition Competition. In comparison to a preliminary evaluation of the RWTH-OCR system in 2009, the official results from 2011 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

BABEL

The Babel Program is developing agile and robust speech recognition technology that can be rapidly applied to any human language in order to provide effective search capability for analysts to efficiently process massive amounts of real-world recorded speech. Today's transcription systems are built on technology that was originally developed for English, with markedly lower performance on non-English languages. These systems have often taken years to develop and cover only a small subset of the languages of the world. Babel intends to demonstrate the ability to generate a speech transcription system for any new language within one week to support keyword search performance for effective triage of massive amounts of speech recorded in challenging real-world situations.

The goal of the Babel Program is to develop methods to build speech recognition technology for a much larger set of languages than has hitherto been addressed. The Program requires innovations in how to rapidly model a novel language with significantly less training data that are also much noisier and more heterogeneous than what has been used in the current state-of-the-art. Babel's technical measures of success are focused on how well the generated model works to support effective word-based search of noisy channel speech in the languages to be investigated. The new methods are being systematized so that they can be applied rapidly to a novel underserved language.

BOLT

The goal of the BOLT 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 2012, the "Lehrstuhl für Informatik 6" participated as a member of the DELPHI team, led by IBM. RWTH contributes translations from Arabic to English and from Chinese to English to this project. In addition, RWTH provides consensus translations generated from translations of all team members in this language pair.

EU-Bridge

EU-Bridge aims at developing automatic transcription and translation technology that will permit the development of innovative multimedia captioning and translation services of audiovisual documents between European and non-European languages. The project will provide streaming technology that can convert speech from lectures, meetings, and telephone conversations into the text in another language.

Therefore EU-Bridge intends to put together academics, engineering and business expertise in order to create competitive offers to existing needs of translation, communication, content processing and publishing. The four use cases are: Captioning Translation for TV broadcasts, University Lecture Translations, European Parliament Translations, Mobile Devices Communication Translation. The prospective users of the project are European companies operating in an audiovisual market (in particular TV captioning and translation).

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.

SCALE

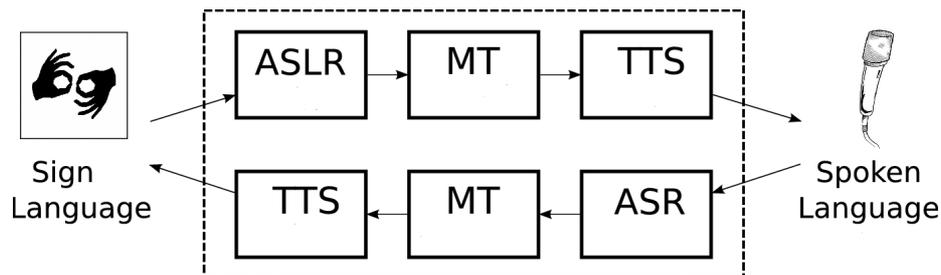
The European Marie Curie Initial Training Network SCALE aims at the education of researchers in all aspects of speech processing, to accelerate the rate of advance in speech technology and thereby supporting the growing speech processing market.

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.

transLectures

The overall aim of the transLectures project is to develop innovative, cost-effective solutions to produce accurate transcriptions and translations in the well-known VideoLectures.NET repository, with generality across other repositories based on the widely used Opencast Matterhorn platform. Our starting hypothesis is that there is only a relatively small gap for the current technology on automatic speech recognition and machine translation to achieve accurate enough results in the kind of audio-visual object collections we are considering; and that this gap can be closed by using massive adaptation and intelligent interaction with users. In order to enable real-life evaluation, integration into Matterhorn is also a main project objective.

Publications

- J. Andres-Ferrer, M. Sundermeyer, and H. Ney. Conditional Leaving-One-Out and Cross-Validation for Discount Estimation in Kneser-Ney-Like Extensions. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 5013-5016, Kyoto, Japan, March 2012.
- M. A. Basha Shaik, D. Rybach, S. Hahn, R. Schlüter, and H. Ney. Hierarchical Hybrid Language models for Open Vocabulary Continuous Speech Recognition using WFST. In Workshop on Statistical and Perceptual Audition (SAPA), pages 46-51, Portland, OR, USA, September 2012.
- M. A. Basha Shaik, A. El-Desoky Mousa, R. Schlüter, and H. Ney. Investigation of Maximum Entropy Hybrid Language Models for Open Vocabulary German and Polish LVCSR . In Interspeech, Portland, OR, USA, September 2012.
- P. Doetsch, M. Hamdani, A. Giménez, J. Andrés-Ferrer, A. Juan, and H. Ney. Comparison of Bernoulli and Gaussian HMMs using a vertical repositioning technique for off-line handwriting recognition. International Conference on Frontiers in Handwriting Recognition, accepted for publication, Bari, Italy, September 2012.
- P. Dreuw. Probabilistic Sequence Models for Image Sequence Processing and Recognition. PhD Thesis, Aachen, Germany, April 2012.
- P. Dreuw, D. Rybach, G. Heigold, and H. Ney. RWTH OCR: A Large Vocabulary Optical Character Recognition System for Arabic Scripts. In Volker Märgner, and Haikal El Abed: Guide to OCR for Arabic Scripts Chp. Part II: Recognition, pages 215-254, Springer, London, UK, July 2012. ISBN 978-1-4471-4071-9.
- A. El-Desoky Mousa, M. A. Basha Shaik, R. Schlüter, and H. Ney. Morpheme Level Feature-based Language Models for German LVCSR . In Interspeech, Portland, OR, USA, September 2012.
- A. El-Desoky Mousa, R. Schlüter, and H. Ney. Investigations on the Use of Morpheme Level Features In Language Models for Arabic LVCSR. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 5021-5024, Kyoto, Japan, March 2012.
- J. Forster, C. Schmidt, T. Hoyoux, O. Koller, U. Zelle, J. Piater, and H. Ney. RWTH-PHOENIX-Weather: A Large Vocabulary Sign Language Recognition and Translation Corpus. In International Conference on Language Resources and Evaluation (LREC), Istanbul, Turkey, May 2012.
- M. Freitag, S. Peitz, M. Huck, H. Ney, T. Hermann, J. Niehues, A. Waibel, A. Allauzen, G. Adda, B. Buschbeck, J. M. Crego, and J. Senellart. Joint WMT 2012 Submission of the QUAERO Project. In NAACL 2012 Seventh Workshop on Statistical Machine Translation (WMT 2012), pages 322-329, Montreal, Canada, June 2012.
- P. Golik, B. Harb, A. Misra, M. Riley, A. Rudnick, and E. Weinstein. Mobile Music Modeling, Analysis and Recognition. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Kyoto, Japan, March 2012.
- Y. Gweth, C. Plahl, and H. Ney. Enhanced Continuous Sign Language Recognition using PCA and Neural Network Features. In CVPR 2012 Workshop on Gesture Recognition (CVPR 2012), accepted for publication, Providence, Rhode Island, June 2012.

S. Hahn, P. Vozila, and M. Bisani. Comparison of Grapheme-to-Phoneme Methods on Large Pronunciation Dictionaries and LVCSR Tasks. In Interspeech, Portland, OR, USA, September 2012.

B. Hoffmeister, G. Heigold, D. Rybach, R. Schlüter, and H. Ney. WFST Enabled Solutions to ASR Problems: Beyond HMM Decoding . Audio, Speech, and Language Processing, IEEE Transactions on, volume 20, number 2, pages 551-564 , February 2012.

M. Huck, and H. Ney. Insertion and Deletion Models for Statistical Machine Translation. In Proceedings of the North American Chapter of the Association for Computational Linguistics - Human Language Technologies conference (NAACL HLT), pages 347-351, Montreal, Canada, June 2012.

M. Huck, and H. Ney. Pivot Lightly-Supervised Training for Statistical Machine Translation. In Conference of the Association for Machine Translation in the Americas 2012 (AMTA 2012), San Diego, California, USA, October 2012. To appear.

M. Huck, S. Peitz, M. Freitag, and H. Ney. Discriminative Reordering Extensions for Hierarchical Phrase-Based Machine Translation. In 16th Annual Conference of the European Association for Machine Translation (EAMT), pages 313-320, Trento, Italy, May 2012.

M. Huck, S. Peitz, M. Freitag, M. Nuhn, and H. Ney. The RWTH Aachen Machine Translation System for WMT 2012. In NAACL 2012 Seventh Workshop on Statistical Machine Translation (WMT 2012), pages 304-311, Montreal, Canada, June 2012.

M. Huck, J. Peter, M. Freitag, S. Peitz, and H. Ney. Hierarchical Phrase-Based Translation with Jane 2. The Prague Bulletin of Mathematical Linguistics, number 98, pages 37-50, Prague, Czech Republic, October 2012.

O. Koller, A. Abad, and I. Trancoso. Automatic Speech Recognition and Identification of African Portuguese. In PROPOR'2012 - MSc/PhD Thesis Contest (Propor 2012), Coimbra, Portugal, April 2012.

M. Kozielski, J. Forster, and H. Ney. Moment-based Image Normalization for Handwritten Text Recognition. In International Conference on Frontiers in Handwriting Recognition (ICFHR), accepted for publication, Bari, Italy, September 2012.

Y. Kubo, S. Watanabe, A. Nakamura, S. Wiesler, R. Schlüter, and H. Ney. Basis Vector Orthogonalization for an Improved Kernel Gradient Matching Pursuit Method. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 1909-1912, Kyoto, Japan, March 2012.

P. Lehnen, S. Hahn, V. Guta, and H. Ney. Hidden Conditional Random Fields with M-to-N Alignments for Grapheme-to-Phoneme Conversion. In Interspeech, Portland, OR, USA, September 2012.

S. Mansour, and H. Ney. Arabic-Segmentation Combination Strategies for Statistical Machine Translation. In International Conference on Language Resources and Evaluation (LREC), Istanbul, Turkey, May 2012.

D. Nolden, D. Rybach, R. Schlüter, and H. Ney. Joining Advantages of Word-conditioned and Token-passing Decoding. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 4425-4428, Kyoto, Japan, March 2012.

- D. Nolden, R. Schlüter, and H. Ney. Extended Search Space Pruning in LVCSR. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 4429-4432, Kyoto, Japan, March 2012.
- M. Nuhn, A. Mauser, and H. Ney. Deciphering Foreign Language by Combining Language Models and Context Vectors. In Annual Meeting of the Assoc. for Computational Linguistics (ACL), Jeju, Republic of Korea, July 2012. To appear.
- I. Oparin, M. Sundermeyer, H. Ney, and J. Gauvain. Performance Analysis of Neural Networks in Combination with N-Gram Language Models. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 5005-5008, Kyoto, Japan, March 2012.
- H. Pesch, M. Hamdani, J. Forster, and H. Ney. Analysis of Preprocessing Techniques for Latin Handwriting Recognition. In International Conference on Frontiers in Handwriting Recognition (ICFHR), accepted for publication, Bari, Italy, September 2012.
- L. Pishchulin, T. Gass, P. Dreuw, and H. Ney. Image warping for face recognition: From local optimality towards global optimization. *Pattern Recognition*, volume 45, number 9, Available Online, September 2012. <http://dx.doi.org/10.1016/j.patcog.2011.10.017> Best Papers of Iberian Conference on Pattern Recognition and Image Analysis (IbPRIA'2011).
- C. Plahl, T. N. Sainath, B. Ramabhadran, and D. Nahamoo. Improved Pre-training of Deep Belief Networks using Sparse Encoding Symmetric Machines. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Kyoto, Japan, March 2012.
- A. Rosti, X. He, D. Karakos, G. Leusch, Y. Cao, M. Freitag, S. Matsoukas, H. Ney, J. Smith, and B. Zhang. Review of Hypothesis Alignment Algorithms for MT System Combination via Confusion Network Decoding. In NAACL 2012 Seventh Workshop on Statistical Machine Translation (WMT 2012), pages 191-199, Montreal, Canada, June 2012.
- D. Rybach, R. Schlüter, and H. Ney. Silence is Golden: Modeling Non-speech Events in WFST-based Dynamic Network Decoders. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 4205-4208, Kyoto, Japan, March 2012.
- R. Schlüter, M. Nußbaum-Thom, and H. Ney. Does the Cost Function Matter in Bayes Decision Rule?. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, volume 34, number 2, pages 292-301, February 2012.
- D. Stein, C. Schmidt, and H. Ney. Analysis, preparation, and optimization of statistical sign language machine translation. *Machine Translation*, pages 1-33, March 2012.
- M. A. Tahir, M. Nußbaum, R. Schlüter, and H. Ney. Simultaneous Discriminative Training and Mixture Splitting of HMMs for Speech Recognition. In Interspeech, Portland, OR, USA, September 2012.
- Z. Tüske, R. Schlüter, and H. Ney. Comparison and combination of different CRBE based MLP features for LVCSR. In IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), pages 4081-4084, Kyoto, Japan, March 2012.
- D. Vilar, and H. Ney. Cardinality pruning and language model heuristics for hierarchical phrase-based translation. *Machine Translation*, volume 26, number 3, pages 217-254, September 2012.

D. Vilar, D. Stein, M. Huck, and H. Ney. Jane: an advanced freely available hierarchical machine translation toolkit. *Machine Translation*, volume 26, number 3, pages 197-216, September 2012.

J. Wuebker, M. Hwang, and C. Quirk. Leave-One-Out Phrase Model Training for Large-Scale Deployment. In *NAACL 2012 Seventh Workshop on Statistical Machine Translation (WMT 2012)*, pages 460-467, Montreal, Canada, June 2012.

J. Wuebker, and H. Ney. Phrase Model Training for Statistical Machine Translation with Word Lattices of Preprocessing Alternatives. In *NAACL 2012 Seventh Workshop on Statistical Machine Translation (WMT 2012)*, pages 450-459, Montreal, Canada, June 2012.

J. Wuebker, H. Ney, and R. Zens. Fast and Scalable Decoding with Language Model Look-Ahead for Phrase-based Statistical Machine Translation. In *Annual Meeting of the Assoc. for Computational Linguistics (ACL)*, pages 28-32, Jeju, Republic of Korea, July 2012.

PhD Theses

S.Hasan. Triplet Lexicon Models for Statistical Machine Translation. November 2011. External Evaluator: Prof. Dr. Francois Yvon, LIMSI, France.

D.Vilar. Investigations on Hierarchical Phrase-based Machine Translation. November 2011. External Evaluator: Prof. Dr. Francisco Casacuberta, Universitat Politecnica de Valencia, Spain.

D. Stein. Soft Features for Statistical Machine Translation of Spoken and Signed Languages. January 2012. External Evaluator: Univ.-Prof. Dr. Andy Way, Dublin City University, Irland.

P. Dreuw. Probabilistic Sequence Models for Image Sequence Processing and Recognition. April 2012. External Evaluaor: Univ. Prof. Dr.-Ing. Habil. Gerhard Rigoli, Technische Universitaet München.

Logic & Theory of Discrete Systems



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Overview

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



Martin Grohe

The most important event of the year for us was the appointment of Martin Grohe, previously at Humboldt University, Berlin, as the future director of the chair.

The official starting date of his office was 1st October 2012, i.e., just one day after the period covered by the present report (1st October 2011 until 30th September 2012). So we do not give here detailed information about his research and his projects, but defer this to the report of 2013.

It is planned that Wolfgang Thomas will stay at the chair with full duties in teaching and research for the coming three years.

Major projects in which our group participated were 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 GASICS (“Games for analysis and synthesis of interactive computational systems”) of the ESF (European Science Foundation).
- The DFG Project “Verification of resource bounded systems” (under the direction of C. Löding) started in April 2011.
- The EU Project CASSTING (Collaborative Adaptive System Synthesis via Non-Zero Games) was approved and is scheduled to start in April 2013.

The group also participates 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.

A special interdisciplinary event took place in March 2012: Our Emeritus, Prof. Oberschelp, organized a workshop on surprising insights about the work of the astronomer and mathematician Johannes Kepler – based on new careful reading of his fictional text “Somnium” (“The Dream”). For more information see the report in the subsequent section.

Research Projects

Regular Infinite Games

N. Chaturvedi, M. Gelderie, D. Neider, J. Olschewski, W. Thomas, M. Zimmermann

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

The algorithmic theory of infinite games with “regular” winning conditions (i.e. conditions that are definable by finite omega-automata) is presently the main field of research of the chair. Much of it 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.

In this area, the doctoral dissertation of Martin Zimmermann “*Solving Infinite Games with Bounds*” [29] was completed.

- *Logic, Language Theory, and Strategies in Infinite Games*
In this project, the format of winning conditions of infinite games is related to the format of possible winning strategies. By “format” we refer to notions of definability in systems of (monadic second-order or first-order) logic, or equivalently, language theoretical notions of definability for subclasses of the class of regular languages. 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 [4]).
- *Strategy Machines*
In his doctoral research, Marcus Gelderie developed a format of “controller”, called strategy machine, that overcomes weaknesses of the classical model of “finite automaton with output”. Strategy machines are multitape Turing machines, in which the memory function is cleanly separated between the purposes of storing fixed global parameters and dynamic aspects that evolve over the course of a play. Also the time to compute the next step (latency) is classified in a finer way as for finite automata. First results show that sharper and in some sense better results than previously known can be shown for important classes of games, in particular Muller games and Streett games. These results were presented at MFCS 2012 [11].
- *Optimality Concepts for Strategies in Infinite Games*
In this vast field we mention only two contributions of the group. In joint work with colleagues of ENS Cachan, Jörg Olschewski studied a classification of winning strategies in infinite games via the measure of nondeterminism. It was shown that optimal strategies in this sense (called permissive strategies) can be guaranteed [2].
In joint work N. Fijalkow (LIAFA and University of Warsaw) and Martin Zimmermann introduced a new class of infinite games, so called cost-parity and cost-Streett games [8] which extend classical parity and Streett games as well as finitary parity and Streett games. In such games, edges are labeled by costs and the winning conditions require

requests to be answered with bounded costs. It is shown that cost-parity games retain many nice properties of parity games, e.g., positional winning strategies for Player 0 and the same complexity of solving such games. Analogous results are shown for cost-Streett games.

- *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 [5]. 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 the classical notions of reducibility) to decrease the level of a game with respect to the fundamental hierarchy in this context, the Borel hierarchy (see [21]).

- *Applying Algorithmic Learning to Infinite Games*

In this project, Daniel Neider developed techniques that apply algorithmic learning, i.e., learning of finite automata, to solve infinite games. One result is an algorithm that learns the winning region of reachability games played on finite and infinite automatic graphs. A second result, presented at the ATVA 2011 conference, allows computing small representations of winning strategies in safety games efficiently, see [20]. The latter includes domain-specific improvements of both Angluin's and Kearns and Vazirani's well-known learning algorithms. In ongoing research, off-the-shelf SAT and SMT solvers are incorporated into the learning process to speed up computations.

Omega-Automata

S. Breuers, D. Issak, J. Olschewski, C. Löding, W. Thomas,

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

- *Complementation of Büchi Automata*

The complementation problem for Büchi automata has attracted much attention because of the wide use of these automata in verification. Many complementation constructions have been proposed in the literature. The original approach taken by Büchi (now often referred to as the Ramsey based approach) is conceptually very appealing but has a higher asymptotic complexity than the other approaches, which makes it less useful in practice. In [3] several heuristics have been developed to make the Ramsey based approach compete with the other methods in practical evaluations. Furthermore, a variation of the approach is proposed that achieves the same asymptotic complexity as the other known constructions.

- *Equivalence Test for Unambiguous Büchi Automata*

The equivalence problem for Büchi automata and for standard finite automata on finite words is known to be PSPACE-complete. On finite words, the problem becomes tractable if the given automata are unambiguous, that is, if they have at most one accepting run for

each input. In [14] these results have been lifted to certain subclasses of Büchi automata, namely unambiguous reachability and safety automata.

Foundations of Model-Checking

I. Felscher, A. Spelten, W. Thomas

- *Compositional Methods in Model-Checking*
In the doctoral project of Ingo 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. A drawback of the approach is, however, the nonelementary complexity of the formula sizes involved in this decomposition. Ingo Felscher succeeded in overcoming this effect to a large extent for properties of discrete orderings formalizable in linear-time temporal logic LTL; see [6].
- *Automata over Infinite Alphabets and over Infinite 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. Simultaneously, a theory of “regular” omega-languages over infinite alphabets was developed, in which the two logics to specify properties of letters and properties of sequences of letters (words) are clearly separated.

Pushdown Systems and Pushdown Games

W. Fridman, S. Repke, C. Löding, M. Slaats, W. Thomas, M. Zimmermann

Funding: B-IT Research School, DFG

Pushdown games (or: context-free games) are a setting in which algorithmic solutions to the verification problem as well as the synthesis problem can be developed, generalizing well-known results on finite-state systems. We studied several questions on pushdown systems and pushdown games, treated in the subprojects listed below.

- *Higher-order Pushdown Systems*
A higher-order pushdown system has a nested structure of pushdown stacks. This generalization of pushdown systems has been a focus of our research for several years.

This year, a dissertation in the field was completed by Michaela Slaats: *Infinite regular games in the higher-order pushdown and the parameterized setting* (see [24]). In this work, a new procedure for constructing higher-order pushdown strategies was developed, and “higher-order pushdown generators” were introduced, producing infinite sequences (or, in the case of the Boolean alphabet, sets of natural numbers). It was shown how infinite regular games parameterized by such sequences (as a kind of external oracle) can be solved again with winning strategies implemented by higher-order pushdown systems.

- *Regularity Problems for Pushdown Systems and Games*

The regularity problem for pushdown automata asks for a given pushdown automaton whether there is an equivalent finite automaton. This problem is known to be decidable for deterministic pushdown automata on finite words, and it is open for pushdown automata on infinite words. A partial solution has been achieved in [19] for deterministic pushdown automata on infinite words with a weak acceptance condition. For this class of automata a reduction of the regularity problem to the regularity problem for pushdown automata on finite words is possible. As a side effect, this also provides an equivalence test for this class of pushdown automata on infinite words.

An extension of the problem asks whether for a given pushdown game the winning player has a finite state winning strategy, where the finite automaton representing the strategy only has access to the sequence of actions played during the game. It is shown in [19] that this problem is undecidable for almost all kinds of winning conditions of the game.

- *Reachability over Pushdown Graphs with Resource Bounds*

In a project funded by the DFG, reachability problems with constraints on resource consumption over systems with infinite state space are analyzed. In a first step, it has been shown that over pushdown systems this resource bounded reachability problem is decidable. To solve this problem, a general framework of cost automatic structures has been developed, which extends the theory of automatic structures using distance automata instead of standard finite automata. The results of this joint work between M. Lang and C. Löding have been submitted for publication to LMCS [17]. In future work, the bounded reachability problem will be analyzed over more general infinite state systems, and furthermore we plan to develop different kinds of specification logics for expressing properties over systems with resource consumption.

- *Winning Infinite Games on Pushdown Graphs in Finite Time*

W. Fridman and M. Zimmermann extended the results of McNaughton on finite-time games over finite arenas to the case of pushdown games. A finite-duration variant of parity pushdown games was introduced by extending McNaughton’s scoring functions, which give a condition on termination of plays, to stair-scoring functions exploiting the intrinsic structure of pushdown graphs. For this new game definition, it was proved that any finite-duration pushdown game with an exponential threshold stair-score value has the same winner as the corresponding infinite-duration pushdown game. This result gives a new reduction method which allows to determine the winner of a pushdown game by solving a reachability game on a finite game graph (see [9]).

A Game Theoretic Approach to Dynamic Networks

S. Gruener, F. Radmacher W. Thomas

Funding: DFG (Excellence Cluster UMIC)

This project is a contribution to the Aachen Excellence Cluster UMIC (“Ultra high-speed Mobile Information and Communication”). Starting from the paradigm of “sabotage games”, the doctoral thesis of F. Radmacher, titled *Games on Dynamic Networks: Routing and Connectivity*, several models of dynamic networks are introduced in a game-theoretic framework [22]. Part of these studies was the paper [12], in which the solvability of games is investigated in which player “destructor” (deleting or occupying connections) and player “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.

Surveys and Papers for Non-Specialists

C. Löding, W. Thomas

Members of the research group contributed to the task of writing surveys, exposing recent work in the fastly developing field of automata theory in a uniform and well-organized manner. Two surveys were published in a volume “Modern Applications of Automata Theory” of the Indian Institute of Science: C. Löding wrote a survey on the state-of-the-art of the theory of automata on finite trees [18], and W. Thomas contributed a paper on the application of finite automata in the analysis of infinite-state systems [27].

Further articles of a general nature were published on the occasion of the Alan Turing Year, commemorating the 100th birthday of Alan Turing. Together with F. Baader (Dresden), W. Thomas edited a special issue of the journal “Informatik-Spektrum” of Gesellschaft für Informatik, and he co-authored (with U. Schöning) an article on Turings work in the area of computability (see [1], [23]).

In the framework of the Aachen Competence Center for the History of Science, W. Thomas contributed (with M. Jarke) a paper on the “two cultures in informatics” [15].

New Analysis of Kepler's "Somnium"

W. Oberschelp, W. Steinicke, W. Thomas, Th. Hebbeker

Workshop March 2012 at RWTH with support of Forum Informatik

Kepler's posthumous novel "Somnium – The Dream" (1634) describes the experiences of a fictive observer on the surface of the moon. The complicated cinematic events on a cosmic object of third order (satellite of a planet with the sun in center), which can be visualized today using astro-software, are here described for the first time. Though the revolutionary arguments of Kepler are amazing, there remain essential mistakes. It turns out, that these mistakes arise from wrong assumptions, which could not be corrected at Kepler's time. But Kepler's arguments are logically sound. In particular essential errors of his time concern the astronomic unit, and there was also general ignorance about the rotation of a (cosmic) spinning top like the moon, about gravitation, the refraction of light etc. Kepler's wrong statements about the apparent size of the planets can mostly be justified when accepting these wrong assumptions. Also Kepler cannot be blamed for carelessly failing to discover the libration of the moon in length and breadth, which is due to Galilei, who could use a telescope.

It is impossible to use commercial software (e.g. Redshift) in order to control and justify the logic of Kepler's considerations, since instead of Kepler's wrong values the correct values are nowadays built in as *fixed* parameters. The realization of *flexible* software which admits variable parameters for the critical quantities is still missing. But our first calculations and visualisations yield an amazing consistency in Kepler's thinking. Since he nowhere else published his arguments, our analysis (which completes earlier results of Ludwig Günther (1898) and Edward Rosen (1967)) shows, that Somnium is an important source of the history of science and not merely science fiction.

The lecture course "Space Travel and World View – Facts and Fiction" given by Walter Oberschelp in SS 2012 describes part of these results. A documentation is in preparation.

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 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)
 - RP 2012 (Workshop on Reachability Problems)
- 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 jury for the final round of "Bundeswettbewerb Informatik"
- Member of the program committees of the conferences:
 - FSTTCS 2012 (IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science)
 - GAMES 2012 (Annual Workshop of the ESF Networking Programme on Games for Design and Verification)
 - MOVEP 2012 (School for young researchers about Modelling and Verifying Parallel processes)

Talks and Publications

Talks

- N. Chaturvedi: On omega-Regular Trace Languages: Classification and Synthesis, Annual Workshop of the ESF Networking Programme on Games for Design and Verification, GAMES 2012, Naples, Italy, September 2012
- N. Chaturvedi: On omega-Regular Trace Languages: Classification and Synthesis, 4th Workshop on Games for Design, Verification and Synthesis, GASICS 2012, Newcastle upon Tyne, UK, September 2012
- N. Chaturvedi, M. Gelderie: Traces and Trace Languages: Tutorial, AlgoSyn Seminar, Aachen, July 2012
- I. Felscher: LTL-Model-Checking via Model Composition, RP 2012, Bordeaux, September 2012
- M. Gelderie: Strategy Machines and their Complexity, AlgoSyn Seminar, Aachen, February 2012
- M. Gelderie: Strategy Machines and their Complexity, MFCS 2012, Bratislava, Slovakia, August 2012
- M. Lang: Bounded reachability in resource pushdown systems, Automata Seminar, University of Warsaw, Poland, December 2011
- M. Lang: Bounded reachability in recursive systems with resources, AIMoTh 2012, Ilmenau, Germany, February 2012
- C. Löding: Tolerant Strategies in Infinite games, 21st Workshop on Games, Logic, language, and Interaction, ILLC, Universiteit van Amsterdam, November 2011
- D. Neider: Learning Small Strategies for Safety Games, ATVA 2011, Taipei, Taiwan, October 2011
- D. Neider: Regular Model Checking Using SAT and SMT Solvers, AlgoSyn Seminar, Aachen, Germany, February 2012
- D. Neider: Down the Borel Hierarchy: Solving Muller Games via Safety Games, GandALF 2012, Naples, Italy, September 2012
- J. Olschewski: Improved Ramsey-based Büchi Complementations, ETAPS 2012, Tallinn, Estonia, March 2012
- J. Olschewski: Improved Ramsey-based Büchi Complementations, Brussels, Belgium, November 2011
- S. Repke: Regularity Problems for Weak Pushdown omega-Automata and Games, MFCS 2012, Bratislava, Slovakia, August 2012
- A. Spelten: Trees over Infinite Structures and Path Logics with Synchronization, Infinity 2011, Taipei, Taiwan, October 2011
- W. Thomas: “Good” Strategies in Infinite Games, Dagstuhl, October 2011
- W. Thomas: Informatik und ihre zwei Kulturen, Workshop „Wissenskulturen“ des AKWG (Aachener Kompetenzzentrum für Wissenschaftsgeschichte), Aachen, Oktober 2011

W. Thomas: Computability in 1936: Pioneering Papers and Perspectives, Invited Talk, COMPUTING 2011, Karlsruhe, October 2011.

W. Thomas: Computability in 1936: Pioneering Papers and Perspectives, AlgoSyn Workshop, Rolduc, November 2011

W. Thomas, Unendliche Spiele und automatische Programmsynthese, Informatik-Kolloquium, Halle, November 2011.

W. Thomas: Computability in 1936: Pioneering Papers and Perspectives, Promotionskolleg der Universität Ulm, Reisensburg, February 2012

W. Thomas: Infinite Games for Verification and Synthesis: Basic Theory and Quantitative Aspects, Tutorial, School on Quantitative Model-Checking, Copenhagen, February 2012

W. Thomas: Algorithmen und Turingmaschinen: Eine historische Perspektive, Informatik-Didaktik-Kolloquium, Jena, March 2012.

W. Thomas: Alan Turing und die Grundfrage der Informatik: Was können Algorithmen? Informatik-Kolloquium, Aachen, April 2012

W. Thomas: Composition for Orders with an Extra Binary Relation, Workshop in Honor of Bruno Courcelle, Bordeaux, May 2012

W. Thomas: Synthesis and some of its challenges, keynote talk, CAV 2012 (Computer-Aided Verification), Berkeley (Cal.), July 2012.

W. Thomas: Alan Turing – Pionier und Visionär der Informatik, keynote talk, INFORMATIK 2012 (Jahrestagung der GI), Braunschweig, September 2012

W. Thomas: Games, Logic, and Strategies, Invited Lecture, GAMES, Naples, September 2012.

M. Zimmermann: Solving Infinite Games with Bounds, Oberseminar Informatik, RWTH Aachen University, Germany, February 2012

M. Zimmermann: Down the Borel Hierarchy: Solving Muller Games via Safety Games, Gasics Meeting, Brussels, Belgium, November 2011

M. Zimmermann: Playing Infinite Games in Finite Time, AlgoSyn Workshop 2011, Kerkrade, Netherlands, November 2011

M. Zimmermann: Playing Pushdown Parity Games in a Hurry, Games Workshop 2012, Naples, Italy, September 2012

M. Zimmermann: Playing Pushdown Parity Games in a Hurry, GandALF 2012, Naples, Italy, September 2012

M. Zimmermann: Playing Pushdown Parity Games in a Hurry, AISS 2012, Dubrovnik, Croatia, June 2012

M. Zimmermann: Down the Borel Hierarchy: Solving Muller Games via Safety Games, LICS 2012, Dubrovnik, Croatia, June 2012

M. Zimmermann: Solving Infinite Games with Bounds, Seminar Automata Theory, University of Warsaw, Poland, February 2012

Publications

[1] F. Baader and W. Thomas: Editorial (Special Issue on Alan Turing), Informatik Spektrum 35(4): 247-248, 2012.

- [2] P. Bouyer, N. Markey, J. Olschewski, and M. Ummels: Measuring permissiveness in parity games: Mean-payoff parity games revisited. In *Automated Technology for Verification and Analysis*, volume 6996 of *Lecture Notes in Computer Science*, pages 135-149. Springer, 2011.
- [3] S. Breuers, C. Löding, and J. Olschewski: Improved Ramsey-based Büchi complementation. In *FoSSaCS 2012*, volume 7213 of *Lecture Notes in Computer Science*, pages 150-164. Springer, 2012.
- [4] N. Chaturvedi, J. Olschewski, and W. Thomas: Languages vs. ω -languages in regular infinite games. *International Journal of Foundations of Computer Science*, 23(05):985-1000, August 2012.
- [5] J. Fearnley and M. Zimmermann: Playing Muller Games in a Hurry. *International Journal of Foundations of Computer Science*, 23:649-668, 2012, World Scientific Publishing Company.
- [6] I. Felscher: LTL-Model-Checking via Model Composition, *Reachability Problems*, 6th International Workshop, RP 2012, Bordeaux, France, September 17-19, 2012. Series: *Lecture Notes in Computer Science*, Vol. 7550, Subseries: *Theoretical Computer Science and General Issues*, editors: Finkel, Alain; Leroux, Jerome; Potapov, Igor, pages 42-53.
- [7] I. Felscher, W. Thomas: Compositional Failure Detection in Structured Transition Systems. In Béatrice Bouchou-Markho, Pascal Caron, Jean-Marc Champarnaud, and Denis Maurel, editors, *CIAA*, volume 6807 of *Lecture Notes in Computer Science*, pages 130-141. Springer, 2011.
- [8] N. Fijalkow and M. Zimmermann: Cost-parity and Cost-Streett Games. To appear at *FSTTCS 2012*
- [9] W. Fridman and M. Zimmermann: Playing Pushdown Parity Games in a Hurry. In M. Faella and A. Murano, editors, *Proceedings of the Third International Symposium on Games, Automata, Logic, and Formal Verification, GandALF 2012*, volume 95 of *Electronic Proceedings in Theoretical Computer Science*, pages 183-196, 2012.
- [10] M. Gelderie: Strategy machines and their complexity. Technical Report AIB-2012-04, RWTH-Aachen, 2012.
- [11] M. Gelderie: Strategy machines and their complexity. In Branislav Rován, Vladimiro Sassone, and Peter Widmayer, editors, *MFCS 2012*, vol. 7464 of *Lecture Notes in Computer Science*, p. 431-442. Springer Berlin / Heidelberg, 2012.
- [12] S. Grüner, F. Radmacher, and W. Thomas: Connectivity Games over Dynamic Networks. In *Proceedings of the 2nd International Symposium on Games, Automata, Logics and Formal Verification, GandALF 2011*, *ENTCS 54*, pp. 131-145, 2011.
- [13] M. Holtmann, L. Kaiser and W. Thomas: Degrees of Lookahead in Regular Infinite Games. *Logical Methods in Computer Science* 8(3), 2012
- [14] D. Isaak and C. Löding: Efficient inclusion testing for simple classes of unambiguous omega-automata. *Information Processing Letters*, 112(14-15):578-582, 2012
- [15] W. Thomas, M. Jarke: Die Informatik und ihre zwei Kulturen, in: H. Müller, F. Eber (Hrsg.), *Wissenskulturen, Bedingungen wissenschaftlicher Innovation*, *Studien des Aachener Kompetenzzentrums für Wissenschaftsgeschichte Bd. 12*, Kassel University Press 2012, pp. 117-126.

- [16] D. Klein, F. Radmacher and W. Thomas: Moving in a network under random failures: A complexity analysis. *Sci. Comput. Program.* 77(7-8): 940-954, 2012
- [17] M. Lang and C. Löding: Modeling and Verification of Infinite Systems with Resources. Submitted to *Logical Methods in Computer Science (LMCS, open-access journal)*
- [18] C. Löding: Basics on tree automata. In Deepak D'Souza and Priti Shankar, editors, *Modern Applications of Automata Theory*. World Scientific, 2012
- [19] C. Löding, S. Repke: Regularity Problems for Weak Pushdown omega-Automata and Games. In *MFCS 2012, LNCS vol. 7464*, p. 764-776.
- [20] D. Neider: Small strategies for safety games. In *Proceedings of the 9th Symposium on Automated Technology for Verification and Analysis (ATVA 2011)*, volume 6996 of *Lecture Notes in Computer Science*, pages 306-320, Springer, 2011.
- [21] D. Neider, R. Rabinovich, and M. Zimmermann: Down the Borel Hierarchy: Solving Muller Games via Safety Games. In M. Faella and A. Murano, editors, *Proceedings of the Third International Symposium on Games, Automata, Logic, and Formal Verification, GandALF 2012*, volume 95 of *Electronic Proceedings in Theoretical Computer Science*, pages 169-182, 2012.
- [22] F. Radmacher: *Games on Dynamic Networks: Routing and Connectivity*. PhD thesis, RWTH Aachen University, 2011.
- [23] U. Schöning and W. Thomas: Turings Arbeiten über Berechenbarkeit - eine Einführung und Lesehilfe. *Informatik Spektrum*, 35(4): 253-260, 2012
- [24] M. Slaats: *Infinite Regular Games in the Higher-Order Pushdown and the Parametrized Setting*. PhD thesis, RWTH Aachen University, 2011.
- [25] A. Spelten, W. Thomas, and S. Winter: Trees over infinite structures and path logics with synchronization. In Fang Yu and Chao Wang, editors, *Proceedings of the 13th International Workshop on Verification of Infinite-State Systems*, volume 73 of *EPTCS*, pages 20-34, 2011
- [26] W. Thomas: Infinite games and uniformization. In M. Banerjee and A. Seth, editors, *Proceedings of the 4th Indian Conference on Logic and Its Applications, ICLA 2011*, volume 6521 of *Lecture Notes in Computer Science*, pages 19-21. Springer, 2011.
- [27] W. Thomas: *Finite Automata and the Analysis of Infinite Transition Systems*. In Deepak D'Souza and Priti Shankar, editors, *Modern Applications of Automata Theory*. World Scientific, 2012
- [28] W. Thomas: *Synthesis and Some of Its Challenges*. In P. Madhusudan and Sanjit A. Seshia, editors, *CAV*, volume 7358 of *Lecture Notes in Computer Science*, page 1. Springer, 2012.
- [29] M. Zimmermann, *Solving Infinite Games with Bounds*. PhD thesis, RWTH Aachen University, 2012.
- [30] M. Zimmermann: *Optimal Bounds in Parametric LTL Games*. To appear in *Theoretical Computer Science*, Elsevier.

Mathematical Foundations of Computer Science



Staff

- **Faculty**
Prof. Dr. Erich Grädel
- **Secretary**
Silke Cormann
- **Research Assistants**
Dipl.-Inform. Faried abu Zaid
Dipl.-Inform. Diana Fischer
Dipl.-Inform. Simon Leßenich (since January 2012)
M.Sc. Francicleber Martins Ferreira (until February 2012)
Dipl.-Gyml. Wied Pakusa
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, S. Leßenich, 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, S. Leßenich, 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.

Partial Information in Logic and Games

E. Grädel, B. Puchala, R. Rabinovich.

Partial Information in Logic and Games (Partielle Information in Logik und Spielen) is a research project funded by the DFG (Deutsche Forschungsgemeinschaft) since November 2011. It is a follow-up of the LINT project (Logic for Interaction) that was funded by the ESF until September 2011 as part of the ESF EUROCORES research project LogICCC. It pursues and intensifies certain aspects of the research conducted within LINT.

The general objective of the project is the development and study of mathematical foundations for interaction, especially interaction under partial information. This includes modelling and classifying partial information in interactive scenarios as well as algorithmic solutions of relevant questions within formal models for interaction, especially games. Partial information is also closely related to the concepts of dependence and independence which form the basis of certain logical systems like Hintikka and Sandu's IF-logic and dependence logic, introduced more recently by Väänänen. The connection between these concepts and logics is explored further within this project, particularly with regard to model checking games. A central algorithmic question is that of strategy synthesis, that means, to decide whether a player or a group of players has a strategy for a given game that would guarantee them to reach a predefined goal and, if so, to construct such a strategy automatically.

Among current contributions to this research area has been the introduction of a new logical system, called independence logic, which is more expressive than dependence logic and facilitates systematic implementations of dependence and independence into logical systems as well as elaborate analyses of the relationship to imperfect information in the corresponding model checking games. Moreover, new algorithms for synthesizing winning strategies in games with imperfect have been developed that exploit different characteristics and magnitudes of partial information. Those algorithms improve known solutions with regard to the classes of games that they can handle and, at the other end of the spectrum, (worst case) running time.

Finite and Algorithmic Model Theory

E. Grädel, F. Abu Zaid, W. Pakusa, F. Martins Ferreira

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
- Editor of Mathematical Logic Quarterly
- Editor-in-Chief of FoLLI Publications on Logic, Language, and Information (Subline of LNCS)
- Member of the Programme Committees of GAMES 2011, ICALP2012, MEMICS2012, GandALF2012, GAMES 2012.

Talks and Publications

Talks

F. Abu Zaid, All omega-automatic integral domains are finite, Algorithmic Model Theory, Ilmenau, February 2012.

F. Abu Zaid, The Field of Reals is not omega-Automatic, 29th Symposium on Theoretical Aspects of Computer Science, Paris, March 2012.

F. Abu Zaid, The Field of Reals is not omega-Automatic, Workshop on Finite and Algorithmic Model Theory, Les Houches, May 2012.

Diana Fischer, Model Checking the Quantitative mu-Calculus on Initialised Linear Hybrid Systems, Long Lunch Seminar, Oxford, January 2012.

E. Grädel, Model-Checking Games for Logics of Incomplete Information, Workshop on Algorithmic Model Theory, Ilmenau, February 2012

E. Grädel, Dependence, Independence, and Incomplete Information. Keynote Talk at EDBT/ICDT 2012 Joint Conference, March 2012, Berlin

E. Grädel, Infinite Games, Game Theory Seminar, University of Maastricht, May 2012

S. Leßenich, A Counting Logic for Structure Transition Systems, DFG Research Training Group AlgoSyn Seminar, Aachen, January 2012.

S. Leßenich, Counter Games and Imperfect Recall, GRK Workshop 2012, Dagstuhl, June 2012.

S. Leßenich, Solving Counter Parity Games, 37th International Symposium on Mathematical Foundations of Computer Science, Bratislava, August 2012.

S. Leßenich, Banach-Mazur Games with Simple Winning Strategies, 21st EACSL Annual Conference on Computer Science Logic, Fontainebleau, September 2012.

S. Leßenich, Banach-Mazur Games with Simple Winning Strategies, Annual Meeting of GT Jeux, Cachan, September 2012.

W. Pakusa, Definability of linear equation systems over groups and rings, Workshop on Algorithmic Model Theory, Ilmenau, February 2012

W. Pakusa, Definability of linear equation systems over groups and rings, Logical Approaches to Barriers in Complexity II, Cambridge, March 2012

W. Pakusa, Definability of linear equation systems over groups and rings, Workshop on Finite and Algorithmic Model Theory, Les Houches, May 2012

Publications

- F. Abu Zaid, E. Grädel, and Ł. Kaiser. The Field of Reals is not omega-Automatic. In Proceedings of the 29th International Symposium on Theoretical Aspects of Computer Science, STACS 2012 (C. Dürr and T. Wilke, Eds.), 2012.
- D. Berwanger, Ł. Kaiser, and S. Leßenich. Solving Counter Parity Games. In Mathematical Foundations of Computer Science 2012 (B. Rovan, V. Sassone, and P. Widmayer, Eds.), vol. 7464 of Lecture Notes in Computer Science, pp. 160-171. Springer Berlin / Heidelberg, 2012.
- D. Berwanger, Ł. Kaiser, and B. Puchala. A Perfect-Information Construction for Coordination in Games. In 31st IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science, FSTTCS '11, pp. 387-398. Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2011.
- A. Dawar, E. Grädel, B. Holm, E. Kopczynski, and W. Pakusa. Definability of linear equation systems over groups and rings. In Computer Science Logic (CSL'12) - 26th International Workshop/21st Annual Conference of the EACSL (P. Cégielski, and A. Durand, Eds.), vol. 16 of Leibniz International Proceedings in Informatics (LIPIcs), pp. 213-227, Dagstuhl, Germany. Schloss Dagstuhl, Leibniz-Zentrum für Informatik, 2012.
- D. Fischer and Ł. Kaiser. Model Checking the Quantitative mu-Calculus on Linear Hybrid Systems. Logical Methods in Computer Science, vol. 8(3), 2012.
- T. Ganzow. Definability and Model Checking: The Role of Orders and Compositionality. PhD thesis, RWTH Aachen University, 2012.
- E. Grädel, F. Canavoi, and R. Rabinovich. The discrete strategy improvement algorithm for parity games and complexity measures for directed graphs. In Proceedings of the Third International Symposium on Games, Automata, Logic, and Formal Verification, GandALF 2012 (M. Faella and A. Murano, Eds.), Electronic Proceedings in Theoretical Computer Science, 2012.
- E. Grädel and S. Leßenich. Banach-Mazur Games with Simple Winning Strategies. In Computer Science Logic (CSL'12) - 26th International Workshop/21st Annual Conference of the EACSL (P. Cégielski, and A. Durand, Eds.), vol. 16 of Leibniz International Proceedings in Informatics (LIPIcs), pp. 305-319, Dagstuhl, Germany. Schloss Dagstuhl, Leibniz-Zentrum für Informatik, 2012.
- E. Grädel and S. Siebertz. Dynamic Definability. In Proceedings of 15th International Conference on Database Theory, ICDT 2012, 2012.
- E. Grädel and J. Väänänen. Dependence, Independence, and Incomplete Information. In Proceedings of 15th International Conference on Database Theory, ICDT 2012, 2012.
- Ł. Kaiser and S. Leßenich. A Counting Logic for Structure Transition Systems. In Computer Science Logic (CSL'12) - 26th International Workshop/21st Annual Conference of the EACSL (P. Cégielski, and A. Durand, Eds.), vol. 16 of Leibniz International Proceedings in Informatics (LIPIcs), pp. 366-380, Dagstuhl, Germany. Schloss Dagstuhl, Leibniz-Zentrum für Informatik, 2012.
- D. Neider, R. Rabinovich, and M. Zimmermann. Down the Borel Hierarchy: Solving Muller Games via Safety Games. In Proceedings of the Third International Symposium on Games, Automata, Logic, and Formal Verification, GandALF 2012 (M. Faella and A. Murano, Eds.), Electronic Proceedings in Theoretical Computer Science, 2012.

B. Puchala and R. Rabinovich. Graph Searching, Parity Games and Imperfect Information. arXiv:1110.5575v1 [cs.GT], 2011.

Computer Graphics and Multimedia

Staff

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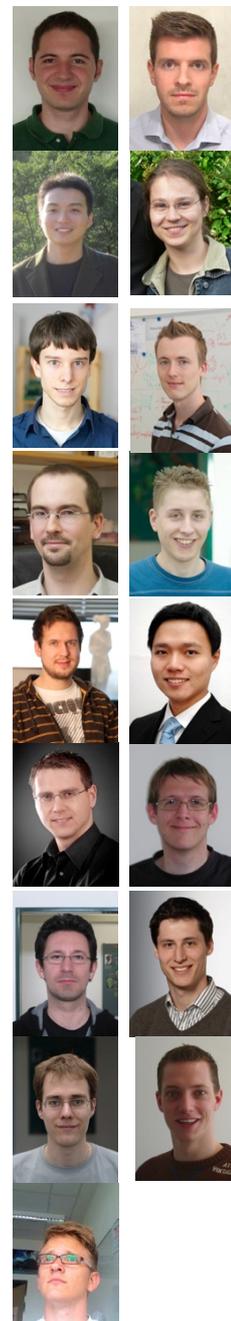
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Overview

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

The *Geometry Processing Unit* addresses research questions in the context of the generation, reconstruction, optimization, and modification of digital 3D models most often represented by polygonal meshes. The typical application domains for the algorithms developed in our group are CAD/CAM in architecture and engineering, simulation sciences, rapid prototyping, as well as medical applications. Our recent activities in Geometry Processing were concerned with the automatic generation of high-quality quad meshes and global patch layouts as well as 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 useable on mobile devices. In particular we are looking into ways how to overcome the restrictions implied by limited resources (e.g. compute performance, memory, transmission bit-rate) and how to recover and exploit the location context of the mobile user for novel application scenarios.

The *Computer Vision Unit* is concerned with the reconstruction of faithful 3D models from images and video. We distinguish different classes of objects, e.g., human faces in motion, static medium sized 3D objects, and entire urban environments. 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 partially reconstructed 3D model of the urban environment.

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. Extending these concepts to dynamic scenes will be the next challenge.

Besides the reconstruction of existing objects, we are also investigating new algorithms and concepts for the generation, modeling, 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.

Another 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.

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.

Our teaching curriculum currently comprises a number of basic and advanced courses covering the most important sub-disciplines in Graphics and Geometry Processing. Besides the "*Introduction to Computer Graphics*" course, Prof. Kobbelt is offering advanced courses on "*Geometry Processing*", "*Global Illumination*" and "*Game Programming*". On the undergraduate level we offer an introductory seminar and practical exercises on topics in Computer Graphics.

On the following pages, we are going to give a brief overview of our current research projects.

Research Projects

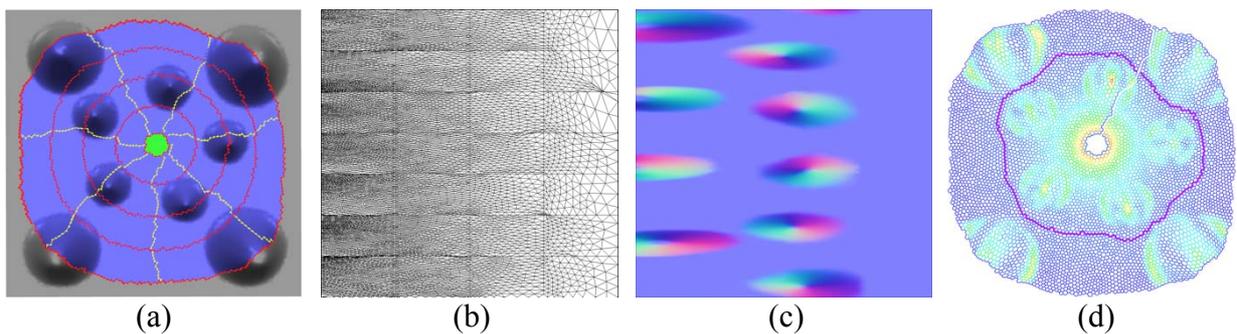
Geometry Seam Carving

Ellen Dekkers, Leif Kobbelt

In this project, we developed a novel approach to feature-aware mesh deformation. Previous mesh editing methods are based on an elastic deformation model and thus equally distribute the distortion in a least squares sense over the entire deformation region. Results from image resizing, however, show that discrete local modifications like deleting or adding connected seams of image pixels in regions with low saliency lead to far superior preservation of local features compared to uniform scaling -- the image-analogue to least squares mesh deformation. Hence, we developed a discrete mesh editing scheme that combines elastic as well as plastic deformation (in regions with little geometric detail) by transferring the concept of seam carving from image retargeting to the mesh deformation scenario.

A geometry seam consists of a connected strip of triangles within the mesh's deformation region. By collapsing or splitting the interior edges of this strip, we perform a deletion or insertion operation that is equivalent to image seam carving. We use a feature measure to rate the geometric saliency of each triangle in the mesh and a well-adjusted distortion measure to determine where the current mesh distortion asks for plastic deformations, i.e., for deletion or insertion of geometry seams. Pre-computing a fixed set of low-saliency seams in the deformation region allows us to perform fast seam deletion and insertion operations in a predetermined order such that the local mesh modifications are properly restored when a mesh editing operation is (partially) undone.

Geometry seam carving hence enables the deformation of a given mesh in a way that causes stronger distortion in homogeneous mesh regions while salient features are preserved much better.

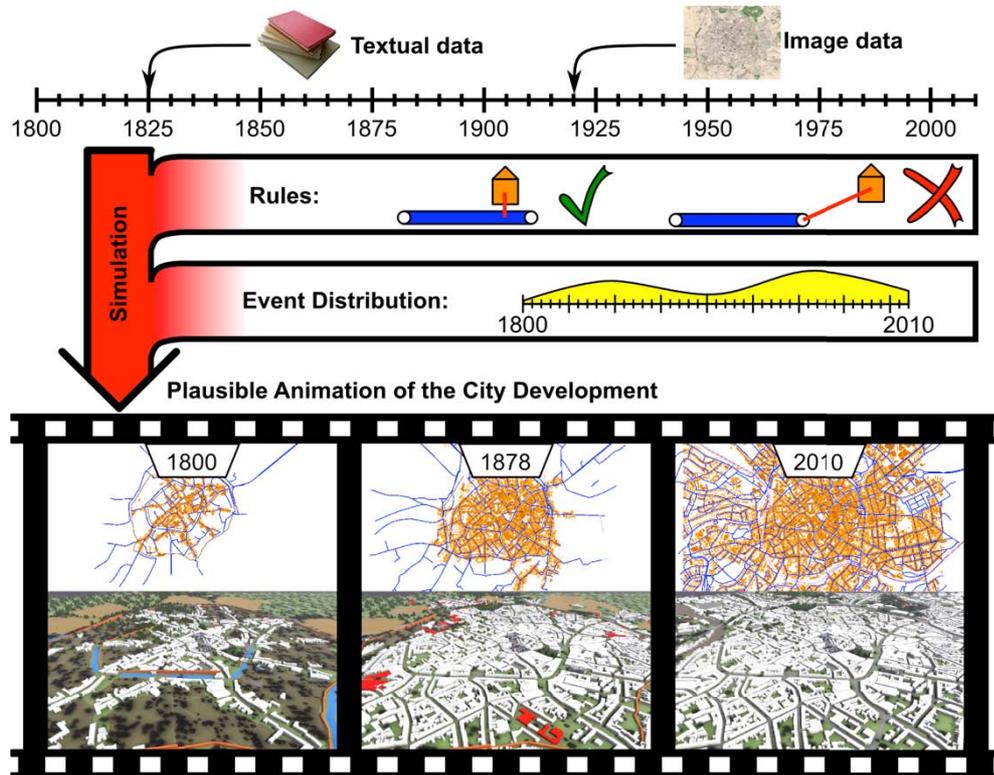


Our method is based on a parametrization (b) of a user-defined deformation region (a) on a given input model. A normal image (c) of this parameterization guides the computation of geometric seams (d) that can later be inserted or deleted during an interactive mesh editing session.

Procedural Interpolation of Historical City Maps

Lars Krecklau, Christopher Manthei, Leif Kobbelt

funded by B-IT Research School



We propose a novel approach for the temporal interpolation of city maps. The input to our algorithm is a sparse set of historical city maps plus optional additional knowledge about construction or destruction events. The output is a fast forward animation of the city map development where roads and buildings are constructed and destroyed over time in order to match the sparse historical facts and to look plausible where no precise facts are available. A smooth transition between any real-world data could be interesting for educational purposes, because our system conveys an intuition of the city development. The insertion of data, like when and where a certain building or road existed, is efficiently performed by an intuitive graphical user interface.

Our system collects all this information into a global dependency graph of events. By propagating time intervals through the dependency graph we can automatically derive the earliest and latest possible date for each event which are guaranteeing temporal as well as geographical consistency (e.g. buildings can only appear along roads that have been constructed before). During the simulation of the city development, events are scheduled according to a score function that rates the plausibility of the development (e.g. cities grow along major roads). Finally, the events are properly distributed over time to control the dynamics of the city development. Based on the city map animation we create a procedural city model in order to render a 3D animation of the city development over decades.

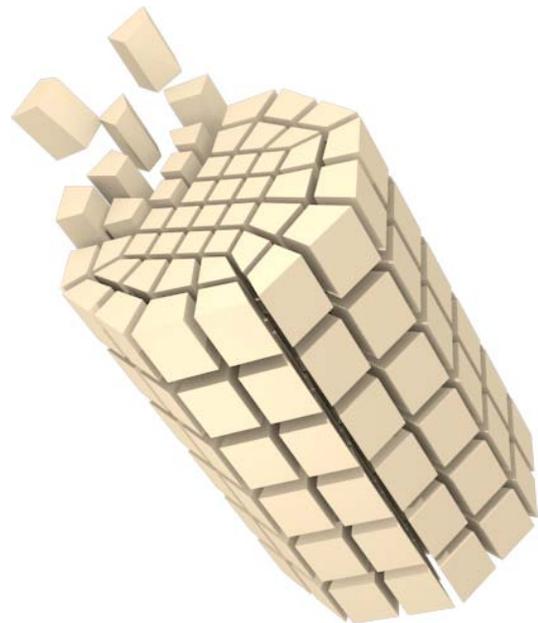
OpenVolumeMesh – A Versatile Index-Based Data Structure for 3D Polytopal Complexes

Michael Kremer, David Bommers, Leif Kobbelt

funded by AICES Graduate School

OpenVolumeMesh is a data structure which is able to represent heterogeneous 3-dimensional polytopal cell complexes and is general enough to also represent non-manifolds without incurring undue overhead. Extending the idea of half-edge based data structures for two-manifold surface meshes, all faces, i.e. the two-dimensional entities of a mesh, are represented by a pair of oriented half-faces.

The concept of using directed half-entities enables inducing an orientation to the meshes in an intuitive and easy to use manner. We pursue the idea of encoding connectivity by storing first-order top-down incidence relations per entity, i.e. for each entity of dimension d , a list of links to the respective incident entities of dimension $d-1$ is stored. For instance, each half-face as well as its orientation is uniquely determined by a tuple of links to its incident half-edges or each 3D cell by the set of incident half-faces. This representation allows for handling non-manifolds as well as mixed-dimensional mesh configurations. No entity is duplicated according to its valence, instead, it is shared by all incident entities in order to reduce memory consumption. Furthermore, an array-based storage layout is used in combination with direct index-based access. This guarantees constant access time to the entities of a mesh. Although bottom-up incidence relations are implied by the top-down incidences, our data structure provides the option to explicitly generate and cache them in a transparent manner. This allows for accelerated navigation in the local neighborhood of an entity.



We provide an open-source and platform-independent implementation of the proposed data structure written in C++ using dynamic typing paradigms. The library is equipped with a set of STL compliant iterators, a generic property system to dynamically attach properties to all entities at run-time, and a serializer/deserializer supporting a simple file format. Due to its similarity to the OpenMesh data structure, it is easy to use, in particular for those familiar with OpenMesh. Since the presented data structure is compact, intuitive, and efficient, it is suitable for a variety of applications, such as meshing, visualization, and numerical analysis.

OpenVolumeMesh is open-source software licensed under the terms of the LGPL and can be downloaded from www.openvolumemesh.org.

The Design of a Segway AR-Tactile Navigation System

Ming Li, Lars Mahnkopf, Leif Kobbelt

funded by B-IT Research School



A Segway is often used to transport a user across mid-range distances in urban environments. It has more degrees of freedom than car/bike and is faster than pedestrian. However a navigation system designed for it has not been researched. The existing navigation systems are adapted for car drivers or pedestrians. Using such systems on the Segway can increase the driver's cognitive workload and generate safety risks. In this paper, we present a Segway AR-Tactile navigation system, in which we visualize the route through an Augmented Reality interface displayed by a mobile phone. The turning instructions are presented to the driver via vibro-tactile actuators attached to the handlebar. Multiple vibro-tactile patterns provide navigation instructions. We evaluate the system in real traffic and an artificial environment. Our results show the AR interface reduces users' subjective workload significantly. The vibro-tactile patterns can be perceived correctly and greatly improve the driving performance.

Improving Image-Based Localization by Active Correspondence Search

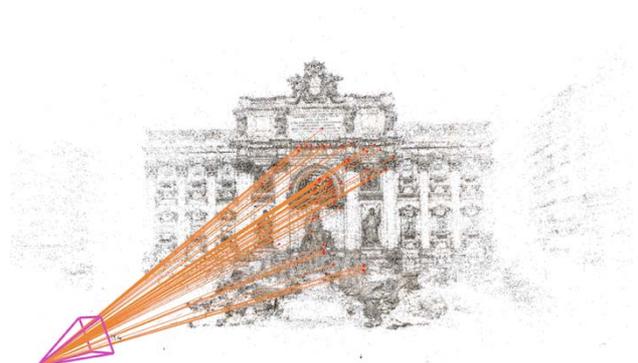
Torsten Sattler, Bastian Leibe, Leif Kobbelt

funded by UMIC

With the widespread adoption of computationally powerful smartphones, location-aware services are gaining popularity as they enable many interesting applications, such as tourist information and navigation. While in some scenarios the localization accuracy of sensors such as GPS, gyro-, or accelerometers is sufficient, other applications such as Augmented Reality systems require much more precise estimates.

These demands for higher localization accuracy can be met using image-based localization approaches which try to determine the position from which an image was taken relative to a 3D model. Here, the challenge is to quickly establish correspondences between points in the image and 3D points in the model as these are needed to estimate the pose of the camera, i.e., its position and orientation. This matching problem is made difficult due the sheer size of the models, which consists of millions of 3D points. As a result, it is hard to achieve both efficiency, i.e., fast localization times, and effectiveness, i.e., being able to localize as many images as possible.

In this project, we have developed a matching approach that is both effective and efficient. It is able to register as many images as methods that run for multiple seconds. At the same time, our approach preserves, or even improves on, the good efficiency of our previous method. This increase in performance is made possible by exploiting information about co-visibility of 3D points that we obtained when creating the model. Once we find an initial 2D-to-3D match, we are able to quickly generate and verify a list of other matching candidates, which helps to bootstrap the matching process. We further use co-visibility information to accelerate other parts of the localization pipeline.



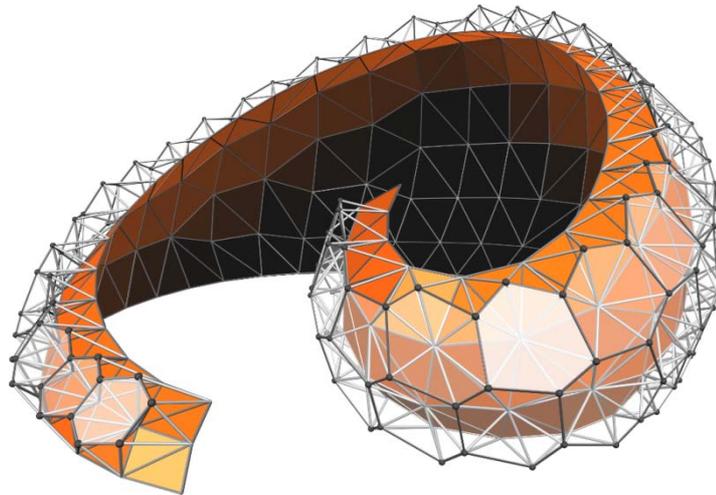
The left image shows a typical query image. Using local features describing salient regions in the image, we are able to establish correspondences between 2D points in the query image and 3D points in the model (orange lines in the right image). The pink pyramid in the right image symbolizes the estimated camera pose of the query image. Even when matching against large models containing more than 1 million points, our system only needs 250-300 ms on average to compute the correspondences and determine the pose.

Variational Tangent Plane Intersection for Planar Polygonal Meshing

Henrik Zimmer, Marcel Campen, Ralf Herkrath, Leif Kobbelt

Several theoretical and practical geometry applications are based on polygon meshes with planar faces. The planar *panelization* of freeform surfaces is a prominent example from the field of *architectural geometry*. One approach to obtain a certain kind of such meshes is by intersection of suitably distributed tangent planes. Unfortunately, this simple tangent plane intersection (TPI) idea is limited to the generation of hex-dominant meshes: as vertices are in general defined by three intersecting planes, the resulting meshes are basically duals of triangle meshes. The explicit computation of intersection points furthermore requires dedicated handling of special cases and degenerate constellations to achieve robustness on freeform surfaces. Another limitation is the small number of degrees of freedom for incorporating design parameters.

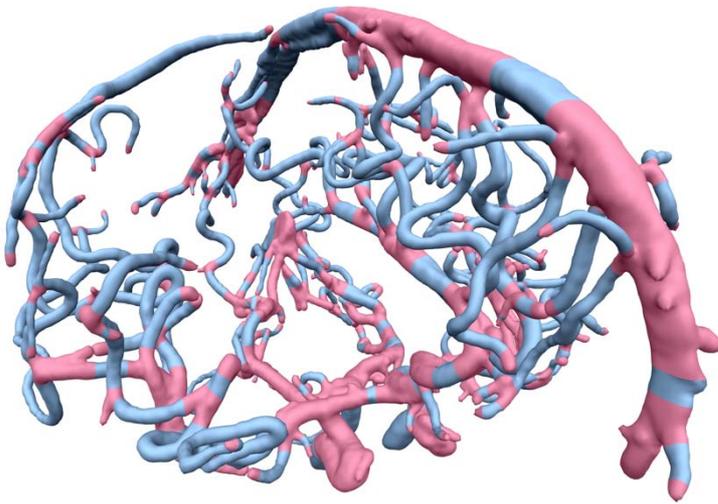
Using a variational re-formulation, we equipped the concept of TPI with additional degrees of freedom to obtain a robust, unified approach for creating polygonal structures with planar faces that is readily able to integrate various objectives and constraints needed in different applications scenarios.



This formulation is not only able to elegantly handle the task of planar panelization, but with an additional set of constraints, it can be used to create a certain kind of intersection-free *Multi-Layer Support Structures* – a structural concept which has received much attention in recent research in the area of architectural geometry.

Topology aware Quad Dominant Meshing for Vascular Structures

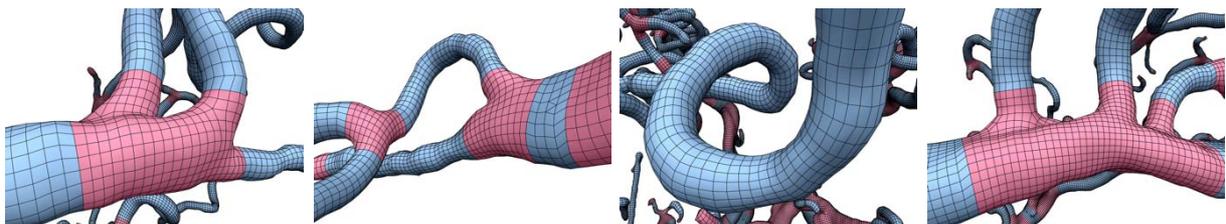
Dominik Sibbing, Hans-Christian Ebke, Kai Ingo Esser, Leif Kobbelt



Modern medical imaging techniques like, e.g., Magnetic Resonance Imaging (MRI) or X-ray computed tomography (CT) are able to capture many details of anatomical structures. Often however the relevant information is hidden by additional data, simultaneously collected during the scan. Besides this, a pure image based representation is often insufficient for subsequent processing. Mesh based representations on the other hand open the door to a broad range of

applications, like physical simulation (fluid simulation, deformable objects), high quality renderings (global illumination and shadows) or even modeling and animation. Such polygonal meshes often have to fulfill some application specific quality requirements. Compared to commonly used unstructured triangular representations, shape-adaptive quad meshes have proven to be visually more pleasant, require fewer elements, produce much more stable results for Finite Elements Methods and enable the implementation of intuitive modeling metaphors.

We present a pipeline to generate high quality quad dominant meshes for vascular structures from a given volumetric image like (see below). As common for medical image segmentation we use a Level Set approach to separate the region of interest from the background. However in contrast to the standard method we control the topology of the deformable object – defined by the Level Set function – which allows us to extract a proper skeleton which represents the global topological information of the vascular structure. Instead of solving a complex global optimization problem to compute a quad mesh, we divide the problem and partition the complex model into junction and tube elements, employing the skeleton of the vascular structure. After computing quad meshes for the junctions using the Mixed Integer Quadrangulation approach, we re-mesh the tubes using an algorithm inspired by the well-known Bresenham Algorithm for drawing lines which distributes irregular elements equally over the entire tube element.



Dual Loops Meshing: Quality Quad Layouts on Manifolds

Marcel Campen, David Bommes, Leif Kobbelt

funded by DFG Cluster of Excellence UMIC, grant DFG EXC 89

In recent years a wealth of automatic quad-meshing techniques has been presented. These enable the construction of high-quality quad meshes – with controlled element alignment, orientation, sizing, aspect ratio, etc. Together with the inherent ability of orienting elements according to principal curvature directions, the regularity and structuredness of quad meshes provide benefits over traditional triangle meshes in numerous application areas.

So far, however, significantly less attention has been paid to the high-level, global structure of the resulting meshes. On this level, each quad mesh implicitly defines a unique coarsest underlying patch layout with quadrilateral patches, also termed base complex. In practice, the quality of this patch layout of a quad mesh is of interest for numerous reasons. It is desired to be coarse and simple (while still appropriately respecting the underlying geometry) in order to enable a broad and efficient applicability in many areas.

In this project we analyzed the fundamental structural constraints and geometric requirements which constitute the general class of quad layouts and, based on that, developed a theoretical framework and novel practical method for the automatic construction of simple, all-quadrilateral patch layouts on three-dimensional object surfaces. The resulting layouts are ideally suited as domains and base complexes for surface parameterization, spline fitting, or subdivision surfaces and can be used to generate quad meshes with a high-level patch structure that are advantageous in many application scenarios. Our approach is based on the careful construction of the layout graph's combinatorial dual graph. In contrast to the primal, this dual perspective provides direct control over the globally interdependent structural constraints inherent to quad layouts. The dual layout is built from curvature-guided, crossing loops on the surface. A novel method to construct these efficiently in a geometry- and structure-aware manner constitutes the core of our approach.

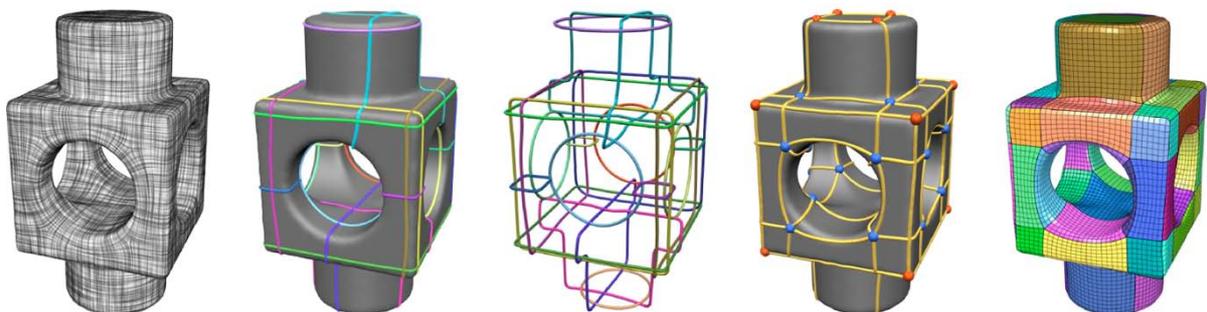


Illustration of our method operating on an example object. Far left: visualization of principal curvature directions. Middle left and middle: curvature-guided loops forming a dual layout. Middle right: primal layout, consisting of only quadrilateral regions. Right: quad mesh generated from the layout; its high-level patch structure is visualized using a color per patch.

Texture Synthesis

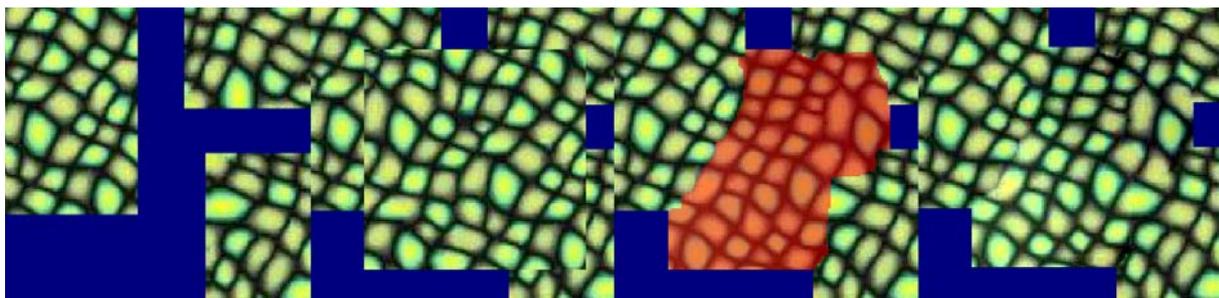
Johannes Frohn, Leif Kobbelt

In a wide variety of applications textures are used to define surface properties such as color or small scale geometry and are vital for a realistic visual appeal of virtual objects. With the increasing demand for high quality by movie and game productions as well as industrial manufacturing the creation process of such textures becomes a time consuming process. The traditional method of tiling a small sample texture to generate a bigger one fails because it is limited to very uniform patterns. For a naturally varying pattern the tiling will be immediately apparent. Procedural methods that generate textures by evaluating a parameterized generator function present an alternative. However, here the difficulty lies in selecting the right parameters and especially the right generator function to achieve a desired outcome.

In our texture synthesis project we propose a hybrid approach by allowing two basic operations that can be performed either automatically or by user request. Given a sample texture the first operation allows to copy fragments from the sample into an output texture. The second operation is able to fill in content in between copied fragments. While the first operation assures that the overall look of the sample texture is preserved the second operation allows arbitrary placement of the fragments without introducing gaps. To make this work special care has to be taken for the fill in operation such that it results in a seamless blending.

Based on the content around the area to be filled our algorithm searches a fragment in the sample texture which maximizes a cross-correlation energy. Rewriting the cross-correlation as a convolution allows us to compute the energy in the Fourier domain thus reducing the complexity. The found fragment is embedded into the output texture by computing an optimal blending seam. The pixel grid is encoded as a graph where edge weights are assigned according to differences between neighboring pixel from the output texture and the found fragment. The solution of a graph-cut minimization returns the least visible seam and determines where the blending should take place. To account for slight differences in pixel color the content is not copied directly but rather used to define the image gradient in the area. The actual pixel values are computed by solving a 2D Poisson equation which is constrained by the pixel values at the blending seam and the gradient retrieved from the found fragment.

Our implementation of the algorithm computes the cross-correlation with the help of the graphics card and also the iterative multi grid 2D Poisson solver takes advantage of the GPU. This allows us to achieve feedback at an interactive rate. In addition the texture synthesis framework allows to process even Gigapixel sized images and is thus applicable for the highest quality needs.



Copied fragments best matching fragment optimal seams final result

OpenFlipper – An Open Source 3D Geometry Modeling Framework

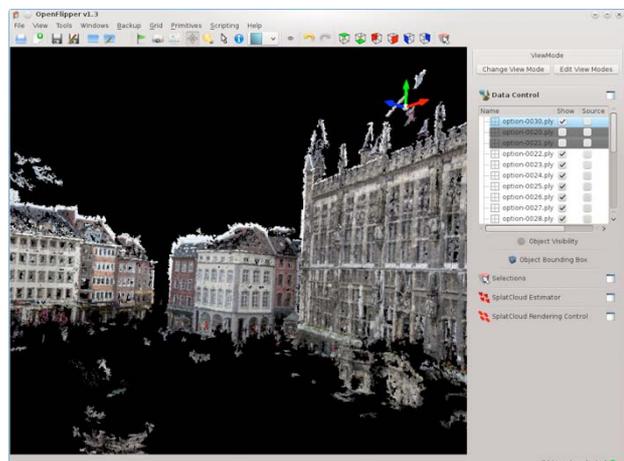
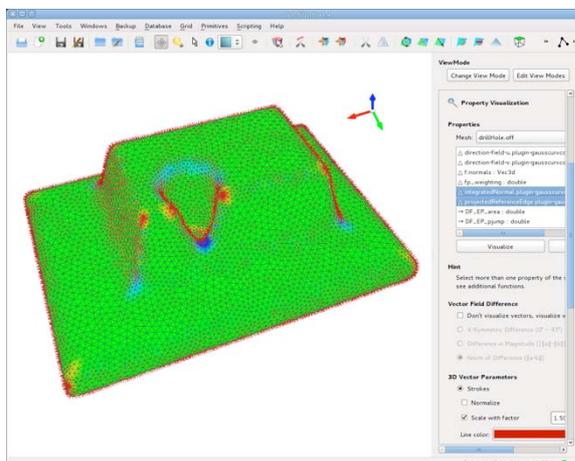
Jan Möbius, Leif Kobbelt

In 2010, we started to develop our open source 3D geometry processing and modeling framework OpenFlipper. The main goal of this framework has been to create a flexible modular software basis that reduces the coding effort not only for the implementation of new research projects but also for the development of commercial applications from these projects. This goal was achieved by providing basic functionality like selections, rendering and of course various geometry processing algorithms to the framework. The developers can therefore build on a large pool of existing algorithms for their own research projects, allowing them to focus on the scientific aspects of their work.

One integral part that has been significantly improved over the last year is the analysis of polygonal meshes. Most algorithms compute or depend on various properties that are attached to the meshes. For example quad-meshing algorithms need to evaluate the Gaussian curvature (left figure below) to estimate good positions for singular vertices. The new Property Visualization Plugin can be used to visualize arbitrary properties attached to a mesh and therefore helps researchers to analyze the influence of these properties on their algorithms. Furthermore, a plugin has been introduced to compare meshes based on their distance, normal deviation, and other measures, to evaluate how the surface is changed by an algorithm.

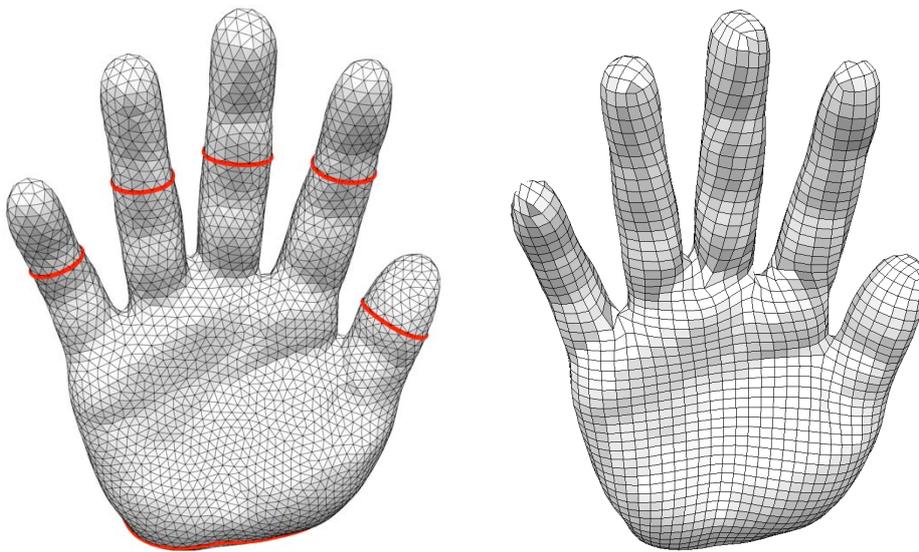
We also added new data types to the framework to deal with new research requirements. Beside the creation of good quad meshes, we also investigate the creation of volumetric meshes constructed of various primitives. The new OpenVolumeMesh data type allows for easy creation of and navigation on such volumetric meshes. It supports comfortable handling of arbitrary polytopal meshes and is directly integrated in OpenFlipper. To simplify the analysis of the interior of these volumetric meshes, we added a Dual Depth Peeling Renderer that is capable of rendering transparency such that one can easily look inside the volume. Furthermore we added polygonal lines as a separate data type which can be used to guide the corresponding meshing algorithms.

The rendering of splat clouds has been analyzed and improved to get a better performance when handling large data sets. Especially for city reconstructions (right figure) where several millions of points have to be handled, this leads to a much better reaction time of the system.



Evaluation of a Class of Non-Linear Energies for High Quality Integer Grid Parametrizations

Hans-Christian Ebke, David Bommes, Leif Kobbelt



In recent years, parametrization based quad meshing approaches such as the Mixed-Integer Quadrangulation method have proven to be powerful and versatile. Usually they comprise four steps: The estimation of principal curvature directions, the construction of a smooth cross field based on these directions, the parametrization of the input mesh guided by the cross field and the extraction of the quad mesh defined by the canonical integer grid in the parameter domain. In our work we focus on the third step, the parametrization of the input mesh, and develop an alternative parametrization approach. For all other parts of the pipeline we rely on our existing Mixed-Integer Quadrangulation (MIQ) implementation.

In the traditional MIQ approach a convex energy penalizing the deviation of the parametrization from the guiding cross field is optimized. Thus, a parametrization which is optimally aligned to the input guiding field in a least squares sense is generated. We examine a different, non-convex energy which does not prescribe an orientation, leaving it as a degree of freedom while optimizing for the least amount of distortion. As a sensible target orientation of the parametrization can only be determined with confidence in areas of high anisotropic curvature on the input surface, the guiding field required for the traditional parametrization energy interpolates these directions in areas of low curvature. We propose to use said energy without target orientation in areas where no target orientation can be determined in order to achieve parametrizations with less distortion.

As the optimization of a non-convex energy incurs significantly higher computational complexity we are currently in the process of optimizing our method in order to find an acceptable tradeoff between higher quality results and the inevitable slower run time.

City Rendering

Jan Robert Menzel, Leif Kobbelt

Maps based on aerial images are well established for online as well as offline maps applications from various providers. Recently, these maps were augmented by 3D reconstructions of individual buildings in urban regions. The automatic creation of these 3D city models is still an active research field.

The resulting models used today in 3D maps are still coarse representations of the actual buildings with low resolution textures and few details on the facades. Current 3D city representations are thus not suited to allow high quality renderings of scenes at street level. This however is desirable for many applications, e.g., for pedestrian navigation, city planning, gaming or virtual tourism.

There are some challenges to provide realistic renderings of real cities with high details at street level. E.g. the most widely available input data are random sets of street level photos, often taken with different cameras at different times or even dates. Pedestrians or vehicles may occlude the buildings from some perspectives but not from others, a problem that is less obvious when creating low resolution building textures. 3D scans can have the same problems with occluders and are less likely to be available.

We evaluate ways to combine the available input data into a consistent city model that can be visualized in real-time. When the goal is to represent realistic facades from any position in a city, the huge amount of data in total becomes a problem of its own. Efficient ways of compressing or streaming the city representation have to be evaluated.

Currently we are working on merging street level photos taken at different locations, times, cameras and camera settings into one facade model which represents the appearance of this building best from the given virtual camera position and angle.



The image on the left shows a facade textured with parts of street-level photos. As those were taken under various lighting conditions, the borders are quite visible. On the right side the colors are adjusted to mimic one virtual photo of the full building.

Other Activities

Prof. Dr. Leif Kobbelt

Committees

- Member of the International Papers Committee, ACM SIGGRAPH 2012
- Member of the International Program Committee Eurographics 2012
- Member of the International Program Committee 10th Symposium on Geometry Processing 2012
- Member of the International Program Committee of the Symposium on Solid and Physical Modeling SPM 2012
- Member of the Program Committee of the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games (I3D) 2012
- Member of the International Program Committee Pacific Graphics Conference, PG 2012
- Member of the International Program Committee 3D Imaging, Modeling, Processing, Visualization & Transmission, 3DIMPVT 2012
- Member of the International Program Committee: Geometric Modeling and Processing 2012 (GMP 2012)
- Member of the International Program Committee of Computational Visual Media Conference, CVM 2012, Tsinghua University, Beijing, China
- Member of the International Program Committee Point Cloud Processing in Computer Vision (PCP2012) Workshop, CVPR 2012
- Member of the International Program Committee, 8th International Symposium on Visual Computing, ISVC 2012

Other Academic Activities

- Member of the RWTH Steering Committee for the Profile Area: “Computational Science & Engineering” (Institutional Strategy for the DFG Excellence Initiative), 2012 -
- 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 2009-2015
- 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

- M. Habbecke, L. Kobbelt
Linear Analysis of Non-Linear Constraints for Interactive Geometric Modeling
Günter Enderle Best Paper Award (1. Prize), Eurographics 2012

Major Research Grants

Prof. Dr. Leif Kobbelt

- “PREserv”
Wettbewerb “IKT.NRW”, Ziel 2-Programm (EFRE), 2012-2015
- “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), 2011-2012
- “Research and Development of Algorithms for the Reconstruction and Animation of Digital Models” Verold Ltd. (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, 2006-2017, German Research Foundation (DFG), principal investigator
- “B-IT Research School for Applied Informatics”
Graduate school, 2009-2013, State Government of North-Rhine-Westphalia, principal investigator, area coordinator “Computer Graphics”

Talks and Publications

Invited Talks

“Geometric Modeling on Different Levels of Abstraction”
Workshop on Mesh Processing in Medical Image Analysis at MICCAI, MeshMed 2012,
Nice, France

Invited Speaker at Computational Visual Media Conference, CVM 2012,
Tsinghua University, Beijing, China

Invited Speaker at Vision, Modeling, and Visualization Conference 2012
Magdeburg, Germany

Conference presentations

R. Menzel, M. Königs, L. Kobbelt: *A Framework for Vision-based Mobile AR Applications*,
MobileHCI 2012, San Francisco, USA, September 2012

H. Zimmer, M. Campen, R. Herkrath, L. Kobbelt, *Variational Tangent Plane Intersection for
Planar Polygonal Meshing*, Advances in Architectural Geometry 2012, Paris, France,
September 2012

T. Sattler, T. Weyand, B. Leibe, L. Kobbelt, *Image Retrieval for Image-Based Localization
Revisited*, British Machine Vision Conference (BMVC) 2012, Surrey, Great Britain,
September 2012

T. Sattler, B. Leibe, L. Kobbelt, *Improving Image-Based Localization by Active
Correspondence Search*, in: Lecture Notes in Computer Science (LNCS): 12th European
Conference on Computer Vision (ECCV), Florence, Italy, October 2012

M. Li, L. Mahnkopf, L. Kobbelt, *The Design of a Segway AR-Tactile Navigation System*,
Pervasive 2012, Newcastle, UK, June 2012

M. Kremer, D. Bommes, L. Kobbelt, *OpenVolumeMesh - A Versatile Index-Based, Data
Structure for 3D Polytopal Cell Complexes*, 21st International Meshing Roundtable, San José,
CA, USA, October 2012

M. Campen, D. Bommes, L. Kobbelt, *Dual Loops Meshing: Quality Quad Layouts on
Manifolds*, Siggraph 2012, Los Angeles, August 2012

M. Campen, M. Attene, L. Kobbelt, *A Practical Guide to Polygon Mesh Repairing*,
Eurographics 2012 Tutorial Course, Cagliari, Italy, May 2012

L. Krecklau, L. Kobbelt, *Interactive Modeling by Procedural High-Level Primitives*, SMI
2012, College Station, Texas, USA, May 2012

L. Krecklau, C. Manthei, L. Kobbelt, *Procedural Interpolation of Historical City Maps*,
Eurographics 2012, Cagliari, Italy, May 2012

Publications

K. Arning, M. Ziefle, M. Li, L. Kobbelt Title, *Insights into user experiences and acceptance
of mobile indoor navigation devices*, 11th International Conference on Mobile and Ubiquitous
Multimedia (MUM) 2012, December 4-6 2012, Ulm, Germany

M. Attene, M. Campen, L. Kobbelt, *Polygon Mesh Repairing: An Application Perspective*,
ACM Computing Surveys, to appear 2013

- D. Bommes, H. Zimmer, L. Kobbelt, *Practical Mixed-Integer Optimization for Geometry Processing*, in: Curves and Surfaces – 7th International Conference, Series: Lecture Notes in Computer Science, Vol. 6920/2012, pp. 193-206, ISBN 978-3-642-27412-1
- M. Campen, D. Bommes, L. Kobbelt, *Dual Loops Meshing: Quality Quad Layouts on Manifolds*, Siggraph 2012, in: ACM Transactions on Graphics, Vol. 31 (4), Article No. 110, 2012
- M. Habbecke, L. Kobbelt, *Linear Analysis of Nonlinear Constraints for Interactive Geometric Modeling*, Günter Enderle Award (1. Prize), Eurographics 2012, in: Computer Graphics Forum, Vol. 31 (2), 2012, pp. 641-650, Wiley-Blackwell, ISSN 0167-7055
- W. Jarosz, V. Schönefeld, L. Kobbelt, H. W. Jensen, *Theory, Analysis and Applications of 2D Global Illumination*, Transactions on Graphics (ACM TOG)
- L. Krecklau, C. Manthei, L. Kobbelt, *Procedural Interpolation of Historical City Maps*, Eurographics 2012, in: Computer Graphics Forum, Vol. 31 (2pt3), 2012, pp. 691-700, ISSN 1467-8659, Blackwell Publishing Ltd
- L. Krecklau, L. Kobbelt, *Interactive Modeling by Procedural High-Level Primitives*, Shape Modeling International (SMI) 2012, in: Computers and Graphics, Vol. 36 (5), 2012, pp. 376-386, ISSN 0097-8493, Pergamon Press, Inc.
- M. Kremer, D. Bommes, L. Kobbelt, *OpenVolumeMesh - A Versatile Index-Based, Data Structure for 3D Polytopal Cell Complexes*, 21st International Meshing Roundtable, 2012, San José, CA, USA
- M. Li, L. Kobbelt, *Dynamic Tiling Display: Building an Interactive Display Surface using Multiple Mobile Devices*, 11th International Conference on Mobile and Ubiquitous Multimedia (MUM 2012)
- M. Li, L. Mahnkopf, L. Kobbelt, *The Design of a Segway AR-Tactile Navigation System*, in: Lecture Notes in Computer Science (LNCS), Pervasive Computing, Vol. 7319, 2012, pp. 161-178, Springer Verlag Berlin Heidelberg, ISBN 978-3-642-31204-5
- R. Menzel, M. Königs, L. Kobbelt: *A Framework for Vision-based Mobile AR Applications*, MobileHCI 2012
- J. Möbius, L. Kobbelt, *OpenFlipper, an Open Source Geometry Processing and Rendering Framework*, in: Curves and Surfaces - 7th International Conference 2010, Avignon, France, Series: Lecture Notes in Computer Science, Vol. 6920/2012, pp. 488-500, Springer, ISBN 978-3-642-27412-1
- T. Sattler, B. Leibe, L. Kobbelt, *Improving Image-Based Localization by Active Correspondence Search*, in: Lecture Notes in Computer Science (LNCS): 12th European Conference on Computer Vision (ECCV), Proceedings, Part I, Vol. 7572, 2012, pp. 752-765, Springer Verlag, Berlin/Heidelberg, ISBN 978-3-642-33717-8
- T. Sattler, B. Leibe, L. Kobbelt, *Towards Fast Image-Based Localization on a City-Scale*, in: Lecture Notes in Computer Science (LNCS), Outdoor Large-Scale Real-World Scene Analysis, Vol. 7474, 2012, pp. 191-211, Springer Verlag Berlin Heidelberg, ISBN 978-3-642-34090-1
- T. Sattler, T. Weyand, B. Leibe, L. Kobbelt, *Image Retrieval for Image-Based Localization Revisited*, British Machine Vision Conference (BMVC) 2012
- A. Schmitz, T. Karolski, L. Kobbelt, *Using Spherical Harmonics for Modeling Antenna Patterns*, IEEE Radio and Wireless Symposium, 15th - 18th January 2012, Santa Clara, USA

D. Sibbing, H.-C. Ebke, K. I. Esser, L. Kobbelt, *Topology Aware Quad Dominant Meshing for Vascular Structures*, in: Lecture Notes in Computer Sciences (LNCS), Vol. 7599, 2012, pp. 147-158, Springer Verlag Berlin Heidelberg, ISBN 978-3-642-33462-7

A. Schmitz, T. Karolski, L. Kobbelt, *Using Spherical Harmonics for Modeling Antenna Patterns*, IEEE Radio and Wireless Symposium, 15th – 18th January 2012, Santa Clara, USA

C. Schretter, L. Kobbelt, P.-O. Dehaye, *Golden Ratio Sequences for Low-Discrepancy Sampling*, in: Journal of Graphics Tools, Vol. 16 (2), 2012, pp. 95-104, Taylor & Francis, ISSN 2165-347X

H. Zimmer, M. Campen, D. Bommes, L. Kobbelt, *Rationalization of Triangle-Based Point-Folding Structures*, Eurographics 2012, in: Computer Graphics Forum, Vol. 31, (2pt3), 2012, pp. 611–620

H. Zimmer, M. Campen, R. Herkrath, L. Kobbelt, *Variational Tangent Plane Intersection for Planar Polygonal Meshing*, Advances in Architectural Geometry 2012, in: Advances in Architectural Geometry 2012, pp. 319-332, Springer Verlag, ISBN 978-3-7091-1250-2

LuFG Informatik 8 (Computer Vision)

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Dipl.-Inform. Patrick Sudowe (*funded by UMIC*)
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- **Guests**

Javier Marin Tur



Overview

The Research Group *Computer Vision* at the Chair of *Computer Graphics, Computer Vision, and Multimedia* at RWTH Aachen University focuses on innovative research in Computer Vision and Machine learning, in particular for mobile applications.

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, mobile visual search, and image based localization 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 and localization. We are pursuing this research line in close collaboration with Prof. Kobbelt’s group and within the cluster of excellence UMIC.

Our teaching curriculum currently comprises several basic and advanced courses covering the most important sub-disciplines in Computer Vision and Machine Learning. Prof. Leibe offers courses on “*Computer Vision*” and “*Machine Learning*”, which will be supplemented by a new course on “*Advanced Machine Learning*” in the upcoming Winter semester 2012/13. In addition, we periodically offer a seminar on “*Current Topics in CV and ML*”. On the undergraduate level, Prof. Leibe teaches the lecture “*Betriebssysteme und Systemsoftware*” in a 3-year rotation together with Prof. Wehrle and Prof. Ney (last time in Summer 2012).

The past year was very successful for our group. Prof. Leibe received an **ERC Starting Grant** comprising a funding sum of 1.5M EUR over a period of 5 years. Together with 3 newly starting EU projects (1 IP and 2 STREPs), this grant will allow our group to expand further increasing our research output. In addition, Prof. Leibe was awarded the prestigious **U.V. Helava Award** for the best paper in the International Journal of Photogrammetry and Remote Sensing in the 4-year period of 2008-2011. Last but not least, he received an **Intel Young Faculty Research Award**.

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

On the following pages, we will give a brief overview of our current research projects.

Research Projects

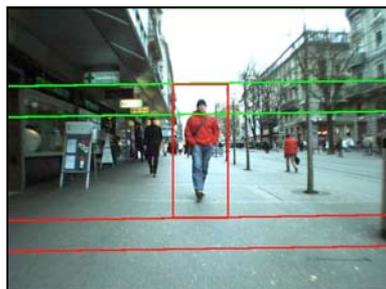
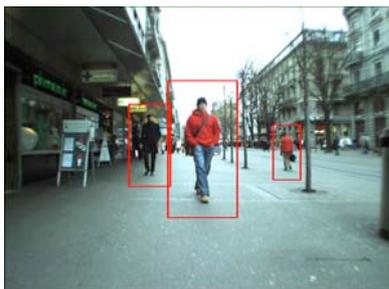
Real-time Visual Object Detection

Patrick Sudowe, Bastian Leibe

Funded by EU project EUROPA / DFG cluster of excellence UMIC

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.



Mobile Tracking of People and Unknown Objects

Dennis Mitzel, Bastian Leibe

The goal of this project is multi-object tracking in very challenging crowded shopping street scenarios. Most current approaches work in a tracking-by-detection framework, which limits them to object categories for which pre-trained detector models are available. In contrast, we propose a novel tracking-before-detection approach that can track both known and unknown object categories in very challenging street scenes. Our approach relies on noisy stereo depth data in order to segment and track objects in 3D. At its core is a novel, compact 3D representation that allows us to robustly track a large variety of objects, while building up models of their 3D shape on-line. Apart from achieving state-of-the-art tracking performance, the adaptive 3D model representation allows us also to analyze the shape of tracked persons in more detail. By comparing the observed shape with a learned probabilistic shape template of pedestrians, we can hypothesize the parts of the shape that are likely to be carried items. Additionally, we can not only track a large number of pedestrians and unknown objects over time, but we save computation, since the person classifier needs to be applied only once for each object track. We evaluate our approach on several challenging video sequences of busy pedestrian zones and show that it outperforms state-of-the-art approaches.



Close-Range Human Detection for Head-Mounted Cameras

Dennis Mitzel, Bastian Leibe

Funded by EU project EUROPA / DFG cluster of excellence UMIC

Robust multi-person detection and tracking is an important prerequisite for many mobile applications. Examples include the use of mobile service robots in busy urban settings or mobile AR applications such as Google's project Glass.

In this project we consider the problem of multi-person detection from the perspective of a head mounted stereo camera. As pedestrians close to the camera cannot be detected by classical full-body detectors due to strong occlusion, we propose a stereo depth-template based detection approach for close-range pedestrians. We perform a sliding window procedure, where we measure the similarity between a learned depth template and the depth image. To reduce the search space of the detector we slide the detector only over few selected regions of interest that are generated based on depth information. The region-of-interest selection allows us to further constrain the number of scales to be evaluated, significantly reducing the computational cost. We have run experiments on stereo sequences recorded from a head-mounted camera setup in crowded shopping street scenarios and show that our proposed approach achieves superior performance on this very challenging data.



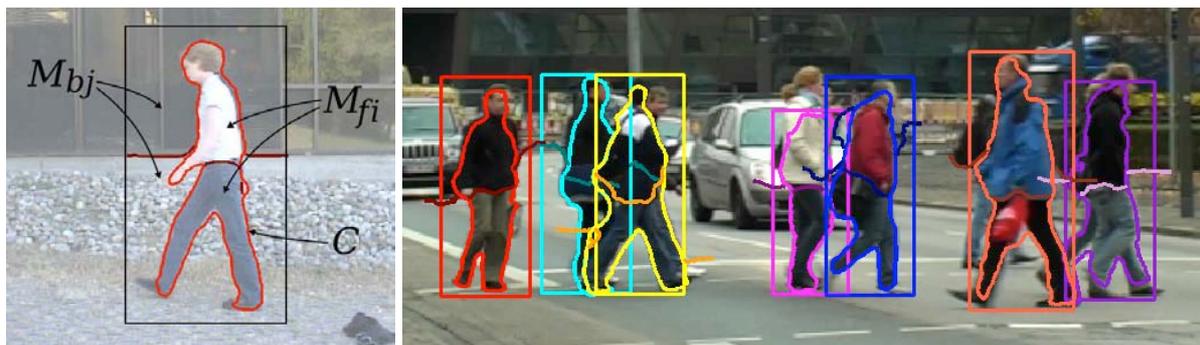
Improved Appearance Models for Person Segmentation and Tracking

Esther Horbert, Bastian Leibe

Funded by RWTH Seed Funds

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.



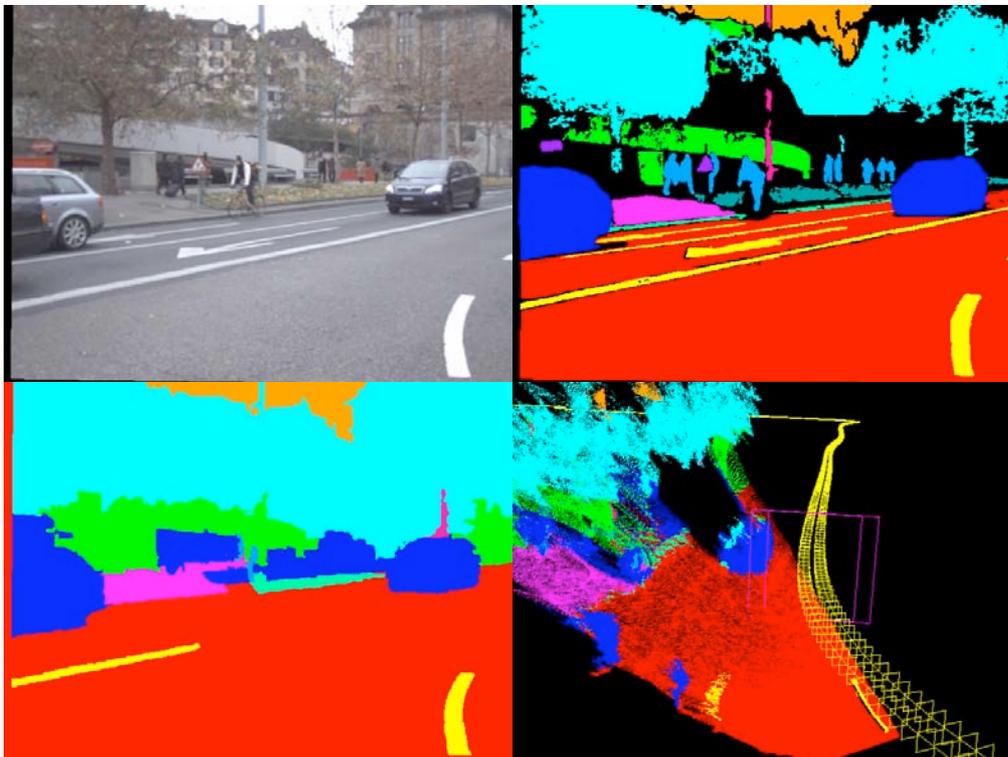
Joint 2D-3D Temporally Consistent Segmentation of Street Scenes

Georgios Floros, Bastian Leibe

Funded by EU project EUROPA

Visual scene understanding from moving platforms has become an area of very active research, and many approaches have been proposed towards this goal in recent years. Multi-class image segmentation has become a core component for many of those approaches, as it can provide semantic context information to support the higher-level scene interpretation tasks. This development has been assisted by significant improvements in state-of-the-art segmentation frameworks. In this project, we build upon this recent progress in order to address the problem of segmenting urban street scenes into semantically meaningful classes, such as *road*, *building*, *street marking*, *car*, etc.

In particular, we propose a novel Conditional Random Field (CRF) formulation for the semantic scene labeling problem which is able to enforce temporal consistency between consecutive video frames and take advantage of the 3D scene geometry to improve segmentation quality. The main contribution of this work lies in the novel use of a 3D scene reconstruction as a means to temporally couple the individual image segmentations, allowing information flow from 3D geometry to the 2D image space. As our results show, the proposed framework outperforms state-of-the-art methods and opens a new perspective towards a tighter interplay of 2D and 3D information in the scene understanding problem.



Discovering Favorite Views of Popular Places

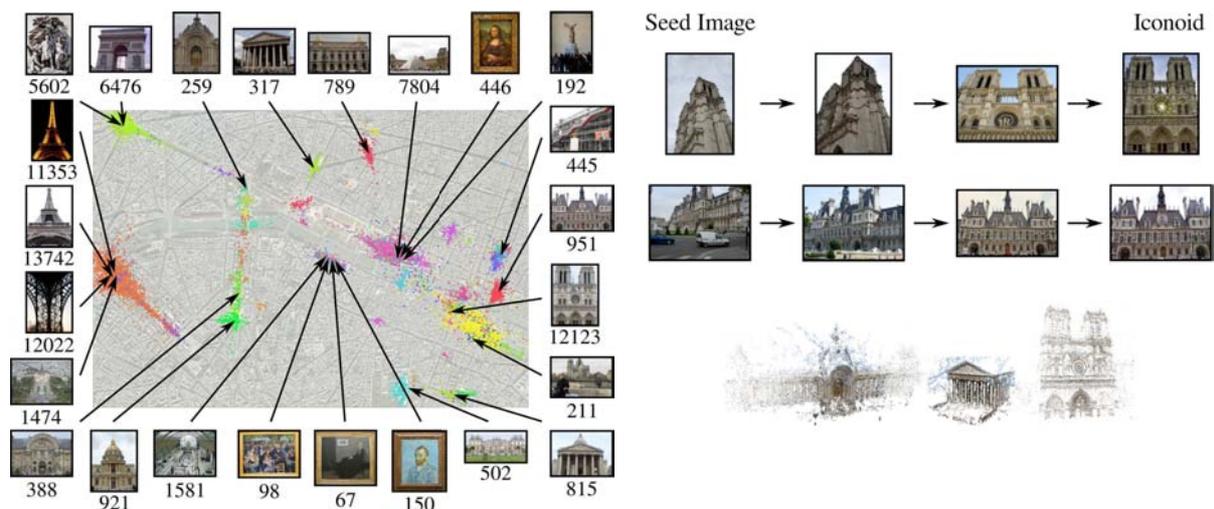
Tobias Weyand, Bastian Leibe

Funded by DFG cluster of excellence UMIC

Community photo collections such as Flickr or Panoramio 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

Courses

Winter semester 2011/12

- Lecture *Computer Vision*

Summer semester 2012

- Lecture *Betriebssysteme und Systemprogrammierung*
- Lecture *Machine Learning*
- Seminar *Advanced Topics in Computer Vision and Machine Learning*,

Prof. Dr. Bastian Leibe's Scientific Activities

Committees

- **Program chair**, European Conference on Computer Vision (ECCV'16), Amsterdam, NL, September 2016
- **Program chair**, International Conference on Computer Vision Systems (ICVS'13), St. Petersburg, July 2013
- Program committee member, European Conference on Computer Vision (ECCV'12), Florence, Italy, September 2012
- Program committee member, IEEE Conference on Computer Vision and Pattern Recognition (CVPR'12), Providence, USA, June 2012
- Program committee member, Canadian Conference on Computer and Robot Vision (CRV 2012), Regina, Saskatchewan, Canada, May 2012
- Program committee member, DAGM Annual Pattern Recognition Symposium (DAGM'12), Graz, Austria, September 2012
- Program committee member, ECCV'12 Articulated Pose Estimation in Still Images Workshop (APSI'12), Florence, Italy, September 2012
- Program committee member, ECCV'12 Parts and Attributes Workshop (PnA'12), Florence, Italy, September 2012
- Program committee member, IEEE Workshop on Computer Vision in Vehicle Technology: From Earth to Mars (CVVT'12), Florence, Italy, September 2012
- Program committee member, CVPR'12 PRCA Workshop, Providence, USA, June 2012
- Reviewer for Eurographics 2012, Cagliari, Italy, May 2012
- Reviewer for SIGGRAPH 2012, Los Angeles, USA, August 2012
- Reviewer for IEEE International Conference on Robotics and Automation (ICRA'13), Karlsruhe, Germany, May 2013
- Reviewer for IEEE International Conference on Robotics and Automation (ICRA'12), St. Paul, USA, May 2012
- Reviewer for Robotics: Science and Systems (RSS'12), Sidney, Australia, July 2012
- Reviewer for Computer Vision and Image Understanding

Offices and Organizations

- 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

- **ERC Starting Grant** for the project *CV-SUPER: Computer Vision for Scene Understanding from a First-Person Perspective*
- **U.V. Helava Award** for the **Best Paper in the Period 2008-2011**, ISPRS Journal of Photogrammetry and Remote Sensing
- **Intel Young Faculty Research Award**
- CVPR'12 Outstanding Reviewer Award

Major Research Grants

“CV-SUPER – Computer Vision for Scene Understanding from a First-Person Perspective”, ERC Starting Grant, 2012-2017, *Principal investigator*.

“STRANDS – Spatio-Temporal Representations and Activities for Cognitive Control in Long-Term Scenarios”, FP7 EU-Project (IP), 2013-2017, *Principal investigator*.

“SPENCER – Social Situation Aware Perception and Action for Cognitive Robots”, FP7 EU-Project (STREP), 2013-2016, *Principal investigator*.

“ROVINA – Robots for Exploration, Digital Preservation and Visualization of Archeological Sites”, FP7 EU-Project (STREP), 2013-2016, *Principal investigator*.

“Situating Vision to Perceive Object Shape and Affordances”, DFG Project (D-A-CH lead agency program), 2013-2016, *Principal investigator*.

“EUROPA – European Robotic Pedestrian Assistant”, FP7 EU Project (STREP), ICT-2008-231888, 2009-2012, *Principal investigator*.

Talks and Publications

Invited Talks

B. Leibe: „Next Steps in Dynamic Visual Scene Understanding“, Pattern Recognition and Computer Vision Colloquium, Czech Technical University, October 18, 2012.

B. Leibe: „Dynamic Visual Scene Understanding: Where Are We and Where Should We Go Next?“, **Keynote, Spatial Cognition 2012 Conference**, September 02, 2012.

B. Leibe: „Visual Object Categorization“, Tutorial, Vision & Sports Summer School, Prague, August 27-31, 2012.

B. Leibe: “(Better Ways to Do) Object Recognition in Video”, 2nd IST Workshop on Computer Vision and Pattern Recognition, IST Austria, October 7, 2011.

Publications

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

T. Sattler, B. Leibe, L. Kobbelt, *Fast Image-Based Localization using Direct 2D-to-3D Matching*, International Conference on Computer Vision (ICCV’11), November 2011.

T. Weyand, B. Leibe, *Discovering Favorite Views of Popular Places with Iconoid Shift*, 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

G. Floros, B. Leibe, *Joint 2D-3D Temporally Consistent Segmentation of Street Scenes*, in IEEE Conference on Computer Vision and Pattern Recognition (CVPR’12), Providence, USA, June 2012.

T. Sattler, B. Leibe, L. Kobbelt, *Towards Fast Image-Based Localization on a City Scale*, in F. Dellaert et al. (editors), *Real-World Scene Analysis*, Lecture Notes in Computer Science, Vol. 7474, Springer, pp. 191-211, 2012.

D. Mitzel, B. Leibe, *Close-Range Human Detection for Head-Mounted Cameras*, in British Machine Vision Conference (BMVC’12), Guildford, UK, Sept. 2012.

T. Sattler, T. Weyand, B. Leibe, L. Kobbelt, *Image Retrieval for Image-based Localization Revisited*, in British Machine Vision Conference (BMVC’12), Guildford, UK, Sept. 2012.

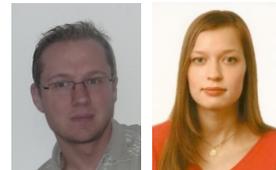
D. Mitzel, B. Leibe, *Taking Mobile Multi-Object Tracking to the Next Level: People, Unknown Objects, and Carried Items*, in European Conference on Computer Vision (ECCV’12), Florence, Italy, Oct. 2012.

T. Sattler, B. Leibe, L. Kobbelt, *Improving Image-based Localization by Active Correspondence Search*, in European Conference on Computer Vision (ECCV’12), Florence, Italy, Oct. 2012.

Data Management and Exploration – i9

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Dipl.-Inform. Anca-Maria Ivanescu
Dipl.-Inform. Steffen Kirchhoff (until July 2012)
Dr. rer. nat. Philipp Kranen (until July 2012)
Dipl.-Inform. Hardy Kremer
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Dipl.-Ing. Roland Assam
Dipl.-Inform. Philipp Meisen



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 Complex Data. Tasks as similarity search or data analysis demand for fast access to complex 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.

Research Projects

Data Analysis and Knowledge Extraction

Philipp Kranen, Stephan Günnemann, Marwan Hassani

Research cluster UMIC (funded by DFG EXC 89)

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 and Energy Awareness of Applications. 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 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.

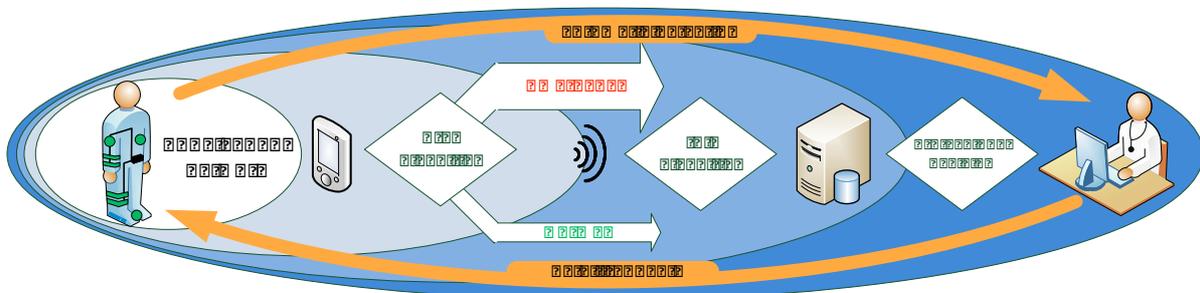


Figure 1: Architecture of HealthNet as a sample scenario for mobile stream mining

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.



Figure 2: Multiple streams context prediction

SFB 686 “Model-Based Control of Homogenized Low-Temperature Combustion“

Anca Maria Ivanescu, Christian Beecks, Philipp Kranen

The aim of the SFB 686 is a model-based control of homogenized low-temperature combustion for efficient and low-emission energy provision. This requires the cooperation of several fields, in order to build up a thorough understanding of the complex physical processes, as well as the investigation and breakdown of the whole chain of effects, which leads from flow and mixture to ignition and then combustion, to finally end up with the combustion instabilities. To make the gained understanding usable, a description of the physical effects on the basis of mathematical models follows.

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 3: 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.

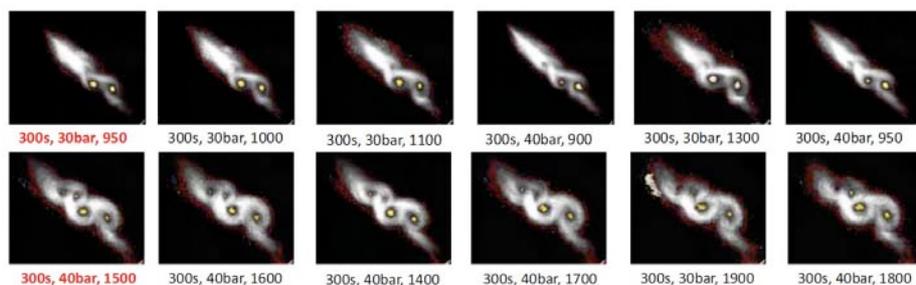


Figure 3: Similarity Search in a Database of Spray Images. The query spray images are marked with red, and to their left are the resulting nearest neighbors from the database.

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 4: Model Predictive Control (MPC) for highly dynamic and high-dimensional processes exemplary 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.

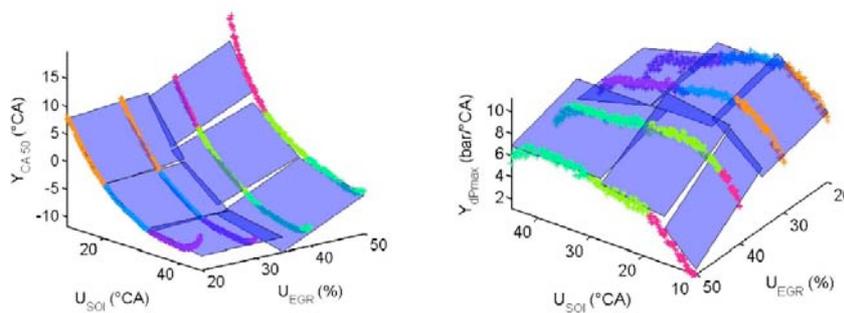


Figure 4: Model Predictive Control (MPC) for highly dynamic and high-dimensional processes

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 a priori unknown stream inter-arrival rates, anytime algorithms provide the best result up to a point of interruption dictated through the arrival of the next stream element. For many mining tasks traditional algorithms are known that provide good results, yet cannot be interrupted in a meaningful manner. We therefore focus on such adaptive techniques for stream mining that enable interruptions at any time and that improve the quality of their results with more execution time available.

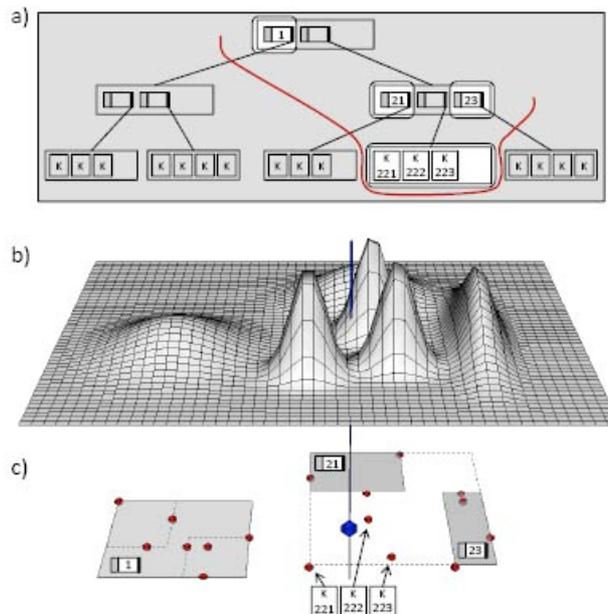


Figure 5: Bayes Tree as hierarchical organization of (Gaussian) mixture models for density estimation

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 to run 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 from the literature for comparison and
- an easily extendable framework for new streams, algorithms and evaluation methods.

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.

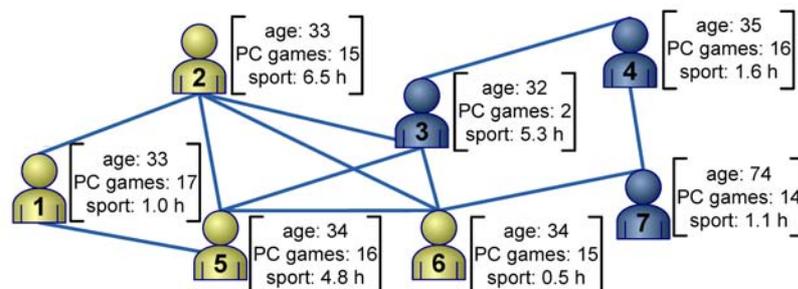


Figure 6: Simultaneous mining of dense subgraphs and subspace clusters in attributed graphs

Subspace Mining for High Dimensional Data

Stephan Günnemann, Ines Färber, 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.

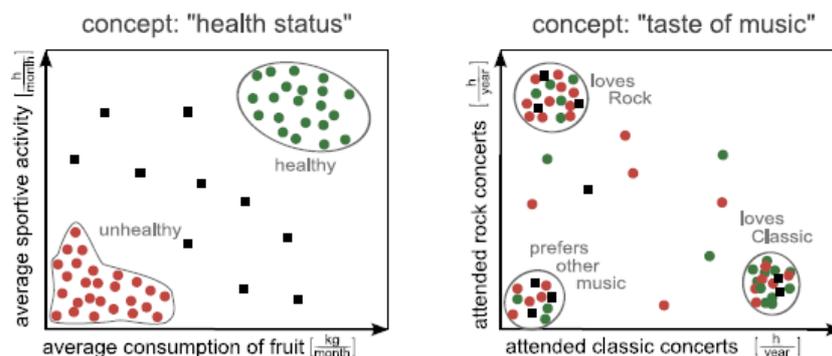


Figure 7: Multiple hidden concepts in subspaces of a high dimensional database

SteerSCiVA: Steerable Subspace Clustering for Visual Analytics

Ines Färber

The main goal of this project is the tight integration of visual analytics into the process of subspace cluster analysis to support the domain scientists' exploration processes through a highly interactive immersive visualization. The considered databases from different fields of scientific and engineering research are usually very large and high dimensional. An approach solely based on automated subspace cluster analysis is rarely appropriate to provide the necessary insights into the various patterns, which are usually hidden by the huge amount and the heterogeneity of the data. Appropriate visualization techniques could not only help in monitoring the clustering process but, with special mining techniques, they also enable the domain expert to guide and even to steer the subspace clustering process to reveal the patterns of interest. To this goal we envision a concept that combines scalable subspace clustering algorithms and interactive scalable visual exploration techniques. This project has the potential to open a new line of research that is not necessarily limited to subspace clustering but applies to any other modeling technique in which the involvement of end-users in the model building process can compensate for the limits the necessary heuristics introduce in the process.

This project "SteerSCiVA: Steerable Subspace Clustering for Visual Analytics" is funded by the DFG in the SPP "Scalable Visual Analytics" and is conducted in collaboration with the "Dep. of Computer and Information Science, University of Konstanz".

OpenSubspace: An Open Source Framework for Evaluation and Exploration of Subspace Clustering Algorithms in WEKA
Stephan Günnemann, Hardy Kremer

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. It 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/>.

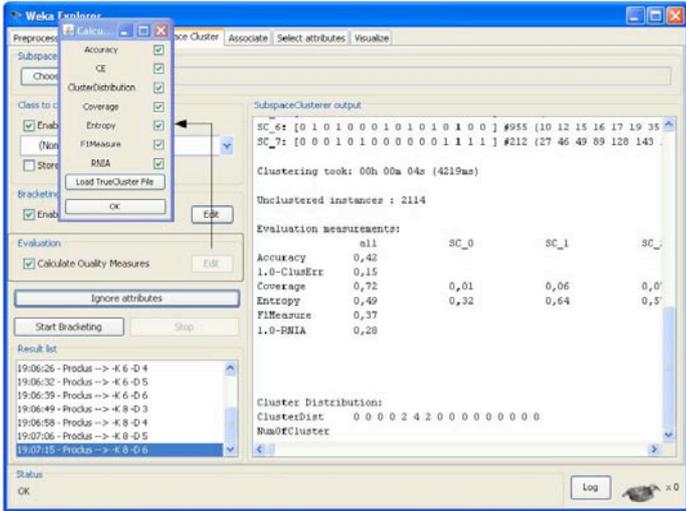


Figure 8: OpenSubspace evaluation framework

**4C-NANONETS: From Clusters and Cooperation to Creativity and Commercialization
in Nano Science and Technology Networks**

(IMP Pathfinder Project)

Brigitte Boden

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 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.

UP-BEAT (IMP Pathfinder Project)

Sergej Fries

Online advertising has become a full member of the marketing mix and is still growing in importance. The US market for online advertising was 22.7 billion USD in 2009 and is expected to grow to 37.2 billion USD in 2013. For Europe the prospects are similarly good. With so much money being spend for online advertising one would expect that there are highly sophisticated controlling systems in place to make sure that the money is spend only for efficient forms of advertising.

However, the reality is far from it. Although there is a large flood of data (e.g., information about online advertising impressions as well as records of each click on an online advertisement) researchers and practitioners very often just use basic regression models to estimate the impact of their advertising campaigns and to optimize the distribution of advertising budget between different forms of online advertising (e.g., email, search engine marketing, banner advertising). Academic research has demonstrated that, in addition to short-term advertising effects, it is important to incorporate long-term and synergy effects when analyzing advertising effectiveness.

The aim of the joint project between Faculties of Business and Economics, Computer Science and Mathematics is to substantially increase both the calculation speed and its flexibility, and to simplify the handling of advertising effectiveness models so that researchers and practitioners can take full advantage of the latest academic insights regarding the efficient allocation of advertising budgets. In that way they will be able to include not only short-term but in particular long-term and synergy effects when analyzing the efficiency of different forms of advertising.

Exploration of Multimedia Databases – Efficient Multimedia Retrieval Based on Earth Mover's Distance

Christian Beecks

Funded by DFG SE 1039/1-3

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.

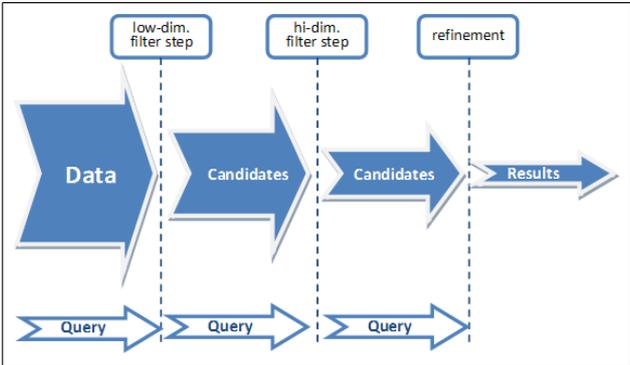


Figure 9: Multistep query processing for fast EMD search

In order to face these problems, the Earth Mover's Distance (EMD) explicitly regards connections of the components while based on a ground distance schema. Whereas algorithms to compute the EMD for pairs of vectors exist, they are too expensive to be applied to large

database of 100,000 or millions of objects. The goal of this research is to develop new algorithms to efficiently support EMD-based similarity search on very large databases.

Relevance Feedback for the Exploration of Large Multimedia Databases

Christian Beecks

Large multimedia databases are common in scientific, commercial and entertainment applications. As the amount of data grows, the effort to get insight into the data grows. Relevance Feedback is a promising approach to explore comprehensive multimedia databases. Based on adaptable distance functions, our research focuses on capturing user preferences. We therefore develop several new techniques for the Earth Mover's Distance (EMD) and for the Quadratic Form Distance (QF) that reflect the users' perception in the search process. In addition to an effective and an efficient search process, we develop new interactive visualization techniques to make the exploration process more accessible and more intuitive. The interaction allows for exploration of large amount of data with modest effort for the user.

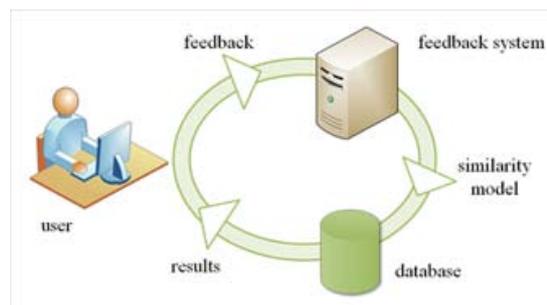


Figure 10: Feedback loop for interactive database exploration

Signature Quadratic Form Distances for Efficient Multimedia Database Retrieval

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 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 enabling users to query large multimedia databases intuitively, effectively, and efficiently.



Figure 11: signature representations of color images

Sequence Similarity Search

Hardy Kremer

Continuous growth in sensor data and other temporal data increases the importance of retrieval and similarity search in time series data. Analysis of this data typically requires searching for similar time series in the data base and for interactive applications efficiency of the search process is essential.

Dynamic Time Warping (DTW) is a widely used high quality similarity measure for time series. As DTW is computationally expensive, efficient algorithms for fast DTW computation are crucial. Scalability to long time series, wide DTW bands, and a high number of attributes are still challenging issues. We proposed a novel technique that exploits the inherent properties of multivariate DTW to substantially reduce the number of calculations required to compare a query time series with the time series in a data base in multistep retrieval. The significant efficiency improvements achieved result in substantial performance gains that scale well to long multivariate time series with large DTW bands. Our technique is highly flexible and can be combined with existing indexing structures and DTW filters.

Fast Access to Complex Data – High Dimensional Indexing

Stephan Günemann, 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.

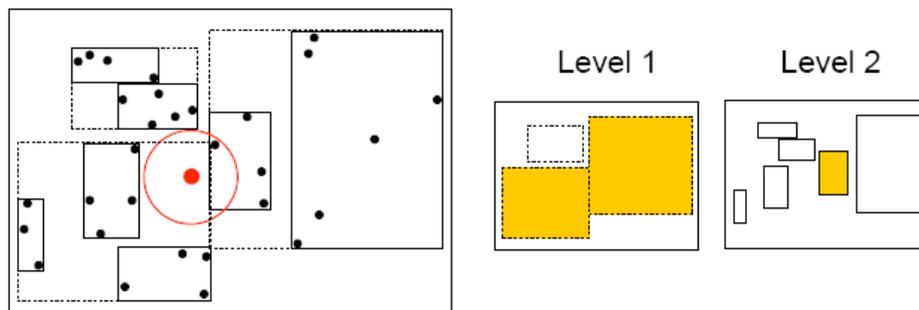


Figure 11: Representation in data space (left) and data structure (right) of an overlap free R-tree

MapReduce

Sergej Fries, Brigitte Boden

As an ongoing trend, tremendously increasing amounts of data are collected in real-world applications of life science, engineering, telecommunication, business transactions and many other domains. For the management and analysis of these data, many different techniques and

algorithms have been developed, ranging from basic database operations to high-level data mining approaches like clustering, classification or the detection of outliers. Processing huge data sets with millions or billions of records on a single computer exceeds the computation capabilities of single computing nodes due to limitations of disk space and/or main memory. Thus, it is indispensable to develop distributed approaches that run on clusters of several computers in parallel.

For the development of distributed algorithms, a variety of structured programming models exists. Aside classic parallel programming, the MapReduce model was proposed by Google, and its open-source implementation Hadoop found wide-spread attention and usage.

In MapReduce, the data is given a list of records that are represented as (key, value) pairs. Basically, a MapReduce program consists of two phases: In the "Map" phase, the records are arbitrarily distributed to different computing nodes (called "mappers") and each record is processed separately, independent of the other data items. The map phase then outputs intermediate (key, value) pairs. In the "Reduce" phase, records having the same key are grouped together and processed in the same computing node ("reducer"). Thus, the reducers combine information of different records having the same key and aggregate the intermediate results of the mappers. The results are stored back to the distributed file system.

On top of this new programming model, Hadoop and other implementations of the MapReduce framework show a lot of non-functional advantages: They are scalable to clusters of many computing nodes, which are easily expanded by new nodes. They are fault-tolerant: If one of the computing nodes fails during the execution of the program, the work of the other nodes is not affected or discarded; just the records that were currently processed on the failing node have to be processed again by another node. This fault tolerance particularly supports running Hadoop on commodity hardware. For example, organizations often have tens or hundreds of desktop computers which are only used at certain times of day and to the most part just for office applications. These computers often show much unused capacity in terms of processor time and disk space. Using Hadoop, these available resources can be easily used for distributed computing.

The goal of the research is the development of high parallelizable data mining techniques with MapReduce framework.

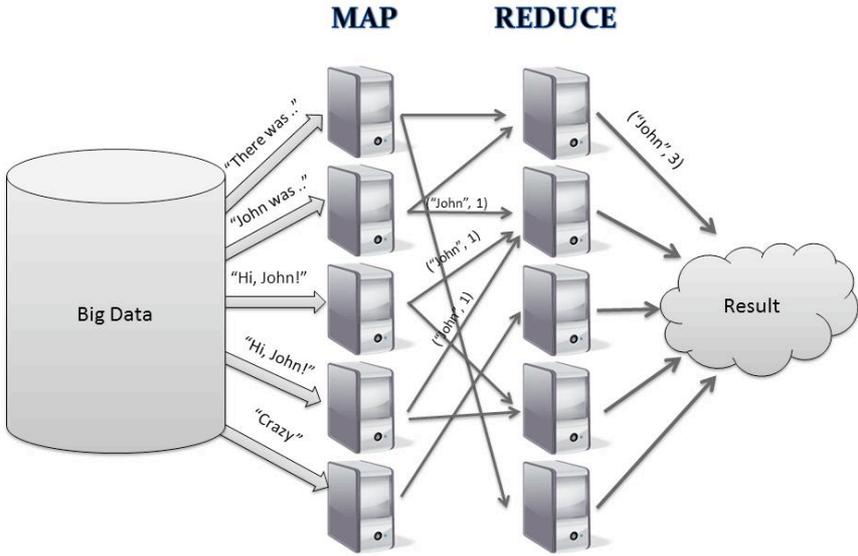


Figure 12: Example of a MapReduce Computation

Other Activities

Teaching

Winter term 2011:

- Lecture on “Data Mining Algorithms” (V3)
- Lecture on “Exploring Temporal and Graph Data: Mining and Retrieval” (V3)
- Lab course “Efficient Moving Objects Querying in Simulation Data”
- Seminar on “Recent Developments in Multimedia Retrieval”

Summer term 2012:

- Lecture on “Exploring High-Dimensional Data: Advanced Mining Techniques” (V3)
- Lecture on “Algorithms and Data Structures” (V2)
- Lab course “High Performance Data Mining with MapReduce”
- Seminar on “Advanced Data Analysis”
- Seminar on “Methods and Tools”
- Contribution to the lecture on “Medical Image Processing”
- Contribution to the project “Helle Köpfe in der Informatik”

Dissertations

- Günnemann S. *Subspace Clustering for Complex Data*. Dissertation, Fakultät für Mathematik, Informatik und Naturwissenschaften, RWTH Aachen University. (2012)

Institutional Collaborations

- B-IT Research School
- REGINA Regional Industry Club Informatics Aachen, Aachen
- SFB 686 Modellbasierte Regelung der homogenisierten Niedertemperatur-Verbrennung
- 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 academic partners

- Aarhus University, Denmark (Prof. Assent, Prof. Jensen)
- Charles University, Prague, Czech Republic (Prof. Skopal)
- LMU München (Prof. Kriegel, Prof. Böhm)
- National Institute of Informatics, Tokyo, Japan (Prof. Michael E. Houle)
- RWTH Computer Science (many colleagues)
- RWTH Electrical Engineering (UMIC partners)
- RWTH Mechanical Engineering (Prof. Abel, Prof. Kneer, Prof. Peters, Prof. Schmidt)
- RWTH Technology and Innovation Management Group (Prof. Piller, Dr. Ihl)
- RWTH Sociology (Prof. Häußling)
- Univ. Antwerp, Belgium (Prof. Goethals)
- Univ. Trento, Italy (Prof. Palpanas)

- Univ. Konstanz (Prof. Keim, Prof. Deussen, Dr. Bertini)
- Simon Fraser University, Vancouver, Canada (Prof. Ester)
- 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 Boards of the ArchaeoBio-Center at LMU München and the WallViz Project of the Universities of Aarhus and Copenhagen. In 2012, Prof. Seidl was guest editor of the Machine Learning Journal.

Members of the group performed reviews for the following Journals:

1. ACM Computing Surveys
2. Data Mining and Knowledge Discovery (DMKD)
3. Distributed and Parallel Databases (DAPD)
4. Knowledge and Information Systems (KAIS)
5. Knowledge and Data Engineering (TKDE)
6. Statistical Analysis and Data Mining (SAM)
7. The International Journal on Very Large Data Bases (VLDBJ)

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

1. ACM International Conference on Information and Knowledge Management (CIKM 2012) (Senior PC Member)
2. ACM International Conference on Knowledge Discovery and Data Mining (KDD 2012)
3. Conference on Data Analysis, Machine Learning and Knowledge Discovery (GfKI 2012)
4. European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (PKDD 2012)
5. International Conference on Extending Data Base Technology (EDBT 2012)
6. International Conference on Mobile Data Management (MDM 2012)
7. International Conference on Statistical and Scientific Database Management (SSDBM 2012)
8. Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD 2012)

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

1. Instant Interactive Data Mining (IID) at European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (PKDD 2012)
2. 3Clust Workshop at Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD 2012)

Workshop Organization

- Organization of the 3rd Workshop on Discovering, Summarizing and Using Multiple Clusterings (MultiClust 2012) in conjunction with the 2012 SIAM International Conference on Data Mining (SDM 2012) in Anaheim, California, USA

Awards

- Kranen P., Kremer H., Jansen T., Seidl T., Bifet A., Holmes G., Pfahringer B., Read J.: *Stream Data Mining using the MOA Framework*. The 17th International Conference on Database Systems for Advanced Applications (DASFAA 2012), Busan, South Korea (2012) Best Demo Award (First Runner Up)

Other Activities

- Variety of duties for the RWTH Aachen department of computer science (chair of the commission for the use of tuition fees (until March 2012); deputy financial chair; chair of the examination board (since April 2012); 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 the IEEE 28th International Conference on Data Engineering (ICDE 2012), Washington, DC, USA. (2012)
- Tutorial on “Discovering Multiple Clustering Solutions: Grouping Objects in Different Views of the Data” at the 16th Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD 2012), Kuala Lumpur, Malaysia. (2012)

Publications

1. Müller E., Günemann S., Färber I., Seidl T.: *Discovering Multiple Clustering Solutions: Grouping Objects in Different Views of the Data*. Tutorial at IEEE 28th International Conference on Data Engineering (ICDE 2012), Washington, DC, USA (2012)
2. Müller E., Günemann S., Färber I., Seidl T.: *Discovering Multiple Clustering Solutions: Grouping Objects in Different Views of the Data*. Tutorial at the 16th Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD 2012), Kuala Lumpur, Malaysia (2012)
3. Günemann S., Boden B., Seidl T.: *Finding Density-Based Subspace Clusters in Graphs with Feature Vectors*. Data Mining and Knowledge Discovery Journal (DMKD) , Vol. 25, Nr. 2 (2012)
4. Günemann S., Kremer H., Laufkötter C., Seidl T.: *Tracing Evolving Subspace Clusters in Temporal Climate Data*. Data Mining and Knowledge Discovery Journal (DMKD), Vol. 24, Nr. 2 (2012)
5. Ivanescu A., Wichterich M., Beecks C., Seidl T.: *The ClasSi coefficient for the evaluation of ranking quality in the presence of class similarities*. Frontiers of Computer Science, , Vol. 6, Nr. 5 (2012)
6. Kranen P., Assent I., Seidl T.: *An Index-inspired Algorithm for Anytime Classification on Evolving Data Streams*. Datenbank-Spektrum (Springer DASP), Vol. 12, Issue 1 (2012)
7. Hetland M. L., Skopal T., Lokoč J., Beecks C.: *Ptolemaic Access Methods: Challenging the Reign of the Metric Space Model*. Information Systems, Elsevier (2012)
8. Kruliš M., Skopal T., Lokoč J., Beecks C.: *Combining CPU and GPU Architectures for Fast Similarity Search*. Distributed and Parallel Databases (DAPD) , Vol. 30, Nr. 3-4 (2012)
9. Kremer H., Günemann S., Held A., Seidl T.: *Effective and Robust Mining of Temporal Subspace Clusters*. Proc. International Conference on Data Mining (IEEE ICDM 2012), Brussels, Belgium (2012)
10. Günemann S., Dao P., Jamali M., Ester M.: *Assessing the Significance of Data Mining Results on Graphs with Feature Vectors*. Proc. International Conference on Data Mining (IEEE ICDM 2012), Brussels, Belgium (2012)
11. Boden B., Günemann S., Seidl T.: *Tracing Clusters in Evolving Graphs with Node Attributes*. Proceedings of The 21st Conference on Information and Knowledge Management (ACM CIKM 2012), Maui, USA (2012)
12. Seidl T., Boden B., Fries S.: *CC-MR - Finding Connected Components in Huge Graphs with MapReduce*. Proceedings of the European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML PKDD 2012), Bristol, UK (2012)
13. Hassani M., Spaus P., Mohamed Medhat Gaber, Seidl T.: *Density-Based Projected Clustering of Data Streams*. The 6th International conference on Scalable Uncertainty Management (SUM 2012), Marburg, Germany (2012)
14. Günemann S., Färber I., Seidl T.: *Multi-View Clustering Using Mixture Models in Subspace Projections*. Proc. 18th Conference on Knowledge Discovery and Data Mining (ACM SIGKDD 2012), Beijing, China (2012)
15. Günemann S., Färber I., Virochsiri K., Seidl T.: *Subspace Correlation Clustering: Finding Locally Correlated Dimensions in Subspace Projections of the Data*. Proc. 18th Conference on Knowledge Discovery and Data Mining (ACM SIGKDD 2012), Beijing, China (2012)

16. Boden B., Günnemann S., Hoffmann H., Seidl T.: *Mining Coherent Subgraphs in Multi-Layer Graphs with Edge Labels*. Proc. 18th Conference on Knowledge Discovery and Data Mining (ACM SIGKDD 2012), Beijing, China (2012)
17. Günnemann S., Boden B., Seidl T.: *Substructure Clustering: A Novel Mining Paradigm for Arbitrary Data Types*. Proc. 24th International Conference on Scientific and Statistical Database Management (SSDBM 2012), Chania, Greece (2012)
18. Ivanescu A., Kranen P., Seidl T.: *Hinging Hyperplane Models for Multiple Predicted Variables*. Proc. of the 24th International Conference on Scientific and Statistical Database Management (SSDBM 2012), Chania, Greece (2012)
19. Kranen P., Hassani M., Seidl T.: *BT* - An Advanced Algorithm for Anytime Classification*. Proc. of the 24th International Conference on Scientific and Statistical Database Management (SSDBM 2012), Chania, Greece (2012)
20. Hassani M., Seidl T.: *Resource-Aware Distributed Clustering of Drifting Sensor Data Streams*. The 4th International Conference on Networked Digital Technologies (NDT 2012), Dubai, UAE. (2012)
21. Lokoč J., Skopal T., Beecks C., Seidl T.: *Nonmetric Earth Mover's Distance for Efficient Similarity Search*. Proc. 4th International Conference on Advances in Multimedia (MMEDIA 2012), Chamonix/Mont Blanc, France (2012)
22. Kremer H., Günnemann S., Held A., Seidl T.: *Mining of Temporal Coherent Subspace Clusters in Multivariate Time Series Databases*. Proceedings 16th Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD 2012), Kuala Lumpur, Malaysia (2012)
23. Assent I., Kranen P., Baldauf C., Seidl T.: *AnyOut: Anytime Outlier Detection on Streaming Data*. The 17th International Conference on Database Systems for Advanced Applications (DASFAA 2012), Busan, South Korea (2012)
24. Tatu A., Maaß F., Färber I., Bertini E., Schreck T., Seidl T., Keim D. A.: *Subspace Search and Visualization to Make Sense of Alternative Clusterings in High-Dimensional Data*. Proc. IEEE Symposium on Visual Analytics Science and Technology (2012)
25. Beecks C., Seidl T.: *On Stability of Adaptive Similarity Measures for Content-Based Image Retrieval*. Proc. 18th International Conference on MultiMedia Modeling (MMM 2012), Klagenfurt, Austria (2012)
26. Ivanescu A., Albin T., Abel D., Seidl T.: *Employing the Principal Hessian Direction for Building Hinging Hyperplane Models*. Workshop on Optimization Based Techniques for Emerging Data Mining (OEDM 2012) in conj. with International Conference on Data Mining (IEEE ICDM 2012), Brussels, Belgium. (2012)
27. Boden B.: *Efficient Combined Clustering of Graph and Attribute Data*. PhD Workshop of the 38th International Conference on Very Large Data Bases (VLDB 2012), Istanbul (2012)
28. Ivanescu A., Wichterich M., Seidl T.: *ClasSi: Measuring Ranking Quality in the Presence of Object Classes with Similarity Information*. L. New Frontiers in Applied Data Mining (PAKDD 2011 International Workshops Revised Selected Papers). Springer (2012)
29. Assam R., Seidl T.: *TMC-Pattern: Holistic Trajectory Extraction, Modeling and Mining*. 1st International Workshop on Analytics for Big Geospatial Data (BigSpatial-2012) in conj. with 20th International Conference on Advances in Geographic Information Systems (ACM SIGSPATIAL GIS 2012), Redondo Beach, CA, USA (2012)

30. Assam R., Hassani M., Seidl T.: *Differential Private Trajectory Protection of Moving Objects*. 3rd International Workshop on GeoStreaming (IWGS 2012) in conj. with 20th International Conference on Advances in Geographic Information Systems (ACM SIGSPATIAL GIS 2012), Redondo Beach, CA, USA (2012)
31. Günnemann S., Kremer H., Musiol R., Haag R., Seidl T.: *A Subspace Clustering Extension for the KNIME Data Mining Framework*. Proc. International Conference on Data Mining (IEEE ICDM 2012), Brussels, Belgium (2012) (Demo)
32. Kranen P., Wels S., Rohlf T., Raubach S., Seidl T.: *A Tool for Automated Evaluation of Algorithms*. Proc. 21st Conference on Information and Knowledge Management (ACM CIKM 2012), Maui, USA (2012) (Demo)
33. Ivanescu A., Kranen P., Smieschek M., Driessen P., Seidl T.: *PA-Miner: Process Analysis using Retrieval, Modeling, and Prediction*. The 17th International Conference on Database Systems for Advanced Applications (DASFAA 2012), Busan, South Korea (2012) (Demo)
34. Kranen P., Kremer H., Jansen T., Seidl T., Bifet A., Holmes G., Pfahringer B., Read J.: *Stream Data Mining using the MOA Framework*. The 17th International Conference on Database Systems for Advanced Applications (DASFAA 2012), Busan, South Korea (2012) (Demo)

Learning Technologies



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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, mobile learning in context, 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 five 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. After six years of successful work at CiL, Dr. Philipp Rohde and Patrick Stalljohann joined Datenlotsen Informationssysteme GmbH to lead the SharePoint-based projects of the company in Aachen. Several new research assistants joined the CiL team to work on the continuous enhancement of L²P with new eLearning modules.

In addition to continuing our projects L²P, InfoSphere, SAiL-M, go4IT!, and IGaDtools4MINT, we started 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.

23 students successfully finished their Diplom-, Master- and Bachelor theses with our team. This is again a quite high number and will result in new research projects and publications.

Research Projects

L²P – eLearning and eTeaching Portal of RWTH Aachen University

Ulrik Schroeder, Mohamed Amine Chatti, Harald Jakobs, Anna Lea Dyckhoff, Arham Muslim, Ibrahim Cakir, Usman Wahid, René Wagner, Arnab Chakrabarti, Christoph Gingter, Philipp Rohde, Patrick Stalljohann, Christoph Dederichs, Christopher Lie (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 2011/2012 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 Learning Technologies 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.

PELE – Personal Exploratory Learning Environments

Ulrik Schroeder, Mohamed Amine Chatti, Hendrik Thiis

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. Within the framework of the PELE project, we restructured the Web Technologies course, which attracted more than 100 students in the winter semester 2011/2012, 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.

SAiL-M: Semi-automatic Analysis of Individual Learning Processes

Ulrik Schroeder, Daniel Herding, Hendrik Thiis (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.

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.



A pupil learns how to program a robot during a go4IT! workshop.

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 Students of all Ages

Ulrik Schroeder, Nadine Bergner, Jan Holz, Thiemo Leonhardt

An extracurricular learning place serves to teach specific topics of one field to students of different ages. The InfoSphere is an extracurricular learning place especially for computer science topics. It opened in summer 2010. The InfoSphere offers several perspectives on

numerous facets and applications of computer science for students of all ages and types of school beginning with class three.

The InfoSphere provides courses as an addition to regular school lessons. In Germany, North Rhine-Westphalia there are no obligatory computer science lessons in school. This is the reason why many students do not get in contact with computer science topics during K-12. This in turn leads to the problem of many first-year students in computer science having a wrong idea about computer science studies. High dropout rates during the first semesters at university are the result. Besides correcting the students' idea of computer science and encouraging interest in this field we try to reduce these dropout rates by providing a publically available extracurricular learning place.



For achieving this, the InfoSphere offers a wide range of courses for half a day, a full day, or several days. These courses provide experimental and action-oriented learning with a link to the students' everyday experiences. One of the essential features of InfoSphere courses is the very individual access they offer for the different topics. Combined with self-directed learning and peer-teaching, this should encourage school students to discover the various aspects of computer science on their own. Our idea is to enable a learning process that is as natural,



exciting and self-discovering as possible. By this these courses should help to raise interest in computer science even for those who are not tech-savvy or did not get in contact with computer science so far. Another motivation to open an extracurricular place of learning was to assist computer science teachers and students in teacher training in teaching novel topics and becoming more familiar with modern learning materials, methods and media. InfoSphere has

been designed as a research laboratory to test and practice different learning experiences. Moreover, it offers a plethora of modern media and technology (e.g. multi touch tables, smartphones, tablets and interactive whiteboards) to help trainee teachers implement innovative learning scenarios. Furthermore, students in teacher training get the chance to acquire crucial media competences in practice. For these reasons the courses are designed by two to four students in teacher training under supervision of the members of the teacher training chair.

Within the InfoSphere we investigate the following research questions.

- How can an extracurricular learning place like InfoSphere help to convey a realistic picture of computer science?
- What are the most significant criteria to change the existing stereotypes about computer science?
- How can we correct the picture for different target groups?



- What should a workshop look like to create this picture as realistic as possible?
- What are the crucial differences between male and female participants?

IGaDtools4MINT: Integration von Gender and Diversity in MINT-Studiengängen an Hochschulen

Ulrik Schroeder, Mohamed Amine Chatti, Jan Holz (funded by BMBF), Hendrik Thüs in collaboration with Carmen Leicht-Scholten, Rebecca Apel, Tobias Berg (Gender and Diversity in Engineering) and Hans-Ulrich Heiß (TU Berlin)

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.

As part of this project we investigate the influence of application-oriented computer science didactics on students in the introductory phase of CS studies. Therefore we are designing and developing several concrete measures. These include a preliminary course for future CS students to ease the transfer from secondary school to university as well as multiple project workshops about fundamental concepts of computer science. By this we offer a continuous series of supporting additional learning possibilities that are directly linked to universities learning content and everyday life. Within the thesis research we are evaluating the effects of these measures on the motivation, the perceived competence for learning and the self-efficacy of the participating students.

How is my teaching? Tools for gender- and diversity-sensitive action research in blended learning scenarios

Anna Lea Dyckhoff (funded by a gender research grant within the excellence program of RWTH Aachen University) and Ulrik Schroeder

The underlying assumption for the dissertation project is that action research, which is carried out by teachers and learners themselves, improves the quality of their computer-supported teaching and learning scenarios. The concept of action research combines teaching and research for the purpose of quality assurance. As teachers and learners attempt to describe, explore, evaluate and redesign teaching processes and their effects systematically and iteratively, they work for the improvement of their teaching and learning and its environment. While adopting a gender and diversity perspective on the subject, the dissertation project focuses on the research question: How can technology facilitate and support the activities and processes of action research sustainably? The perception as well as the reflection of learning and teaching processes for example is to be augmented through continuous, integrated data acquisition and visualization. During the dissertation project, new 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.

A Generic Platform for Open Assessment Management in Higher Education

Patrick Stalljohann and Ulrik Schroeder

Solving tasks in everyday life and work requires continuous learning of facts, processes, and related skills. This is a lifelong process. On the one hand there are in-formal learning activities, i.e. they are happening unplanned during a normal activity. On the other hand, the first quarter of a human life is strongly affected by formal learning, e.g. in schools or at university. With the increasing use of Web 2.0, its possibilities for knowledge acquisition, communication, and collaboration facilitates the creation of personal learning environments. While these approaches mostly affect informal learning scenarios, their usage in formal settings is an open research question. A more specialized research topic in the context of combining formal and informal learning focuses assessment, the evaluation of learning activities, which takes an important part of formal learning.

Several methods for electronic support of assessment are in use for several years. Related software systems for the management of assessments are available and in use, but the integration of common services from the internet is still an open research question. Especially, the combination of different forms of assessment is difficult. In this context, the thesis at hand tries to cover the question, how the management of assessment scenarios in higher education can be supported technologically, with respect to traditional and new forms of assessment. The main objective of the related project was to build a web-based platform, which provides modular extensible support mechanisms for assessment management as a central service for different courses. This platform is called AMSeL (Assessment Management Services in eLearning systems).

A major problem with present assessment systems is that they are either too generic or too specialized. Generic systems provide basic support of assessment processes regardless of their domain, so that this kind of support is methodically limited. Specialized assessment systems provide extensive support for a specific type of question or a single domain. Therefore, current systems are especially not applicable to new forms of learning, e.g. informal learning or self-directed learning.

A new approach for technology enhanced assessment, which also allows application of current and new assessment and feedback processes to new forms of learning has been developed. Thus, it is discussed, how current assessment systems have to be extended or improved to support informal and self-directed learning as well. Especially, self-direction requires intelligent feedback. With the discrepancy of current generic and specialized assessment systems, the new approach demands the development of an architecture, which allows the integration of specific services into a generic platform.

These requirements have been used to build a modular software design, which takes account of incrementally growing requirements for a centralized service in a heterogeneous environment. A Software-as-a-Service (SaaS) architecture has been realized based on portal technologies to allow modular extension of functionality and integration of services. The implementation of AMSeL and its modules has been realized with portal technology mechanisms and techniques. Modules for assignment management, assessment of wiki contributions, the integration of cloud services to formal assessment processes, management of results and grading criteria, and others have been realized. In conjunction, they show how

different forms of assessment can be combined in a whole assessment management platform. In this way, the advantages of the flexible service-oriented architecture have been demonstrated. As a result, the integrated and powerful assessment management platform AMSeL has been realized as a reference implementation. This platform provides currently unique enhancements related to present assessment systems. It especially addresses the emergent importance of new learning forms as well as social media services in the context of institutional assessment in an unprecedented way.

Mobile Learning in Context

Hendrik Thüs, Mohamed Amine Chatti and Ulrik Schroeder

As mobile devices are becoming ubiquitous, there is an increasing interest in the educational applications of mobile technologies. Mobile learning refers to the use of mobile or wireless devices for the purpose of learning while on the go. Such mobile devices enable learning to take place at any time, in any location, and at a learner's own pace. To support the learner with personalized recommendations and learning units, context information about the learner has to be taken into account. In this project, we research how such context information can be gathered and processed further to provide more personalized and motivating learning experiences.

In order to have a model of contextual information, we developed a framework which is able to receive context information that is generated on various kinds of devices. In the future, we will work on applications that can leverage this framework to enable context-aware mobile learning.

Other Activities

Services

Prof. Schroeder major administrative and service activities in 2011-2012 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-inforamtik.de/>) the out-of-school Computer Science Lab for Pupils
- Member of the advisory board for teachers' education at RWTH Aachen university

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 2012”.

Mohamed Amine Chatti served as a reviewer for IEEE Transactions on Learning Technologies (TLT), International Journal of Technology Enhanced Learning (IJTEL), Journal of Educational Technology & Society (ET&S), and International Journal of Virtual and Personal Learning Environments (IJVPLE). He co-organized the Workshop on Mobile Learning in conjunction with DeLFI '12. He was member of the program committee of the 7th European Conference on Technology Enhanced Learning (EC-TEL'12), 12th IEEE International Conference on Advanced Learning Technologies (ICALT'12), International Conference on Interactive Mobile and Computer Aided Learning (IMCL'12), IADIS International Conference e-Learning (IADIS EL'12), 5th International Conference on Computer Supported Education (CSEDU'12), 10. e-Learning Fachtagung Informatik (DeLFI'12), JTEL Summer School 2012, International Conference on Open Source Systems (OSS'12),), International Conference on Communications and Information Technology (ICCIT): Digital Information Management (ICCIT'12), International Workshop on Interactive Environments and Emergent Technologies for e-Learning (IEETeL'12).

Jan Holz was co-organizer of the “Aachener Informatik Tage” and “Schüleruniversität Informatik 2012”.

Ulrik Schroeder served as a reviewer for several journals such as CSCW journal, Springer Verlag, i_COM, Oldenburg Verlag, IEEE Transactions on Learning Technologies (TLT), International Journal of Technology Enhanced Learning (IJTEL), Journal of Educational Technology & Society (ET&S). He was member of the program committee of the the 7th European Conference on Technology Enhanced Learning (EC-TEL'12), 12th IEEE International Conference on Advanced Learning Technologies (ICALT'12), 15th IASTED International Conference on Computers and Advanced Technology in Education (CATE'12), 5th International Conference on Computer-Supported Education (CSEDU'12), 10th conference on eLearning in Computer Science (DeLFI'12), 6th International Conference eLearning Baltics (eLBA'12), 11th International Conference on Web-based Learning (ICWL'12), 5th Conference on Hochschuldidaktik Informatik (HDI 2012), and 7th Workshop in Primary and Secondary Computing Education WiPSCE 2012.

Hendrik Thüs was co-organizer of the “Beratungstage 2012” for the computer science department. He was member of the program committee of the 2nd Workshop on Mobile Learning, DeLFI 2012.

Talks and Publications

Talks

Mohamed Amine Chatti: Harnessing Collective Intelligence in Personal Learning Environments. 12th IEEE International Conference on Advanced Learning Technologies (ICALT2012), Rome, July 5, 2012.

Publications

Books and Edited Volumes

Mostafa Akbari, Doreen Böhnstedt, Claudia Bremer, Mohamed Amine Chatti, Christoph Rensing: *Mobile Learning - Einsatz mobiler Endgeräte im Lernen, Wissenserwerb sowie der Lehr-/Lernorganisation*. FernUniversität in Hagen, ISSN 1865-3944.

Journal Articles

Mohamed Amine Chatti: Knowledge Management: A Personal Knowledge Network Perspective. In *Journal of Knowledge Management*, 16(5).

Mohamed Amine Chatti, Ulrik Schroeder, Matthias Jarke: LaaN: Convergence of Knowledge Management and Technology-Enhanced Learning. In *IEEE Transactions on Learning Technologies*, 5(2), pp. 177–189.

Mohamed Amine Chatti, Anna Lea Dyckhoff, Ulrik Schroeder, Hendrik Thüs: Forschungsfeld Learning Analytics. In *i-com - Zeitschrift für interaktive und kooperative Medien*, Heft 1/2012, pp. 22-25.

Anna Lea Dyckhoff, Dennis Zielke, Mareike Bültmann, Mohamed Amine Chatti, Ulrik Schroeder: Design and Implementation of a Learning Analytics Toolkit for Teachers. *Journal of Educational Technology & Society*, 15(3), pp. 58–76.

Daniel Herding, Ulrik Schroeder, Patrick Stalljohann, Mohamed Amine Chatti: Formatives Assessment in offenen, informellen, vernetzten Lernszenarie. In *i-com - Zeitschrift für interaktive und kooperative Medien*, Heft 1/2012, pp. 19-21.

Conference and Book Contributions

Fatma Batur, Nadine Bergner: Grundschulkindern begeistern mit der Zauberschule Informatik. In *Ideen und Modelle: 5. Münsteraner Workshop zur Schulinformatik*. Norderstedt: Books on Demand, 2012.

Nadine Bergner, Jan Holz, Ulrik Schroeder: Über fundamentale Ideen hinaus: Informatik im InfoSphere - Schülerlabor Informatik. In *Ideen und Modelle: 5. Münsteraner Workshop zur Schulinformatik*. Norderstedt: Books on Demand, 2012.

Nadine Bergner, Jan Holz, Ulrik Schroeder: Cryptography for Middle School Students in an Extracurricular Learning Place. In *CSEDU 2012 - Proceedings of the 4th International Conference on Computer Supported Education*. Porto, Portugal: SciTePress, 2012.

Philipp Brauner, Hendrik Thüs, Martina Ziefle, Ulrik Schroeder: *ScratchTab - Eine Tablet-basierte Anwendung zum Erlernen von Programmierkonzepten*. In Proceedings of the Workshop on Mobile Learning, DeLFI 2012, pp. 15-22.

Mohamed Amine Chatti, Matthias Jarke, Ulrik Schroeder: Double-Loop Learning. In N.M. Seel (Ed.) *Encyclopedia of the Sciences of Learning*, pp. 1035–1037. Springer.

Mohamed Amine Chatti, Ulrik Schroeder, Hendrik Thüs, Simona Dakova: Harnessing Collective Intelligence in Personal Learning Environments. In *Proceedings of the 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012)*, pp. 344–348. IEEE Computer Society.

Jan Holz, Nadine Bergner, Andreas Schäfer, Ulrik Schroeder: Serious Games on Multi Touch Tables for Computer Science Students. In *CSEDU 2012: proceedings of the 4th International Conference on Computer Supported Education*. Porto, Portugal: SciTePress -Vol. 2, 2012.

Terhi Kilamo, Imed Hammouda, Mohamed Amine Chatti: Teaching collaborative software development: a case study. In *Proceedings of the 2012 International Conference on Software Engineering*, pp. 1165-1174. Piscataway, NJ, USA: IEEE Press.

Media Computing Group



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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 Fablab 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 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 December 2011 the chair for media computing has attracted 180,000 Euros of new third-party funding for the group. The project MACS, in collaboration with Vestfold University in Norway and funded by the Norwegian Research Council, builds on the Media Computing Group's research in using tangible widgets on interactive tabletops, and aims to create the control bridge of future large maritime vessels. The funding will support, among other things, a three-year PhD student position in the Media Computing Group to work on this project.

Research Projects

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

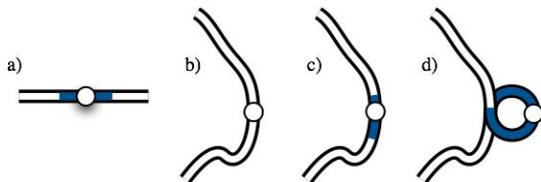
Power consumption is measured in W and Wh, but what do these units mean? Water consumption can easily be understood, as we all know what a liter of water looks like. Common power meters rely on the physical units or their translation to costs as display. We classified existing displays and ambient visualizations 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

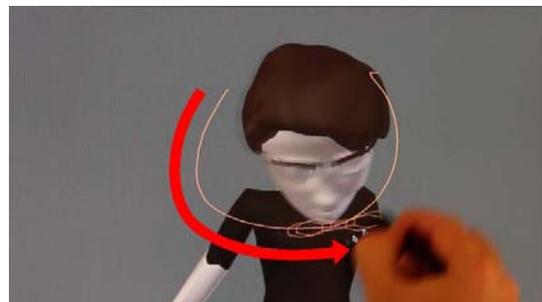
Thorsten Karrer, Moritz Wittenhagen, Jan Borchers

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.



Tangible Interaction on Tabletops

Malte Weiss, Florian Schwarz, Simon Jakubowski, Chatchavan Wacharamanotham, Jan Borchers

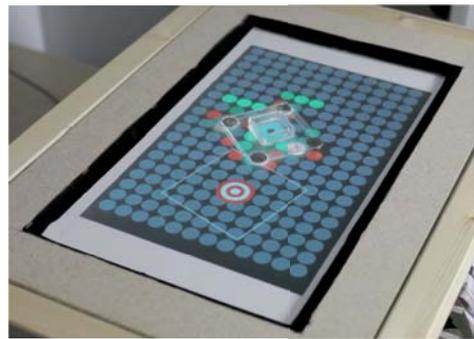
SLAP Widgets

On-screen controls are flexible but directly manipulating them using fingers introduces occlusion and precision issues. Furthermore, the user must focus on the control instead of the data she manipulates. *SLAP Widgets* address these issues by combining the benefits of physical widgets and on-screen controls. *SLAP Widgets* are general-purpose controls made from silicone and acrylic. They provide haptic feedback and allow a precise eyes-free interaction while using the table's back projection to change their appearance dynamically. They are untethered, low-cost, and easy to prototype. Our widget set contains keyboards, sliders, knobs, and keypads.



Madgets

SLAP Widgets provide a physical communication in only one direction: from the user to the system. The table cannot change the physical state of a control. This can cause visual-physical inconsistencies. *Madgets*, magnetic widgets, extend *SLAP Widgets* with the ability of actuation. Our interactive table integrates electromagnetic actuation and fiber optical tracking in a single device without using external projectors or cameras. The table can move and configure *Madgets* consisting of multiple parts. Our system enables well-known GUI concepts for tangible tabletop controls, such as undo or remote collaboration, as well as new actuation dimensions, like height, force feedback, or power transfer.



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.



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.

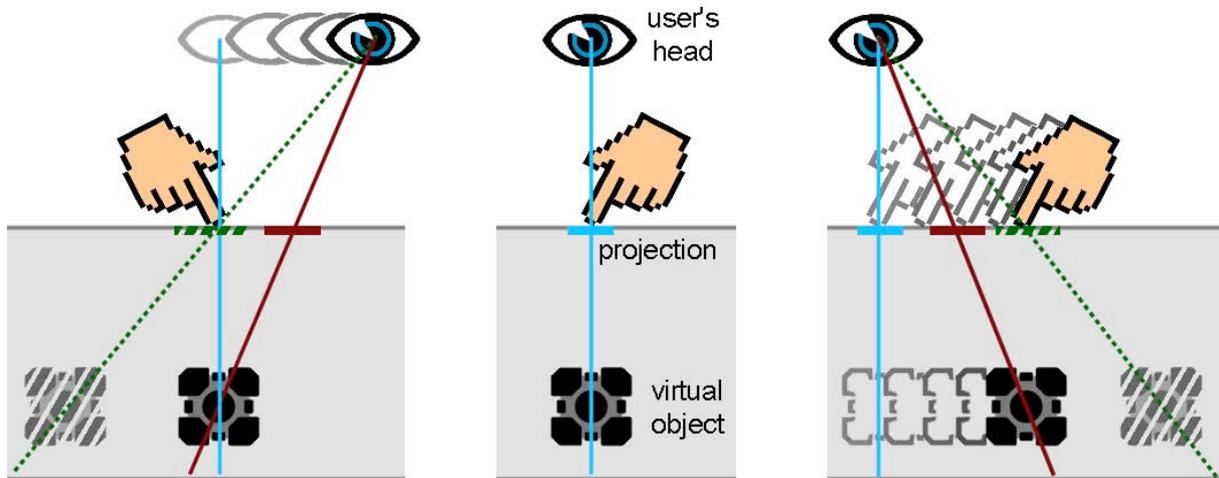


BendDesk is a multi-touch desk environment that seamlessly combines a vertical and a horizontal surface with a curve into one large but still reachable interactive workspace. This workspace can be used to display any digital content like documents, photos, or videos. Furthermore the multi-touch technology 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 comfortable at it.

In a second study we investigated flicking as a common interaction technique to move objects across large interactive surfaces, since little is known about its suitability for use on non-planar, curved surfaces. Flicking consists of two stages: First, visually determining the direction in which to flick the object, then planning and executing the corresponding gesture. Errors in both stages could influence flicking accuracy. We investigated flicking interactions on curved interactive surface to evaluate which type of error influences accuracy. Therefore, we carried out three user studies to analyze how each stage of flicking on a curved surface is influenced. Our main findings are: 1) Flicking gestures are more accurate if horizontal and vertical surface are joined by a continuous curve than if they are separated by an edge or gap. 2) Flicking gestures on curved surfaces are mostly influenced by the motor execution stage of the gesture rather than the visual perception stage. 3) Flicking accuracy decreases as the starting point of the gesture is moved closer to the curve. 4) We conclude with a first mathematical model to estimate the error users will make when flicking across a curve.

Direct Manipulation and the Third Dimension: Co-Planar Dragging on 3D Displays

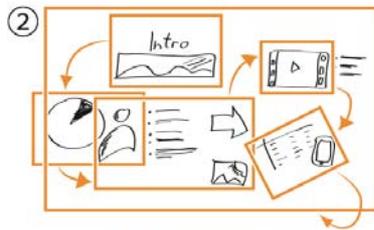
Max Möllers, Patrick Zimmer, Jan Borchers



Recent advances in touch and display technologies are supporting a wide-spread use of touch-based direct manipulation techniques as well as 3D displays that give a perspective correct view. Both techniques have consistency constraints including the following: With direct manipulation, a dragged object should stick to the finger tip. With viewer centered projection, head movement should update the scene's projection to preserve a sound 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 touching or dragging an object, non-trivial. We introduce a design space of perspective adjusted methods for direct manipulation to cope with this limitation, select nine different strategies from it, and evaluate six of them in depth. Participants dragged a box through a 3D maze with multiple, partially occluded levels. We identified one method to be among the fastest while yielding up to 32% less collisions than the other fast methods.

Fly: a canvas presentation software

Thorsten Karrer, Leonhard Lichtschlag, Thomas Hess, Claude Bemtgen, 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 tasks 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.



Route Charlemagne

Malte Weiss, Max Möllers, Gero Herkenrath, Florian Heller, Jan Borchers

Route Charlemagne is a citywide project to attract tourists to the city of Aachen and to convey historical and cultural information to visitors in a modern and appealing way. Our department has contributed five exhibits to the city hall of Aachen that enable users to explore facts around this influential building in an interactive way. 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.).

Other Activities

Courses

Winter semester 2011/12

- Lecture: Designing Interactive Systems I
- Lecture: iPhone Programming
- Lab: Media Computing Project
- Seminar: Post Desktop User Interfaces

Summer semester 2012

- Lecture: Designing Interactive Systems II
- Lab: Multimodal Media Madness

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, reaching the 9th and 13th of the most viewed lectures in October 2011.

World Usability Day

In November 2011, we organized the sixth World Usability Day Aachen Local Event in cooperation with P3 Solutions at our lab. The main purpose of this annual event is to provide an introduction to the topic and create an awareness of the problem of inadequate usability. We covered the fundamentals of designing for usability including an introduction to cognitive psychology, the historical development, the user-centered design process, and methods of prototyping and evaluation.

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 laser cutter (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 Kinderferienspiele der RWTH, Wissenschaftsnacht). In Feb 2011, we offered the *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>.



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>).



Applications

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 laser-cutter 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 work-flow by removing unnecessary steps and make the most common jobs more easy. A driver for laser-cutters named *liblaser* abstracts from the specific laser-cutter model.



AATC/e: Apple Authorized Training Center for Education

In early 2009, our group became an Apple Certified Training Center for Education at RWTH Aachen University. This year, we again organized several Apple-certified courses. Example courses include Apple Support, Server Essentials, Directory Services, and Deployment. All our trainers are experienced administrators and scientists from different faculties of RWTH Aachen University. Our goal is to provide certified, high-quality training for Apple systems to our students, staff members, and anyone else interested (<http://aatc.rwth-aachen.de/>).

Infrastructure

Our infrastructure evolves constantly, but at the time of writing consists of 8 XServe servers with two XServe RAIDs, 18 desktop machines (10 Mac Pros, 8 Mac minis) with 23" and 30" Cinema Displays and iSight cameras for the student laboratory, and individual MacBook Pros and 30" Cinema Displays for our staff. The Media Space contains five 40" mobile interactive LCD screens, an eight-channel networked surround audio setup with four discrete amplifiers and dedicated Firewire audio interface, high-fidelity videoconferencing and a variety of non-standard input and output technologies (infrared batons, various sensors, Bluetooth devices, etc.). The Fab Lab (see above) is another crucial part of our research infrastructure. We create this environment to facilitate experimentation with time-based multimedia and nonstandard interaction techniques for our students and staff.

In 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 hcupatterns.org home page as heads of the IFIP task group.

Talks and Publications

Talks

Jan Borchers. *Von 3D-Printing und Personal Fabrication zum Personal Design: Benutzer als Produzenten der Zukunft*. iteratec Workshop 'IT-Management in der Praxis', Munich, Oct 17, 2012.

Jan Borchers. *From 3D Printing and Personal Fabrication to Personal Design: Users as Makers*, SandCHI Talks, ACM SIGCHI Chapter San Diego, CA, Jun 20, 2012.

Jan Borchers. *Media Computing Research Madness*, Ubicomp & Social Dynamics Group, Dept. of Computer Science, UCSD, San Diego, CA, Jun 5, 2012.

Jan Borchers. *Research Overview & The Silhouettes Interactive Exhibit*, Invited guest lecture, Designing Gesture-Based Interfaces (Spring 2012 Class COGS160), Dept. of Cognitive Science, UCSD, San Diego, CA, May 24, 2012.

Jan Borchers. *Media Computing Research Madness*, DCOG-HCI Meeting, Dept. of Cognitive Science, UCSD, San Diego, CA, Apr 18, 2012.

Jan Borchers. *From Personal Fabrication to Personal Design*. Invited Speaker, 18. Handelsblatt-Tagung, Munich, Jan 25, 2012.

Jan Borchers. *Campus im Vergleich zu den Universitäten in Hamburg und München: Welche Stadt braucht die Universität? Welche Universität braucht die Stadt?*, Discussion Panel Member, Aachen Fenster, SuperC Building, Aachen, Jan 16, 2012.

Jan Borchers. *Making Things Usable*. Invited Speaker, TEDx Conference, University of Hasselt, Nov 7, 2011.

In addition, talks by the respective authors accompanied the publications below.

Publications

Max Möllers, Patrick Zimmer, and Jan Borchers. Direct Manipulation and the Third Dimension: Co-Planar Dragging on 3D Displays. *Proceedings of ITS 2012*, November 2012.

Malte Weiss, Chat Wacharamanatham, Simon Voelker, and Jan Borchers. FingerFlux: Near-surface Haptic Feedback on Tabletops. In *Proc.UIST 2011*, pages 615-620, October 2011.

Marty Pye. *Bimanual Rotation in Midair Combining Multiple and Single Degree of Freedom Manipulation*. Bachelor's thesis, RWTH Aachen University, September 2012.

Stefan Ivanov. *TextiPad: Implementation and Evaluation of a Wearable Textile Touchpad*. Master's thesis, RWTH Aachen University, September 2012.

Ahsan Nazir. *NoteCarrier: A Nomadic Application for Bi-Directional Class-Room Communication*. Master's thesis, Bonn University, September 2012.

Malte Weiss. *Bringing Haptic General-Purpose Controls to Interactive Tabletops*. PhD thesis, RWTH Aachen University, September 2012.

Norbert Dumont. *The Impact of Body Posture on Touchtable Accuracy*. Master's thesis, RWTH Aachen University, June 2012.

Christoph Vobis. *How's My Driving? Providing Driver Feedback to Improve Driving*. Master's thesis, RWTH Aachen University, May 2012.

- Ying Zhang. *A Classification of Interaction Styles that Span Multiple Systems*. Master's thesis, RWTH Aachen University, May 2012.
- Julian Meichsner. *Evaluation of Interactive Tablets for Improving Customer Service in Restaurants*. Master's thesis, RWTH Aachen University, May 2012.
- Mariana Bocoï. *LumiNet 2 — An Organic Interactive Illumination and Sensor Network for Fashion*. Master's thesis, RWTH Aachen University, May 2012.
- Simon Voelker, Christine Sutter, Lei Wang, and Jan Borchers. Understanding Flicking on Curved Surfaces. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems 2012*, pages 189-198, May 2012.
- Jan-Peter Krämer, Joachim Kurz, Thorsten Karrer, and Jan Borchers. Blaze: supporting two-phased call graph navigation in source code. In *CHI '12: Extended abstracts on Human Factors in Computing Systems 2012*, pages 2195-2200, May 2012.
- Benjamin Walther-Franks, Marc Herrlich, Thorsten Karrer, Moritz Wittenhagen, Roland Schröder-Kroll, Rainer Malaka, and Jan Borchers. Dragimation: direct manipulation keyframe timing for performance-based animation. In *Proceedings of the 2012 Graphics Interface Conference, 2012*, pages 101-108, May 2012.
- Florian Heller and Jan Borchers. DiskPlay: In-Track Navigation on Turntables. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*, May 2012.
- Malte Weiss, Gero Herkenrath, and Lucas Braun. Text Entry on Interactive Tabletops Using Transparent Physical Keyboards. In *CHI 2012 Workshop on Designing and Evaluating Text Entry Methods*, May 2012.
- Max Möllers, Patrick Zimmer, and Jan Borchers. Direct Manipulation and the Third Dimension: A Design Space for Co-Planar Dragging on 3D Displays. In *CHI '12: Extended abstracts on Human Factors in Computing Systems 2012*, May 2012.
- Leonhard Lichtschlag, Thomas Hess, Thorsten Karrer, and Jan Borchers. Canvas Presentations in the Wild. In *Proceedings of the CHI 2012 Conference on Human Factors in Computing Systems*, May 2012.
- Leonhard Lichtschlag, Thomas Hess, Thorsten Karrer, and Jan Borchers. Fly: Studying Recall, Macrostructure Understanding, and User Experience of Canvas Presentations. In *Proceedings of the CHI 2012 Conference on Human Factors in Computing Systems*, May 2012.
- Thorsten Karrer, Moritz Wittenhagen, and Jan Borchers. DragLocks: Handling Temporal Ambiguities in Direct Manipulation Video Navigation. In *Proceedings of the CHI 2012 Conference on Human Factors in Computing Systems*, May 2012.
- Otmar Hilliges, David Kim, Shahram Izadi, Malte Weiss, and Andrew Wilson. HoloDesk: direct 3D interactions with a situated see-through display. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*, pages 2421-2430, May 2012.
- Can Liu, Stéphane Huot, Jonathan Diehl, Wendy E. Mackay, and Michel Beaudouin-Lafon. Evaluating the Benefits of Real-time Feedback in Mobile Augmented Reality with Hand-held Devices. In *Proceedings of CHI 2012*, May 2012.
- Zhao He. *Fabiji: A Tablet Kiosk to Facilitate Creating and Sharing Documentation at Fab Labs*. Master's thesis, RWTH Aachen University, March 2012.
- Alexandru Popa. *Tracking hand tremor on touchscreen*. Master's thesis, RWTH Aachen University, March 2012.

Clio Kakoulli. *IdeaBall: A Physical Artifact for Moderating and Analyzing Brainstorming Sessions*. Master's thesis, RWTH Aachen University, February 2012.

Alisa Novosad. *Object Selection and Adaptive Trajectories in DRAGON*. Master's thesis, RWTH Aachen University, February 2012.

Christian Corsten. *Co-Optjects: Instant User Interfaces Through Everyday Objects*. Master's thesis, RWTH Aachen University, January 2012.

Can Liu. *Exploring Mobile Augmented Reality Instructions to Assist Operating Physical Interfaces*. Master's thesis, RWTH Aachen University, January 2012.

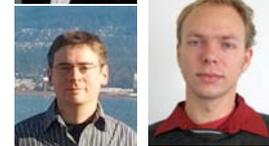
Florian Heller and Jan Borchers. *Physical prototyping of an on-outlet power-consumption display*. *interactions*, **19**:14-17, January 2012.

Embedded Software Laboratory



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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 are 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, three dissertations were successfully defended: Alexander Michailidis and Michael Reke finished their work as external PhD students in industry, both in the area of Automotive Software Engineering, and Ralf Mitsching who left last year, received his PhD with a thesis on Timed Testing. Further research assistants left for industry: Kamal Barakat, Jörg Brauer, Hilal Diab and Dominique Gückel all obtained attractive positions in development departments of large and small embedded systems companies. The gaps will be filled by Christian Dernehl, Thomas Gerlitz, and Florian Göbe, who started at i11 recently. We also welcome our third apprentice, René Strehl.

We look forward to an exciting new academic year. Life in the group may change, as I became dean of our faculty and will have to spend a considerable amount of my time in this job. However, I know that all members of the group will push as hard as in the last years to make sure we can keep up with the high quality of our teaching and research. As in all the last years I am grateful to the whole team for the great work and all the valuable contributions to our research, teaching and organisational activities.

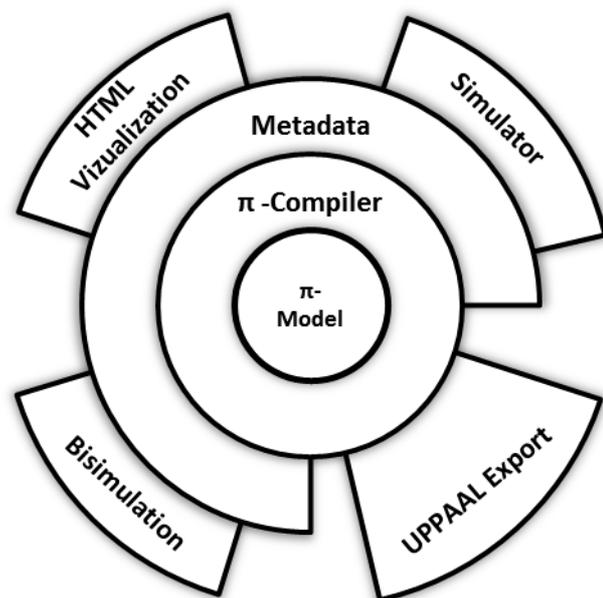
Research Projects

Applying Formal Methods for QoS Provisioning in Mobile Architectures

Kamal Barakat

This work was funded by the DFG Cluster for Excellence on Ultra-High Speed Information and Communication (UMIC), German Research Foundation grant DFG EXC 89.

Applying Formal Methods for Quality of Service Provisioning in Mobile Architectures is a project running under the UMIC excellence cluster. We address the topic of QoS provisioning in telecommunications in general and in mobile architectures in 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 separate software (the interpreter/simulator) 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. The simulator offers two operational modes; real-time and simulation. These two modes enable studying the specification from different aspects because the simulation mode is not Zeno free while the real-time mode is.



The compiler is also the central building block for further rules such as a transformation tool for model-checking using external systems like UPPAAL and a visualization tool for representing modeled protocols interactively using web browsers. Model-checking the specification after transforming it into UPPAAL answers questions about its correctness. In addition, it allows investigating its safety-critical properties. The visualizer on the other hand has two characteristics. It is firstly a document transformation utility that produces a HTML document from the original LATEX spec. Secondly, it allows the user to interactively step through the system and watch how processes interact and evolve. This feature represents a debugging facility. We are also working on a bisimulation engine that is able to verify whether two different pi-calculus specifications are timely equivalent.

The ability to simulate, visualize, debug and model-check telecommunication protocol specs eliminates the need for concrete implementations in order to evaluate a particular specification. Early verification of specifications under progress reduces development time and costs.

Static Analysis of Microcontroller C Code

Eva Beckschulze

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 prominent 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 our static analyze, 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.

Hybrid Systems Verification of a Controlled Platoon of Vehicles with a Topological Changing Communication Network

Ibtissem Ben Makhlof, Hilal Diab, Paul Hänsch

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.

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.

The hardware implementation was also extended with an indoor positioning system to control the safety when crossing an intersection with a platoon formation. Different test cases for signalized and unsignalized intersections are described and tested using scaled trucks.

Furthermore, we extended our formal verification to include non-linear hybrid systems. We implemented therefore, two different techniques: 1) the hybridization technique based on the linearization of the dynamics combined with different bisection techniques of the state space and 2) the prediction/ approximation technique based on a prediction step followed by a correction step. Thereby natural enclosures, mean value enclosure as well as different Taylor enclosure of intervals and zonotopes were implemented.

**Verification of Programs for Programmable Logic Controllers
Using Static Analysis and Model-Checking**

Sebastian Biallas

funded by DFG

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, where they operate in many safety critical circumstances.

To verify such programs, a PLC simulator is used to automatically create a model that can be checked against logic formulae. For larger programs, abstraction techniques are required to represent the possible program behavior in a compact form. The progress of the project is integrated into ARCADE.PLC, which is the PLC specific part of the ARCADE framework developed at the Embedded Software Laboratory.

The current features of ARCADE.PLC were presented at the 27th IEEE/ACM International Conference on Automated Software Engineering. Additional results of the project were presented at the AUTOMATION congress, the 11th International Workshop on Discrete Event Systems and in Automatisierungstechnische Praxis (atp EDITION), 7-8/2012.

Improving Autonomy in Micro Air Vehicles

Christian Dernehl

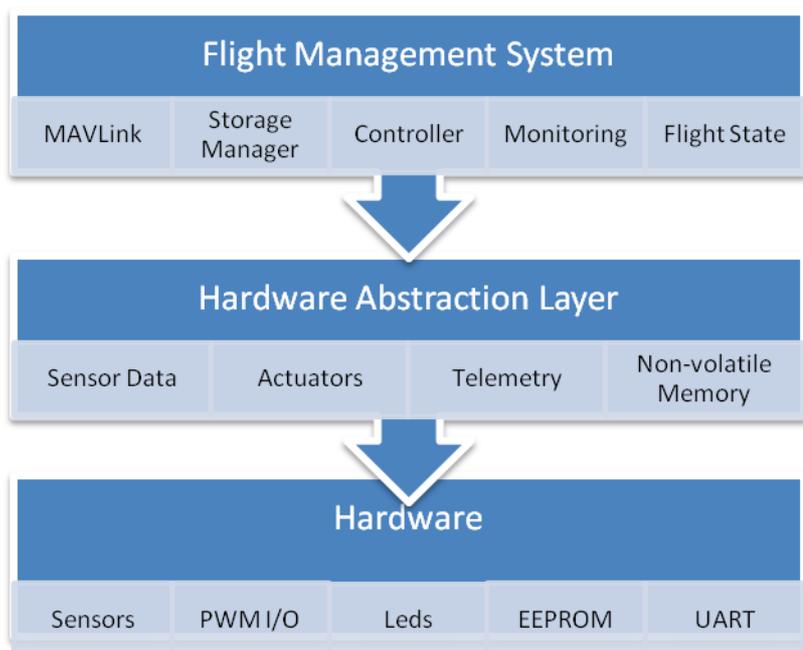
Micro Air Vehicles (MAVs) have become popular over the recent decades and usually describe vehicles with less than 1.5m wingspan. With increasing computational power and decreasing size of microcomputers, the degree of automation in MAVs increases. Research topics in this field include control theory, swarm analysis, materials science and further aspects. Our goal is to implement a tilt-wing MAV, capable of hovering and flying fixed wing, allowing a small airspeed, while taking advantage of energy saving fixed wing concepts. The tilt-wing can be seen as a regular plane with the possibility to change the orientation of the wing, while an extra rotor is mounted at the tail of the vehicle for stabilization during hovering.



In a first approach, models with the Institute for Flight Dynamics at RWTH Aachen University have been developed and the software for the tilt-wing MAV has been implemented. With simple control concepts, the tilt-wing aerial vehicle could be stabilized in certain situations and a flight guidance system could be implemented. The onboard sensors of the prototype include an inertial measurement unit, a magnetometer, a GPS receiver, a barometer

and an ultrasonic sensor. Furthermore a camera for computer vision has been mounted at the front of the tilt-wing MAV. In our scenario the MAV detects a predefined rectangular object at the ground with known position and derives from this position information. Thus, for a more precise navigation solution the data from all sensors are fused by a Kalman filter, which can optionally activate the camera system, depending on the situation. For example, the Kalman filter switches back to regular inertial and GPS navigation, if the object could not be recognized.

During the development of the aerial computer, a flight management system has been implemented, allowing the simulation of the embedded software on a desktop computer. Using abstraction techniques, the software in the higher levels can either run in a simulation environment or on the actual MAV. With an attached Matlab model, designed by the Institute for Flight Dynamics, the physics of the tilt-wing MAV can be



calculated and feed into the simulation, allowing software in the loop simulation. In the given figure, the hardware abstraction layer decides if the corresponding hardware shall be activated, or if data shall be sent to the simulator. Within the flight management system, there are systems taking care of storing control parameters (storage manager), the actual controller, monitoring techniques and the MAVLink protocol, to communicate to a ground control station.

For the next year, fuzzy controller concepts for the stabilization shall be implemented, to allow a safe flight in all possible tilt states. Furthermore, the video detection shall be improved, so that other objects can be detected, as well. For all flight tests so far, good weather conditions were necessary. Improving the controller in a way, so that stronger winds and other environment conditions are considered, is another goal for the upcoming year.

Dependable Reuse and Guarded Integration of Automotive Software Components

Marc Förster

funded by VDA-FAT AK 31

The integration of components to a correct and dependable whole is an important task in the development and maintenance of automotive software. 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, whether the composite system will show the required behaviour, deducible from the properties of its components (regarding functional as well as nonfunctional aspects). 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. 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 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; in the second phase, a selected approach (Rich component model, together with an algebra to formally conjoin, compose and refine contracts) has been applied to the model of

an embedded software system provided by an OEM. At the same time, strengths, weaknesses and open questions of existing approaches have been identified.

The forthcoming project report will enable industrial partners (1) to assess 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.

The UMIC Software Quality Initiative

Dominik Franke

funded by the DFG Cluster for Excellence on Ultra-High Speed Information and Communication (UMIC), German Research Foundation grant DFG EXC 89.

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 develop methods which 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 specification of design patterns and architectures for mobile applications, in order to improve the quality of the mobile software. The current focus is the analysis and improvement of quality related to 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 apply testing and formal methods to analyze lifecycles of different mobile platforms and to build tools that deal with lifecycle implementations at development time. Based on this analysis we developed the tool “AndroLIFT” to support Android developers during the implementation of the Android Activity lifecycle. This tool also provides functionality to test life cycle-related properties of an Android application. Our tool Higgs is capable of executing AndroLIFT test cases on various mobile phones in parallel (iOS and Android phones). For instance, the following scenario can be tested by these two tools: Device1 starts a mail application and types in some text; Device2 calls Device1; the active mail application on Device1 is interrupted by the incoming call from Device2 and is transferred into the pause-state. Device1 dismisses the call and resumes the previously active mail application again. AndroLIFT checks and reports if any mail content, typed in before the incoming call, has been lost. Currently we are working on a third tool to specify life cycle-related requirements in a Frank-like syntax and past time temporal logic. Finally the three tools shall be composed to one single life cycle framework. It shall cover the specification, automatic test generation and execution up to reporting of test results.

eNav – Efficient Routing for Electric Wheelchairs

Dominik Franke

In today's uprising trend towards electric powered vehicles energy efficiency becomes a major objective. We developed a routing algorithm for electric wheelchairs, which computes next to the fastest and shortest routes, also the most efficient route regarding energy consumption. Therefore we modified the A*-routing algorithm to take topological information of the routing graph into account. The algorithm focuses mainly on slopes, but further properties as flooring may be considered, too.

We are currently working on an implementation of an eNav routing server, which will provide the routing functionality to various clients via the Internet. We also are working on two different clients. One is a web interface providing the routing information through a Google Maps-like frontend. The other client is a mobile Android application called "AndNav 2" which allows mobile access to the routing functionality.

Reachability and invariance in continuous-time dynamical systems

Paul Hänsch

funded by AlgoSyn (DFG reasearch training group 1298)

Reachability analysis is a fundamental method in proving safety of dynamical system models. The principle of invariance is tightly linked to reachability since an invariant by definition gives conservative answers to many instances of reachability problems. Hence, invariant sets can be used to prove safety. In the case of linear dynamic systems, it is known that ellipsoidal invariants can be found using linear matrix inequalities. This is also true, if the system is subject to unpredictable disturbances, provided the disturbances are bounded and the bounds are known. However, it turned out that foregoing transformations of the dynamic system can reveal decompositions of the system that yield tighter invariants. Such transformations can be obtained by, for instance, eigenvector-decomposition or Schur-decomposition. Insights have been gained on how to detect decompositions that pay off. It is under investigation if and how the results can be extended to nonlinear systems.

Real-Time Extensions to the Android Platform

Igor Kalkov

Android is a modern, mobile software platform for embedded systems. Staying reactive with full-fledged multitasking support and high usability makes this open-source operating system an attractive target for users and developers. Nowadays, the industry is exploring the capabilities of Android in automation, monitoring and controlling of essential processes in complex environments.

This raises a question about the suitability of Android for real-time applications, which are typically extended by additional constraints if deployed in safety-critical domains. Our goal is the development of a new version of Android Platform, which is able to serve real-time requests, but still provides full backward-compatibility to existing software applications. This includes the extension of the core Android components like the Linux kernel and the Dalvik virtual machine (DVM) with basic real-time capability. Furthermore, blocking garbage collection becomes an issue in real-time systems if its invocation interrupts a process with real-time requirements or causes violations of predefined deadlines. Thus, providing a real-time capable, automatic memory management is one of the main project parts.

An Android system with the ability to serve real-time requests enlarges the field of application for Android devices to time-critical domains. For instance, real-time Android could then be used as an in-field monitoring device in industrial plants or as a control platform for home automation. Research topics in this field also include the suitability of real-time Android as all-in-one solution for the replacement of simple setups with programmable logic controllers (PLCs). Continuous improvements in the portability, usability and computational power of modern tablet PCs allow the development of an integrated environment for working with PLC-common programming languages. Given the fundamental support of the real-time capable operating system, the development, simulation and execution of typical PLC programs, as well as the communication to external hardware components could be possibly merged and performed on a single Android mobile device.

“Integrated Multi-formalism Tool Support for the Design of Networked Embedded Control Systems” (MULTIFORM)

Volker Kamin

funded by the European Commission (FP7)

MULTIFORM focused 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 has been supported by the Seventh Research Framework

Programme of the European Commission under grant agreement number INFSO-ICT-224249.

Within this project, the Embedded Software Laboratory at RWTH Aachen extended the model checker ARCADE (formally known as [mc]square) to be able to handle complex control software. Firstly, abstraction techniques have been 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 counterexamples has been researched. ARCADE can now automatically refine the state space in order to block certain spurious counterexamples such as time-triggered loops that are never left.

Using the results of the MULTIFORM project, ARCADE was able to uncover a number of software errors in real industrial controller code including errors that were introduced by faulty compilers and not visible on the C code level, i.e., errors invisible to the software engineers. Using the counterexamples ARCADE provided, these errors could be easily located and fixed. For the resulting version of the controller software, ARCADE yielded proofs for the absence of these errors.

In addition to the extension of ARCADE, the Embedded Software 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.

VEMAC and the Embedded Software Laboratory will continue to cooperate after the end of MULTIFORM. Current research efforts focus on the verification indirect control flow and data access as well as checking properties derived directly from C source code (e.g., no index out of bounds, well aligned struct member access).

Model-based Analysis of Design Artefacts in Embedded Software Development

Daniel Merschen and Thomas Gerlitz

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 a major car manufacturer 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 to identify which subsystems in a Simulink model have to be changed and which test cases are affected. For that purpose, also signal dependencies in the Simulink model have to be considered. To tackle these challenges

we are currently developing a framework which (1) integrates artefacts into a common database to overwhelm tool isolation and (2) which can be applied to realise artefact-comprehensive, automated analyses. To this end, we first transfer artefacts into the database and then apply database queries and Java functionality. Furthermore, we focus on establishing traceability and consistency among the related models with the help of an artefact-comprehensive, standardised annotation concept.

**Adaptation of Non-Dedicated Software
for Deployment in Networks of time-critical Systems**

John F. Schommer

funded by the DFG Cluster for Excellence on Ultra-High Speed Information and
Communication (UMIC), German Research Foundation grant DFG 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 non-embedded applications 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. First, the investigation of existing platforms, architectures, middleware and applications along with test implementations are performed. Second, evaluations of hardware and of how far current devices are capable of the propagated requirements are ongoing. From this exhaustive evaluation explicit requirements for such networks of time-critical systems and software running on top of these systems are derived.

In the current stage of the project, the development of new patterns and methodologies to improve platforms, architectures and applications is done. In the last stage, these new patterns have to be evaluated against the derived requirements. This accompanies further evaluation, suitable prototypes, reference implementations and documentation.

Controlled Extracorporeal Lung Assistance (Smart ECLA)

André Stollenwerk

joint work with Philips Lehrstuhl für Medizinische Informationstechnik; Lehr- und Forschungsgebiet Kardiovaskuläre Technik, Lehrstuhl für Angewandte Medizintechnik, Helmholtz-Institut; Klinik für Anästhesiologie

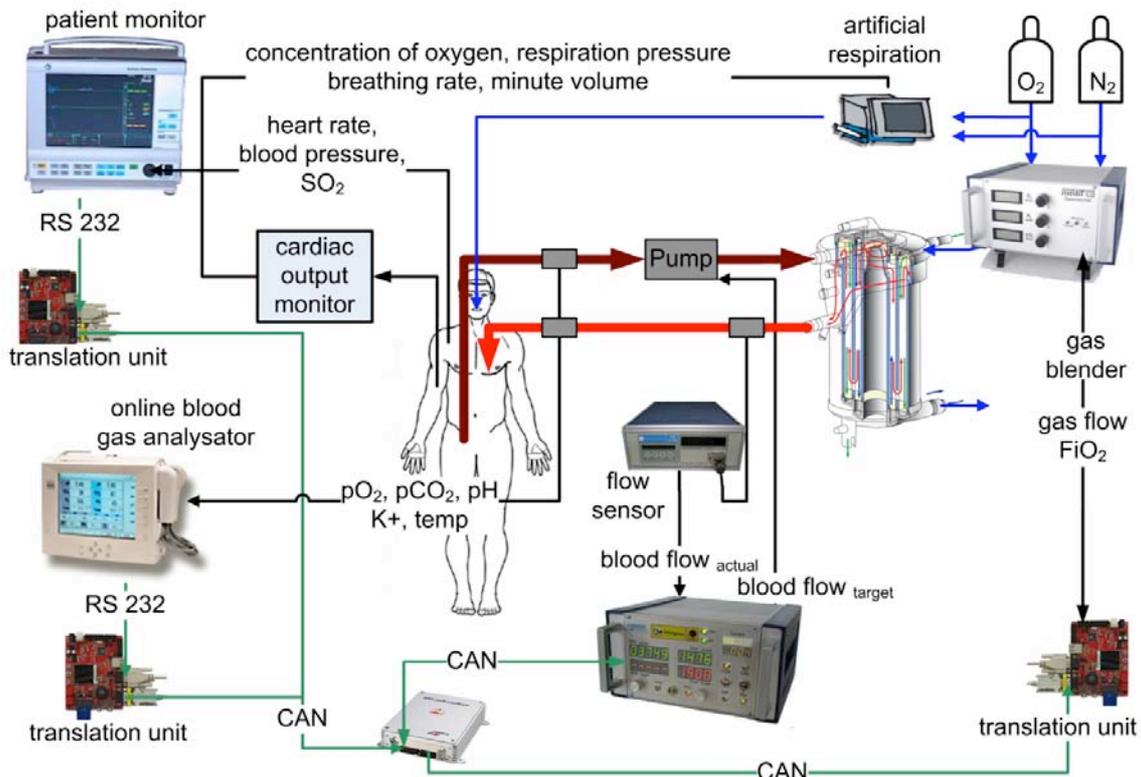
funded by DFG (PAK 138)

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.

Carolo Cup 2012

Benedikt Rieke, Bernard Kirchen and Dominic Gatzen

funded in part by Undergraduate Funds of the Faculty of Mathematics, Computer Science and Natural Sciences

In 2012 the team GalaXIs (www.galaxis.rwth-aachen.de) supported by the Embedded Software Laboratory won the fourth place at the Carolo Cup of developing autonomous model cars. The Team consists of three students (Benedikt Rieke, Bernhard Kirchen and Dominic Gatzen).

In this year the team from Braunschweig (CDLC) has won the competition and the team from Ulm (Spatzenhirn) was placed second, while the team from Zwickau (S.A.D.I) won the third place.



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.

IMAV 2012

Felix Gathmann, Andreas Schumacher and Daniel Schemmel

funded in part by Undergraduate Funds of the Faculty of Mathematics, Computer Science and Natural Sciences

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 second 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, David Osten, Johannes Braukmann and Max Keller, and the Embedded Software Laboratory, represented by Andreas Schumacher, Felix Gathmann and Daniel Schemmel.



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. This year, the team took part in the competition with the model from 2011 (white) and a new version of the model (blue). The resulting planes follow the tiltwing concept, allowing fixed wing flight, tilting the wing and then hovering. This concept for an autonomous air vehicle was unique at the IMAV 2012 and found great attention and feedback from the other participants. Thus in the second year of participation in the IMAV 2012 the MAVerix team won the award for the most innovate MAV. Other teams with multiple years of IMAV-experience, participating at the IMAV were the ENAC Paparazzi (École Nationale de l'Aviation Civile, France) and Akaflieg (Academic Flight Club Bremen, Germany). With their interesting and promising approach the MAVerix team is attending to participate next year once again in the IMAV 2013.



Other Activities

Courses

Winter semester 2011/12

- Lecture “Computer Engineering”
- Lecture “Dynamic Systems for Computer Science Students”
- Lab course “System Programming”
- Lab course “Development of a 3D Replicator”
- Seminar “Model-based Analysis of Simulink Models”
- Seminar “Testing of Mobile Applications”
- Seminar “Dynamical Systems”

Summer semester 2012

- Lecture “Introduction to Embedded Systems”
- Lecture “Safety and Reliability of Software-Controlled Systems”
- Lab course “System Programming”
- Lab course „NXT-Programming”
- Seminar „Robust Software for Heterogeneous Networks“

Stefan Kowalewski

- Dean, Faculty of Mathematics, Computer Science and Natural Sciences, RWTH Aachen University, since 2012
- Member of the Board, „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
- Head of Steering Board Member, Technical Committee “Automotive Software Engineering”, German Society for Computer Science (GI), since 2012.
- Member of the Editorial Board, at-Automatisierungstechnik (German Journal on Control and Automation Theory), Oldenbourg, Munich, since 2005.
- Associate Editor, Journal on Discrete Event Dynamic Systems: Theory and Applications, Springer-Verlag, since 2006.
- Co-Chair 12th European Control Conference (ECC 2013), Zurich, 2013
- Chairman, Technical Committee "Cyber Physical Systems", German Society on Measurement and Automation (VDI/VDE-GMA), since 2012.
- Head of Steering Board, Technical Committee “Automotive Software Engineering”, German Society for Computer Science (GI), since 2012 (Member 2005-2012).
- Co-Chair, German Conference on Software Engineering, Aachen, 2013

Talks and Publications

Talks

Stefan Kowalewski and Andre Stollenwerk "Supporting Evolving Requirements in CPS by Abstraction Layers in the Architecture", in Proc. Workshop on Architectures for Cyber-Physical Systems, Chicago, IL, USA, 2011.

Publications

Barakat, K. and Kowalewski, S., "Modeling and Verification of Network Protocol Specs using Timed Pi-Calculus", in Proc. The 4th International Workshop on Mobile Computing and Networking Technologies 2012 (WMCNT-2012), Saint-Petersburg, Russia, 2012, IEEE Press, pp. 735-742, To appear.

Barakat, K., Kowalewski, S., and Noll, T., "A Native Approach to Modeling Timed Behavior in the Pi-Calculus", in Proc. 6th International Symposium on Theoretical Aspects of Software Engineering, 2012, IEEE Computer Society, pp. 253-256.

Beckschulze, E., Brauer, J., and Kowalewski, S., "Access-Based Localization for Octagons", in Proc. The Fourth International Workshop on Numerical and Symbolic Abstract Domains (NSAD 2012), 2012, Elsevier, To appear.

Ben Makhoul, I., Diab, H., and Kowalewski, S., "Safety Verification of a Controlled Cooperative Platoon Under Loss of Communication Using Zonotopes", in Proc. ADHS 2012, Eindhoven, NL, 2012, In Proceedings of the 4th IFAC Conference on Analysis and Design of Hybrid Systems (ADHS 12), pp. 333-338, To appear.

Biallas, S., Brauer, J., and Kowalewski, S., "ARCADE.PLC: A Verification Platform for Programmable Logic Controllers", in Proc. of the 27th IEEE/ACM International Conference on Automated Software Engineering, 2012 in ASE 2012, ACM, pp. 338-341.

Biallas, S., Brauer, J., King, A., and Kowalewski, S., "Loop Leaping with Closures", in Proc. 19th Static Analysis Symposium, 2012 in Lecture Notes in Computer Science, Springer Berlin Heidelberg, pp. 214-230, To appear.

Biallas, S., Kowalewski, S., and Schlich, B., "Automatische Wertebereichsanalyse - Formale Verifikation für SPS-Programme", Automatisierungstechnische Praxis (atp EDITION), 54. Jahrgang, 7-8/2012, pp. 68-74, 2012.

Biallas, S., Kowalewski, S., and Schlich, B., "Automatische Wertebereichsanalyse von SPS-Programmen", in Proc. AUTOMATION 2012, Baden-Baden, Germany, Düsseldorf, 2012 in VDI-Berichte, VDI-Verlag, pp. 79-83, Long version (12 pages) on CD-ROM.

Biallas, S., Kowalewski, S., and Schlich, B., "Range and Value-Set Analysis for Programmable Logic Controllers", in Proc. of the 11th International Workshop on Discrete Event Systems, Guadalajara, Mexico, 2012, To appear.

Brauer, J. and Simon, A., "Inferring Definite Counterexamples through Under-Approximation", in Proc. NASA Formal Methods, 2012, vol. 7226 in Lecture Notes in Computer Science, Springer, pp. 54-69.

Brauer, J., King, A., and Kowalewski, S., "Abstract Interpretation of Microcontroller Code: Intervals meet Congruences", Science of Computer Programming, vol. 77, 2012, To appear.

- Diab, H., Ben Makhlof, I., and Kowalewski, S., "A Platoon of Vehicles Approaching an Intersection: A Testing Platform for Safe Intersections", in Proc. 15th IEEE Intelligent Transportation Systems Conference, 2012, To appear.
- Franke, D., Dzafic, D., Baumeister, D., and Kowalewski, S., "Energieeffizientes Routing für Elektrorollstühle", in Proc. 13. Aachener Kolloquium Mobilität und Stadt, 2012, RWTH Aachen, To appear.
- Franke, D., Elsemann, C., and Kowalewski, S., "Reverse Engineering and Testing Service Life Cycles of Mobile Platforms", in Proc. 2nd DEXA Workshop on Information Systems for Situation Awareness and Situation Management (ISSASiM), 2012, IEEE Computer Society, pp. 16-20.
- Franke, D., Kowalewski, S., and Weise, C., "A Mobile Software Quality Model", in Proc. 12th International Conference on Quality Software (QSIC), 2012, IEEE Computer Society, To appear.
- Franke, D., Kowalewski, S., Weise, C., and Prakobkosol, N., "Testing Conformance of Lifecycle-Dependent Properties of Mobile Applications", in Proc. 5th International Conference on Software Testing, Verification and Validation (ICST), 2012, IEEE Computer Society, pp. 241-250.
- Franke, D., Royé, T., and Kowalewski, S., "AndroLIFT: A Tool for Android Application Life Cycles", in Proc. 4th International Conference on Advances in System Testing and Validation Lifecycle (VALID), 2012, Xpert, To appear.
- Franke, D., Schommer, J., and Kowalewski, S., "Softwarequalität in der Mobilen Welt: Testen von Lebenszyklen Mobiler Applikationen", in Proc. Embedded Software Engineering Kongress, 2012, ELEKTRONIKPRAXIS, To appear.
- Gathmann, F., Dernehl, C., Franke, D., and Kowalewski, S., "An integrated vision aided GPS/INS Navigation System for ultra-low-cost MAVs", in Proc. International Micro Air Vehicle Conference (IMAV), 2012, IMAV, pp. 1-8.
- Hänsch, P. and Kowalewski, S., "Invariants for LTI Systems with Uncertain Input", in Proc. RP, 2012, Springer, pp. 137-148.
- Hänsch, P., Diab, H., Ben Makhlof, I., and Kowalewski, S., "Reachability Analysis of Linear Systems with Stepwise Constant Inputs", in Proc. 1st ETAPS Workshop on "Hybrid Autonomous Systems" (HAS 2011), 2012, Elsevier, To appear.
- Kalkov, I., Franke, D., Schommer, J. F., and Kowalewski, S., "A Real-time Extension to the Android Platform", in Proc. 10th International Workshop on Java Technologies for Real-time and Embedded Systems (JTRES '12), Copenhagen, Denmark, 2012, ACM, pp. 105-114, To appear.
- Kowalewski, S., Rumpe, B., and Stollenwerk, A., "Cyber-Physical Systems - eine Herausforderung an die Automatisierungstechnik?", in Proc. Automation 2012, 2012 in VDI Berichte, VDI-Verlag, pp. 113-116, Langfassung auf CD-Rom.
- Merschen, D., Duhr, Y., Hedenetz, B., and Kowalewski, S., "Evolutionsunterstützung für komplexe, modellbasierte Software-Produktlinien", in Proc. Embedded-Software-Engineering-Kongress (ESE), 2012, To appear.
- Merschen, D., Duhr, Y., Ringler, T., Hedenetz, B., and Kowalewski, S., "Model-Based Analysis of Design Artefacts Applying an Annotation Concept", in Proc. Software Engineering 2012 (SE 2012), 2012, Gesellschaft für Informatik e.V. (GI), pp. 169-180.

Merschen, D., Gleis, R., Pott, J., and Kowalewski, S., "Analysis of Simulink Models Using Databases and Model Transformations", in Proc. 8th International Workshop on Model-based Methodologies for Pervasive and Embedded Software (MOMPES '12), 2012, To appear.

Merschen, D., Pott, J., and Kowalewski, S., "Integration and Analysis of Design Artefacts in Embedded Software Development", in Proc. The 1st IEEE International Workshop on Tools in Embedded Systems Design Process (TIP '12), Izmir, Turkey, 2012, IEEE, pp. 503-508, To appear.

Michailidis, A., "Konzepte für eine virtuelle Integration von AUTOSAR-konformer Fahrzeug-Software in frühen Entwicklungsphasen," PhD Thesis , 2012.

Schommer, J. F., Franke, D., Lange, T., and Kowalewski, S., "Load Balancing for Cross Layer Communication", in Proc. 36th Annual IEEE Computer Software and Applications Conference Workshops (COMPSACW 2012), 2012, IEEE Computer Society, pp. 476-481, To appear.

Walter, M., Brendle, C., Stollenwerk, A., Kopp, R., Arens, J., Bensberg, R., and Leonhardt, S., "Patient oriented closed loop control of extracorporeal lung assist", in Proc. International Conference on Complexity in Acute Illness, 2012, Society for Complexity in Acute Illness, To appear.

Institute for Scientific Computing

Staff

- **Faculty**
Apl. Prof. Dr.-Ing. H. Martin Bucker (until 08/2012)
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Gabriele Meessen (until 12/2011)
- **Research Assistants**
Oliver Fortmeier (until 12/2011)
Michael Lulfesmann (until 10/2011)
- **Technical Staff**
None
- **Student Researchers and Teaching Assistants**
None



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, combinatorial scientific computing, and efficient numerical methods.

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

Martin Bücker

joint work with Christian Bischof and Johannes Willkomm, TU Darmstadt

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.

MeProRisk II: Optimization Strategies and Risk Analysis for Deep Geothermal Reservoirs

Martin Bücker

joint work with C. Clauser, G. Marquart, M. Herty, T. Kuhlen, RWTH Aachen University

funded by

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

In a previous project, an integrated procedure for the exploration of geothermal deposits with reduced risk in exploitation and operation has been developed. The resulting techniques have been analyzed in the context of carefully selected, yet artificial reservoirs. The aim of the successor project MeProRisk II is to transfer these techniques to realistic reservoirs and to examine further changes that are necessary for real-world scenarios. The role of the Institute for Scientific Computing is to reduce computation time of a simulation package by parallel computing and to further develop an existing software tool for optimal experimental design. The project involves partners at RWTH Aachen University, University of Kiel, Free University of Berlin, University of Freiberg, and GEOPHYSICA Beratungsgesellschaft mbH.

Limits of Computability of Metal Forming Process Chains

Martin Bücker

joint work with G. Hirt, M. Bambach, M. Herty, S. Reese, I. Vladimirov, RWTH Aachen University

funded by

Exploratory Research Space (ERS Seed Fund Project), RWTH Aachen University

“Integrated Computational Materials Engineering” is an emerging research field whose focus is on the design of materials and technological processes. This new trend in materials engineering has led to a substantial increase of the complexity of the underlying numerical simulations. The foundations of these analyses, in particular for chains of processes, are often not fully understood. Principle questions concerning the computability in terms of computing time, numerical stability, and propagation of uncertainties arise. The goal of this interdisciplinary project is to explore some of these questions in the context of metal forming and to assess the limits of predictability for the underlying process chains.

Other Activities

The two dissertations by Oliver Fortmeier and Michael Lulfesmann were submitted and defended. Martin Bucker would like to thank Arnold Reusken, RWTH Aachen University, and Rob Bisseling, Utrecht University, for acting as a second reviewer.

Courses

Winter semester 2011/12

- Introduction to Computer Science
- Combinatorial Scientific Computing

Summer semester 2012

- Introduction to High-Performance Computing

Chair Holder's scientific activities

Martin Bucker co-organized the 12th European Workshop on Automatic Differentiation, Berlin, Germany, December 8-9, 2011 and served on the program committee for the following events:

- 6th International Conference on Automatic Differentiation, Fort Collins, USA, July 23-27, 2012.
- 2011 International Conference on Computational Science and its Applications (ICCSA 2011), Santander, Spain, June 20-23, 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.
- 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.

Talks and Publications

Talks

- [1] O. Fortmeier. Algorithmen zur parallelen Simulation von Zweiphasenströmungen, Informatik Oberseminar, RWTH Aachen University, Aachen, 17. November 2011.
- [2] O. Fortmeier. Managing distributed multilevel triangulations: from DDD to DiST, Seminar at the Institute of Computational Science, Università della Svizzera italiana, Lugano, Swiss, 21. September 2011.
- [3] O. Fortmeier. A Graph Model for Minimizing the Storage Overhead of Distributing Data for the Parallel Solution of Two-Phase Flows, 25th Parallel and Distributed Processing Symposium at IPDPS-11, Anchorage, AK, USA, 20. May 2011.

Publications

- [1] A. Wurm and K. Fuchss Portela. Breakup of shearless invariant tori in cubic and quartic nontwist maps. *Communications in Nonlinear Science and Numerical Simulation*, 17(5):2215-2222, 2012.
- [2] M. A. Petera. *Automatic differentiation of the CapeML high-level language for process engineering*. Dissertation, Department of Computer Science, RWTH Aachen University, 2012.
- [3] M. Lülkesmann. *Full and partial Jacobian computation via graph coloring: Algorithms and applications*. Dissertation, Department of Computer Science, RWTH Aachen University, 2012.
- [4] O. Fortmeier, H. M. Bucker, B. O. Fagginger Auer, and R. H. Bisseling. Partitioning Finite Element Triangulations for Distributed-Memory Computers Using an Exact Hypergraph Model for the Communication Volume. Preprint of the Institute for Scientific Computing RWTH-CS-SC-12-03, RWTH Aachen University, Aachen, 2012.
- [5] S. Seuren, J. Willkomm, H. M. Bucker, M. Bambach, and G. Hirt. Sensitivity analysis of a force and microstructure model for plate rolling. Preprint of the Institute for Scientific Computing RWTH-CS-SC-12-02, RWTH Aachen University, Aachen, 2012.
- [6] J. Willkomm, C. H. Bischof, and H. M. Bucker. The impact of dynamic data reshaping on adjoint code generation for weakly-typed languages such as Matlab. Preprint of the Institute for Scientific Computing RWTH-CS-SC-12-01, RWTH Aachen University, Aachen, 2012.
- [7] M. Probst, M. Lülkesmann, M. Nicolai, H. M. Bucker, M. Behr, and C. H. Bischof. On the Influence of Constitutive Models on Shape Optimization for Artificial Blood Pumps. In G. Leugering, S. Engell, A. Griewank, M. Hinze, R. Rannacher, V. Schulz, M. Ulbrich, and S. Ulbrich, editors, *Constrained Optimization and Optimal Control for Partial Differential Equations*, number 160 in International Series of Numerical Mathematics, pages 611-622. Birkhäuser, Basel, 2012.
- [8] O. Fortmeier. *Parallel Re-Initialization of Level Set Functions and Load Balancing for Two-Phase Flow Simulations*. Dissertation, Department of Computer Science, RWTH Aachen University, 2011.
- [9] J. Willkomm, C. H. Bischof, and H. M. Bucker. A New User Interface for ADiMat: Toward Accurate and Efficient Derivatives of Matlab Programs with Ease of Use. Preprint of

the Institute for Scientific Computing RWTH-CS-SC-11-02, RWTH Aachen University, Aachen, 2011.

[10] A. Wolf. *Ein Softwarekonzept zur hierarchischen Parallelisierung von stochastischen und deterministischen Inversionsproblemen auf modernen ccNUMA-Plattformen unter Nutzung automatischer Programmtransformation*. Dissertation, Department of Computer Science, RWTH Aachen University, 2011.

[11] M. Lulfesmann and Ken-ichi Kawarabayashi. Sub-exponential graph coloring algorithm for stencil-based Jacobian computations. Preprint of the Institute for Scientific Computing RWTH-CS-SC-11-01, RWTH Aachen University, Aachen, 2011.

[12] O. Fortmeier, A. Bastea, and H. M. Bucker. A Graph Model for Minimizing the Storage Overhead of Distributing Data for the Parallel Solution of Two-Phase Flows. In *2011 IEEE International Symposium on Parallel and Distributed Processing Workshops and PhD Forum, Proceedings of the 12th International Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC 2011), Anchorage, Alaska, USA, May 16-20, 2011*, pages 1313-1321, Los Alamitos, CA, USA, 2011. IEEE Computer Society.

[13] O. Fortmeier and H. Martin Bucker. Parallel re-initialization of level set functions on distributed unstructured tetrahedral grids. *Journal of Computational Physics*, 230(12):4437-4453, 2011.

Software and Tools for Computational Engineering



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Viktor Mosenkis

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Lihn Bui Ngoc (until June 2012)

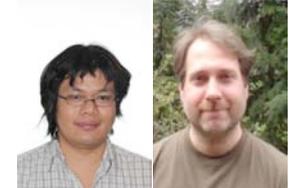
- **Student Researchers**

Klaus Leppkes

Lukas Razik (until December 2011)

Michael Maier

Sinan Gezgin



Overview

The focus of our research and development efforts is on derivative code compiler technology and on combinatorial problems in derivative accumulation.

Derivative code compilers transform numerical code that implements multivariate vector functions $y=F(x)$, $F : \mathbb{R}^n \rightarrow \mathbb{R}^m$ into code for computing various derivatives including products of the transposed Jacobian matrix $(\nabla F)^T = (\nabla F)^T(x)$ with a vector $\bar{y} \in \mathbb{R}^m$. The underlying technique is known as Automatic Differentiation (AD). Large gradients can thus be accumulated at a (hopefully small) constant multiple of the computational cost of F . A factor between three and four is highly desirable for large-scale numerical simulation codes running at the limits of modern high-performance computers. The minimization of the constant overhead is the major motivation of our research that combines elements from graph theory, combinatorial optimization, compiler construction, and software engineering with applications from various areas in science and engineering.

Derivative code compilers are one of the corner stones of the numerical solution of inverse problems via discrete adjoints. The application of such techniques to a large number of broadly defined inverse problems in computational engineering is the main theme of the Aachen Institute for Advanced Study in Computational Engineering Science (AICES, <http://www.aices.rwth-aachen.de>) that has been established within the framework of the Excellence Initiative of the German federal and state governments in November 2006.

Research Projects

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 Jülich 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.

Towards Global Robust Optimization

M. Beckers, V. Mosenkis, M. Maier, U. Naumann

*Collaborators: Prof. B. Christianson, Phd., University of Hertfordshire, UK, Prof. A. Mitsos,
Phd., MIT, USA*

funded by: German Research School for Simulation Sciences

Optimization problems in engineering often have nonconvex objectives and constraints and require global optimization algorithms. Furthermore the achieved global optimum is supposed to be insensitive against variations of the influencing parameters, i.e. they have to be robust. We tackle this problem by a combination of two scientific areas, i.e. Nonsmooth Analysis of McCormick Relaxations and Uncertainty Quantification.

McCormick relaxations are certain convex and concave under- and overestimators of the objective function and constraints. Since convex functions are possibly nonsmooth, subgradients are used instead of usual derivatives. Subgradients are natural extensions of usual derivatives providing similar information for nondifferentiable functions. AD methods can be used to propagate the values of McCormick Relaxations as well as their subgradients. A first version implementing the forward mode of AD 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 reimplementaion in Fortran also providing source code transformation. This was extended by a reverse mode which provides the same advantages as usual adjoints. The subgradients, computed either in forward- or reverse-mode, are used in the context of an deterministic Branch-and-Bound algorithm for global optimization.

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. 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. AD allows the efficient computation of higher order derivatives and therewith more precise approximations.

The application of this method allows to transform the given optimization problem into a robust one, also considering uncertainties in certain parameters. This adapted problem is accordingly solved by the above mentioned Branch-and-Bound algorithm for global optimization delivering the desired robust minimum.

Sensitivity Analysis in Telemac/Sisyphe

J. Riehme, U. Naumann

funded by: German Federal Waterways Engineering and Research Institute, Karlsruhe

The morphodynamic model Sisyphe (developed at EDF Department Laboratoire National D'Hydraulique et Environnement, [www.telemac system.com](http://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 parametrization. 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 modelling system for free surface hydrodynamics, sedimentology, water quality, waves and underground flows, which can be coupled with Sisyphus.

Elimination Techniques on Linearized DAGs

V. Mosenkis, U. Naumann

funded by: DFG

The aim of this research is to minimize the number of operations to accumulate the Jacobian of a given numerical program implementing a multivariate function. This problem is called Optimal Jacobian Accumulation (OJA) problem. OJA was shown to be NP-hard by Prof. Naumann. The problem can be formulated on graphs by attaching the corresponding local partial derivatives to the edges of the computational graph of the underlying program yielding a linearized computational graph. A graph-based interpretation of the chain rule of differential calculus allows to compute the partial derivative by multiplying all edge labels along all paths from the corresponding input to the output and adding the results. In practice to reduce the search space graph transformation techniques like vertex-, edge- and face elimination based on associativity of differential calculus are used. Thereby the linearized computational graph is transformed into a bipartite graph whose edge labels correspond to the entries of the Jacobian. This approach yields the problem of finding a vertex, edge or face elimination sequence with minimal number of operations (costs). Even this version of the OJA problem is believed to be NP-hard although the proof is still outstanding. Henceforth we are interested in developing fast heuristics to find an elimination sequence with costs close to minimal.

To support the theoretical research in this field we provide a Branch and bound algorithm which finds an optimal vertex, edge or face elimination sequence. Depth first search is used for the branching step of the algorithm. Lower bounds for the operation number as well as the knowledge of equivalent elimination sequences are used to reduce the search space. Currently we are working on the proof of sharper lower bounds to be used in the algorithm.

Adjoint MPI

M. Schanen, U. Naumann

Collaborators: Dr. Jean Uike, Argonne National Laboratory, USA, Dr. Laurent Hascoet, INRIA, France

funded by: Fond National de la Recherche of Luxembourg

We investigate the robust and efficient applicability of reverse mode algorithmic differentiation to numerical simulation codes that use MPI. Since MPI is the de facto parallelization standard in large scale simulation codes, there have been numerous attempts to compute adjoints of MPI parallelized code. Until today, they all heavily rely on manual manipulation of the original code. Our generic approach tries to reverse the entire flow of computation and thus reverse all the MPI communication patterns automatically.

The focus has been on the programming languages C and Fortran. In Fortran, adjoint MPI has been inserted in the development branch of the COMPAD project based on the NAG Fortran Compiler. Additionally, covering the language C/C++, the technique is being used with the in house developed dcc compiler and the dco overloading library.

The outcome should be a generic and versatile adjoint MPI library that may be coupled with any algorithmic differentiation software. It is not restricted to any specific language or tool.

Automatically Parallelizing Jacobian Accumulation with MPI

E. Charoenwanit, U. Naumann

funded by: NSTDA (Thailand)

To accumulate the Jacobian matrix, we build a directed acyclic graph (DAG) corresponding to the mathematical function and perform elimination on the DAG. In this work we parallelize the accumulation of the Jacobian matrix by having each slave processor build only the parts, referred to as blocks, of the DAG it will be eliminating following a Round-Robin strategy. Thereafter, the eliminated blocks are sent to the merger, which merges and performs elimination on the resulting block, thereby accumulating the entire Jacobian matrix.

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 allow to restrict the tape of the whole process, which is too 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.

Toward a Discrete Adjoint Model for OpenFOAM

M. Towara, N. Safiran, U. Naumann

The OpenFOAM (Open Field Operation and Manipulation) CFD Toolbox is a free, open source CFD software package developed by OpenCFD Ltd. owned by ESI Group. 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 cost functionals in the scope of CFD shape optimization.

Points of ongoing work are incorporating efficient checkpointing schemes and the analytical treatment of linear solvers to increase the feasible problem size.

Adjoint OpenMP

M. Förster, U. Naumann

This project examines the question of how to provide first and higher order derivative code of input code that is augmented by pragmas for parallel programming. In scientific computation, parallelism is often exploited by augmenting code with compiler directives.

OpenMP is known for years to provide a standard of compiler directives for parallelization.

In addition, the recent standard OpenACC shows that the pragma-based parallelization is a promising approach. The in-house compiler solution for providing algorithmic differentiation by source transformation is used in a collaboration with the institute Aachener Verfahrenstechnik (AVT).

AVT provides C code that implements a mathematical model of a DAE system. Since the number of equations in DAE systems which implements chemical reaction processes often reach thousands equations and more, the parallelisation of this C code is crucial.

An easy way to exploit parallelism is to augment the given C code with pragmas defining parts of the code as independent in terms of data dependences.

These pragmas can be as defined in the OpenMP standard (www.openmp.org) or as in the OpenACC standard (www.openacc.org).

The task in this project is to provide a correct source transformation that keeps most of the inherit parallelism of the origin code.

Algorithmic Differentiation of Numerical Methods

J. Lotz, M. Towara, V. Mosenkis, N. Safiran, K. Leppkes, U. Naumann

The natural use of algorithmic differentiation is widely dominated by the differentiation of user-code, where the differentiated version is used for numerical methods such as nonlinear system solvers. The purpose of this project indeed is the differentiation of numerical methods. This kind of problem occurs as soon as, e.g., the solution of the nonlinear system is part of an objective function for an optimizer. The nonlinear system solve is then only a constraint to the optimization algorithm. Because every gradient-based optimizer expects derivatives of the objective function, i.e., of the solution of the nonlinear system with respect to parameters, we need to differentiate the nonlinear system solver itself. We therefore face the problem of differentiating a numerical method. This task may get very time and memory consuming when treating for example iterative solvers in the usual way algorithmic differentiation is applied. Exploitation of mathematical insight to the content of the respective algorithm may yield significant speed-up rates. During this project we aim to apply those insights and generate differentiated versions of the numerical libraries gsl (gnu scientific library), lapack (linear algebra package) and blas (basic linear algebra system).

Talks and Publications

Plenary Talks

Naumann, Uwe: Fast Greeks through Adjoint Algorithmic Differentiation – and further speedup through Mathematical Structure Insight, NAG Quant Seminar, July 2012, New York, USA

Naumann, Uwe: Adjoint Parameter Calibration in Computational Finance, ICBI Global Derivatives Trading & Risk Management, April 2012, Barcelona, Spain

Naumann, Uwe: Do we need an adjoint NAG Library? Yes we do!, NAG Annual General Meeting, September 2012, Oxford, UK

Naumann, Uwe: Toward First- and Higher-Order Discrete Adjoint Flow Solvers, Conference on Industrial Design and Optimization for Fluid Flow, March 2012, Munich, Germany

Naumann, Uwe: One-Day Short Course on Algorithmic Differentiation, 7City Learning, July 2012, London, UK

Talks

Beckers, Markus: Adjoint Mode Computation of Subgradients for McCormick Relaxations. 6th International Conference on Automatic Differentiation, July 2012, Fort Collins, USA.

Lotz, Johannes: Hierarchical Algorithmic Differentiation A Case Study. 6th International Conference on Automatic Differentiation, July 2012, Fort Collins, USA.

Förster, Michael: First- and Second-Order Parameter Sensitivities of a Metabolically and Isotopically Non-Stationary Biochemical Network Model, 9th International Modelica Conference, September 2012, Munich, Germany

Schanen, Michel: Adjoining Hybrid Parallel Code, The Eighth International Conference on Engineering Computational Technology, September 2012, Dubrovnik, Croatia

Schanen, Michel: A Wish List for Efficient Adjoints of One-Sided MPI Communication, Euro MPI, September 2012, Vienna, Austria

Towara, Markus: Toward a Discrete Adjoint Model for OpenFOAM, FlowHEAD project meeting, March 2012, Garching, Germany

Towara, Markus: Sparsity Pattern Detection, ICiS Workshop, July 2012, Park City, USA

Publications

Beckers, Markus; Mosenkis, Viktor; Naumann, Uwe: Adjoint Mode Computation of Subgradients for McCormick Relaxations. *Recent Advances in Algorithmic Differentiation*, pages 103-114, Springer, ISBN 978-3-642-30022-6, 2012.

Corbett, Callum; Naumann, Uwe; Mitsos, Alexander: Demonstration of a Branch-and-Bound Algorithm for Global Optimization using McCormick Relaxations . *Aachener Informatik-Bericht (AIB) 2011-24*.

Corbett, Callum; Maier, Michael; Beckers, Markus; Naumann, Uwe; Ghousey, Amin; Mitsos, Alexander: Compiler-Generated Subgradient Code for McCormick Relaxations. *Aachener Informatik-Bericht (AIB) 2011-25*.

Hannemann, Ralf; Tillack, Jana; Schmitz, Moritz; Förster, Michael; Wyes, Jutta; Nöh, Katharina; von Lieres, Eric; Naumann, Uwe; Wiechert, Wolfgang; Marquardt, Wolfgang:

First- and Second-Order Parameter Sensitivities of a Metabolically and Isotopically Non-Stationary Biochemical Network Model. Proceedings of the 9th International Modelica Conference, pages 641-648, Modelica Association, 2012.

Lotz, Johannes; Naumann, Uwe: Hierarchical Algorithmic Differentiation A Case Study. Recent Advances in Algorithmic Differentiation, pages 186-196, Springer, 2012, ISBN 978-3-642-30022-6.

Lotz, Johannes; Naumann, Uwe: Algorithmic Differentiation of Numerical Methods: Tangent-Linear and Adjoint Direct Solvers for Systems of Linear Equations. Aachener Informatik-Bericht (AIB) 2012-10.

Mosenkis, Viktor; Naumann, Uwe: On optimality preserving eliminations for the minimum edge count and optimal Jacobian accumulation problems in linearized DAGs. Optimization Methods and Software, volume 27, number 2, pages 337-358, doi:10.1080/10556788.2011.580745

Naumann, Uwe; Schenk, Olaf: Combinatorial Scientific Computing. Computational Science Series, Chapman & Hall CRC Press, Taylor and Francis Group, 2012 ISBN 978-1-4398-2735-2.

Naumann, Uwe; Lotz, Johannes; Leppkes, Klaus; Towara, Markus: Algorithmic Differentiation of Numerical Methods: Tangent-Linear and Adjoint Solvers for Systems of Nonlinear Equations. Aachener Informatik-Bericht (AIB) 2012-15.

Schanen, Michel; Förster, Michael; Lotz, Johannes; Leppkes, Klaus; Naumann, Uwe: Adjoining Hybrid Parallel Code. Proceedings of The Eighth International Conference on Engineering Computational Technology, Civil-Comp Press, 2012, ISBN 978-1-905088-55-3.

Dissertations

Ebadollah Varnik, Exploitation of Structural Sparsity in Algorithmic Differentiation, Dr. rer. nat., RWTH Aachen, 2011

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Overview

The Virtual Reality Group was founded in 1998 and is a member of the Center for Computing & Communication as well as an associate member of the Computer Science Department. Our research goal is to develop new Virtual Reality techniques and methods and to push this technology forward towards applicability in complex scientific applications. As such, our work is characterized by basic as well as application-oriented research in collaboration with other RWTH institutes from multiple faculties, industrial companies, and other research groups from around the world in mostly third-party funded joint projects. As a part of the Center for Computing & Communication, we are in particular involved with providing methodical support and complete solutions. Thus, producing journal papers is not the one and only – although undoubtedly important – goal of our scientific work. Instead, we also aim at making our research work available to our partners, allowing them to explore even complex technical and physical phenomena in an intuitive way. Therefore, a lot of effort goes into the development of comprehensive software frameworks in order to make Virtual Reality technology a valuable tool in the scientists' daily work.

In principle, Virtual Reality (VR) is a computer-generated scenario (the virtual world) a user can interact with in real time and in all three dimensions. The interface should be as intuitive as possible, and multiple senses like vision, haptics, and audio should be included into the interaction. By special display technology an immersion effect can be achieved, i.e., users have the impression of being a part of the virtual environment, fully surrounded by it instead of just looking from outside.

VR has proven its potential to provide an innovative human-computer interface, from which multiple application areas can profit. The VR applications fields we are working on comprise architecture, mechanical engineering, medicine, life science, psychology, and more. In the field of mechanical engineering, for instance, we provide immersive visualizations from very big objects like complete plants, over mid-size objects like machine tools and robots, down to microscopic scenarios arising in material science.

In recent years, Simulation Science has more and more attracted our attention. At RWTH Aachen, numerical simulation of technical and physical phenomena has traditionally been an important pillar in engineering research. With the excellence initiative, Simulation Science has definitely become a main focus at the University. In Aachen and elsewhere, simulation is an indispensable and essential tool in production technology and the development of, e.g., airplanes, cars, combustion engines, turbines etc. Even in medical projects at RWTH, numerical simulation is going to play an important role, e.g., in the analysis of flow within artificial blood pumps, or in order to understand the air flow within the human respiratory organs. Researchers are going to simulate phenomena of such a high complexity that traditional methods of post-processing, like producing static images or at best animations, are no longer neither an effective nor an efficient approach to understand the simulation results. Instead, engineers demand interactive exploration of their data in 3-D space, what eventually leads in the use of VR technology. As such, the VR Group actively supports RWTH institutes and research groups in CCES, AICES, GRS, JARA-HPC, and the CoE “Integrative Production Technology for High-Wage Countries” in analyzing their data by means of Virtual Reality. From the computer science point of view, the grand challenge is that on the one hand we are facing huge datasets, and on the other hand we have to handle these data in real time. Thus, new concepts for hybrid visualization environments have to be developed, including advanced data management, parallel approaches, novel methods for feature rendering, and, above all, interaction techniques which allow for an intuitive exploration of complex, transient phenomena in 3-D space.

Since recently, our research is also focusing on VR-based simulators in medicine. In contrast to other research groups mainly working on simulators for minimal invasive surgery, we are concentrating more on standard procedures like palpation or needle intervention. The challenge here is to realistically simulate deformable objects in real time including haptic stimuli and bimanual interaction scenarios.

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. Last 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

Interactive and Multi-Modal Virtual Environments

Dominik Rausch, Sebastian Freitag

Joint work with the RWTH Institute of Technical Acoustics

One key aspect of Virtual Reality is the ability to reproduce believable environments with high immersion. This not only requires graphical aspects like realistic visuals, stereoscopic 3D reproduction of images, and head tracking for a viewer-centered projection. Other important aspects are the interactivity and the multi-modality of the environment.

To be convincing, a virtual environment should behave plausibly. Thus, it is important to make the world interactive, and that the interactivity is realistic. To allow this, the virtual reality application “Inside” is being developed. It uses an actor-like architecture, where independent objects control themselves and communicate with other objects by sending messages. Interactive objects can be modeled using the Lua scripting language to define update routines and add special per-object properties (e.g. physical, acoustic, or visual properties). This allows an easy modelling of interactive elements that for example move according to a physical simulation and produce sounds on collisions. More complex interactions between several objects are handled by controller objects or specialized interaction modes, e.g. physical simulations or collision-based navigation.

A special focus with navigation has been put on the promotion of real walking. Physical walking induces a higher immersion and better perception of the environment, and is mostly preferable over virtual navigation techniques. However, Virtual Environments are often much larger than the physical movement area due to limited tracking range or physical screens. To promote walking, a navigation technique using portals has been developed. This allows moving to distant points in the world by walking through a door-like portal. This technique does not disrupt the immersion of the Virtual Environment, and by placing the portals appropriately, users can utilize physical walking to a much larger extent.

Multi-modality is another important aspect in Virtual Reality. Providing other modalities, e.g. haptics or acoustics, in addition to the graphical representation can enhance the immersive effect significantly. For this, the Virtual Reality Group and the Institute of Technical Acoustics cooperate in developing a spatial sound reproduction system using binaural reproduction and dynamic crosstalk compensation. Furthermore, a room-acoustics simulation calculates the sound propagation in the room based on the listener and sound source position and the acoustic properties of the environment interactively.

Another important feedback modality is haptics. However, while some haptic feedback devices exist, they are not well suited for large virtual environments where the user can move around freely. Thus, a user study examined a virtual dental drilling task with haptic and auditory feedback. Results have shown that for this scenario, sound can help to overcome a lack of haptic feedback.

Virtual Reality-based Medical Training Simulator for Bilateral Sagittal Split Osteotomy

Thomas Knott

*Joint work with the RWTH Chair for Computational Analysis of Technical Systems and the
Department of Oral and Maxillofacial Surgery, University Hospital Aachen*

Funded by the German Research Foundation

This project aims at the creation of an interactive training system for a major maxillofacial surgery procedure. In collaboration with numerical mechanical simulation experts and oral and maxillofacial surgeons a virtual reality (VR)-based simulator is developed. The modeled medical procedure, the bilateral sagittal split osteotomy, allows the correction of mandible malpositions like over- or underbite by splitting and relocating parts of the mandible. In a first step during the intervention a predetermined breaking line is created on the lower mandible with a bone saw or burr. Chisels are then inserted into the created notch and twisted until it broadens and finally the whole mandible breaks into two parts. As complications occurring during the division, e.g. the damage of the contained neurovascular bundle beyond repair, have serious consequences for the patient surgeons have to be trained carefully before performing this procedure.

One important factor for a successful outcome of the procedure is the manual dexterity of the surgeon; therefore, the focus of the simulator is the training of the needed specific motor skills. Thus, one important requisite to the system is the reproduction of the real interaction with a high degree of realism. For this purpose we utilize haptic input/output devices and according haptic rendering algorithms to allow an interaction close-to-reality. Using this specialized hardware the trainee can apply pressure on the virtual mandible and feel its resistance and deformation. To enable a realistic simulation of the breaking bone in real time, the extended finite element method (XFEM) is employed as it allows the effective modeling of deformations and induced structural changes. The needed material parameters are determined experimentally and function, together with anatomical models extracted from cone beam CT-Scans, as foundation for the physical simulation.



Screen snapshot of the splitting process in the BSSO simulator

Visualization of High-Dimensional Meta-Model Data

Sascha Gebhardt

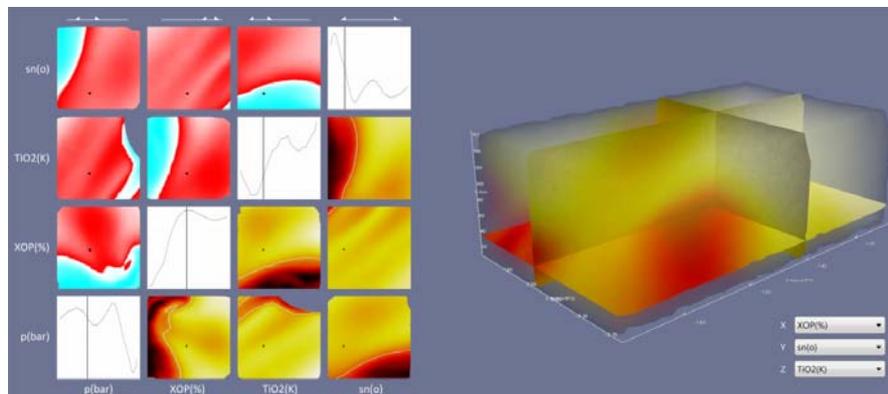
Joint work within the Cluster of Excellence

”Integrative Production Technology for High-Wage Countries”

funded by the German Research Foundation

In the second phase of the “Cluster of Excellence: Integrative Production Technology for High-Wage Countries” the Virtual Production Intelligence (VPI) platform is being developed. It is a holistic and integrative concept for the support of collaborative planning, monitoring and control of core processes within production and product development in various application fields. In the context of the VPI we are developing a tool for the explorative visualization of high-dimensional meta-model data, which is based on the concept of hyperslices, linked with a 3D volume representation. The tool will be applicable for various scenarios of high-dimensional data analysis, but the concrete use case in the current project is using it about ideal configuration parameters for laser cutting machines in the context of factory planning.

The goal is to design a visualization and interaction concept, which is easy to learn and provides an understanding of high-dimensional data in different ways. On the one hand, a general understanding of the interdependencies between different configuration parameters shall be granted, and on the other hand it shall be possible to identify ideal configuration parameters for a certain use case as fast, reliable and simple as possible. Both ways are made possible by providing interactive navigation and exploration of the data-space and by introducing methods to guide the user to points, which are candidates for an ideal configuration parameter set. The main challenge for the realization of this concept lies in the huge amount of data which is to be visualized. The computation times for slices through the data-space rise exponentially with the number of dimensions, and meta-models with seven or more dimensions are currently being created by future users. Interactive rendering times can only be achieved by detail reduction upon interaction and by providing a fully-detailed visual representation only in phases without interaction.



Concept-sket of the high-dimensional meta-model data visualization. Left: hyperslice visualization, right: linked volume rendering

Integrative Simulation Platform and Explorative Multiple Dataset Analysis

Thomas Beer

Joint work within the Cluster of Excellence

”Integrative Production Technology for High-Wage Countries”

funded by the German Research Foundation

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. Tools that allow for interactive navigation in both, temporal and spatial dimensions have been added to facilitate a flexible visual analysis process. To be able to maintain

interactive frame rates at all times, even when displaying long process chains or huge simulation results, a level-of-detail management system is being integrated.

CAVIR: Correspondence Analysis in Virtual Reality

Andrea Bönsch, Daniel Bündgens

Joint work with RWTH School of Business & Economics

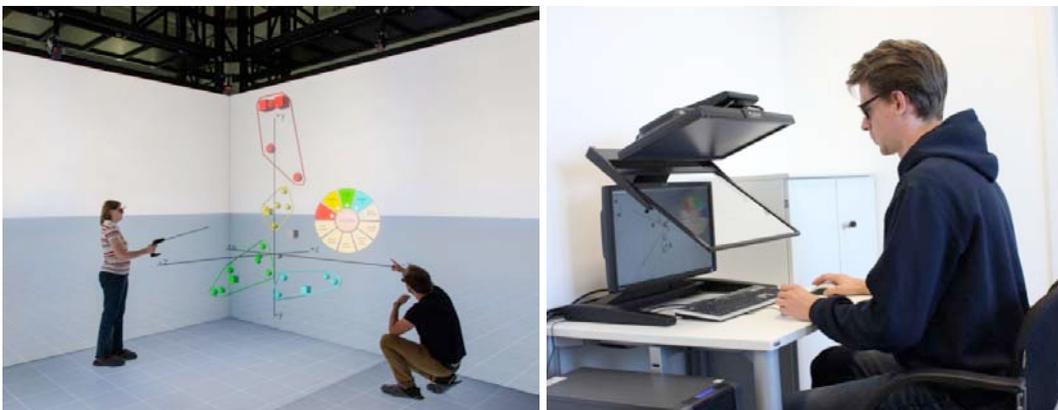
funded as an

IMP Pathfinder Project within the Excellence Initiative

The Virtual Reality Group participated in an interdisciplinary project kindly funded by the IMP, investigating the advantage of using a distortion-free view on a three-dimensional data representation in Correspondence Analysis (CA).

CA is used to interpret correlations between categorical variables in the areas of social science and market research. To do so, coherences of variables are converted to a three-dimensional point cloud and typically plotted as several different 2D-mappings, each containing two axes. The major challenge is to correctly interpret these plottings. But, due to a missing axis, distances can easily be under- or overestimated. This can lead to a misinterpretation and thus a misclustering of data. Hence, an improvement is needed.

The aim of CAVIR, our approach for CA in Virtual Reality, is to accelerate the process of interpreting and clustering CA point clouds and thereby reduce the potential cluster errors mentioned above. Users are able to make better decisions, due to a better and not misleading view onto the three-dimensional representation of the point cloud and different options to show additional information, to measure Euclidean distances, and to cluster points. Besides, our approach is available for two different display system classes as shown in the figure. On the one hand, we use our aixCAVE to enable a collaboration with several people and on the other hand, we provide a semi-immersive low-cost desktop system as quick possibility to cluster points in the office in order to embed its use into the normal workflow.



Collaborative analysis of a CA point cloud in the RWTH aixCAVE (left) and a single-user analysis at a semi-immersive desktop system (right).

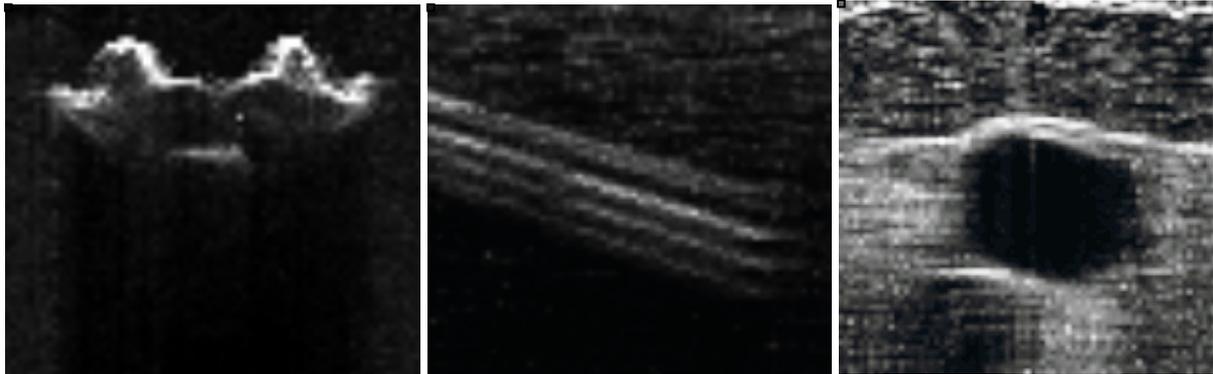
Ultrasound Image Simulation for Training of Needle Insertion Procedures

Yuen C. Law

funded via DAAD scholarship

Brightness modulation (B-Mode) ultrasound (US) images are used to visualize internal body structures during diagnostic and invasive procedures, such as needle insertion for Regional Anesthesia. US imaging allows direct and immediate visualization, is safe and less expensive than other alternatives, i.e. computer tomography (CT) and magnetic resonance (MR), but physicians require training and experience to properly find and identify the structures of interest. This training is hard to come by due to the lack of patients with rare pathologies and patient safety issues. A possible solution for this problem is to use virtual reality-based training simulators to obtain adequate experience in ultrasound guided needle insertion procedures. These simulators should, as accurately as possible, mimic the behavior of the US wave within soft tissue. Other important requirements include interactivity, flexibility to model different scenarios, and simulation of tissue deformation, e.g. due to needle insertion and movement. The project, funded with a DAAD (German Academic Exchange Service) scholarship, aims to develop such a simulator.

To overcome the aforementioned challenges, the current proposed approach uses geometrical acoustics to model the US wave as rays. Their propagation is assumed to be equivalent to that of optic rays. This contributes to accuracy and realism while maintaining interactive times thanks to the parallel nature of ray tracing and the computation capabilities of modern GPUs. With this approach we are able to simulate a large range of artifacts and phenomena common in US images, i.e. reflection, attenuation, acoustic shadows, enhancement, reverberation, speckles and blurriness.



Simulated images. From left to right: a vertebra with strong reflections and acoustic shadows, a needle with reverberation effect, a complex scene with blood vessels and muscle tissue.

VisNEST – Visualization of Simulated Neural Brain Activity

Christian Nowke

joint work with Institute of Neuroscience and Medicine (INM-6), Forschungszentrum Jülich

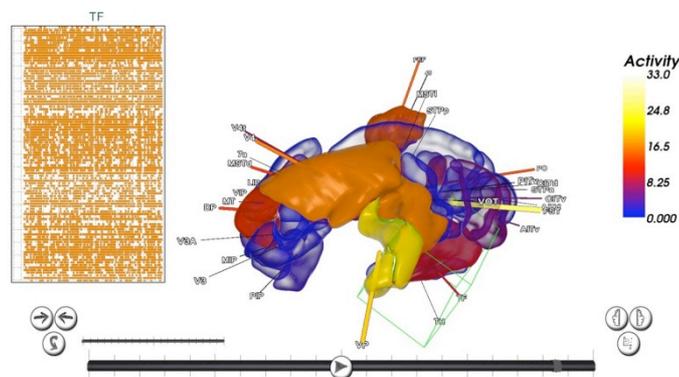
Funded within the Jülich Aachen Research Alliance – JARA-HPC

Understanding the fundamental structures of the human brain poses several formidable challenges. To this end, large scale simulations are performed in order to understand the inner workings of our brain.

Modeling and simulating a brain's connectivity produces an immense amount of data, which has to be analyzed in a timely fashion and leverages the power of today's High Performance Computing machines in order to simulate low level neural activity. In spite of the multitude of data sets resulting from such simulation studies, little has been done to support neuroscientists with interactive tools for the inspection and analysis of these data.

To aid scientists, we developed an interactive visualization within the Jülich Aachen Research Alliance (JARA). One of the driving challenges behind this project is the integration of macroscopic data, e.g. brain areas, with microscopic simulation results, e.g. spiking behavior of individual neurons.

This project addresses three specific questions that have been established as key requirements by domain scientists: First, users need to be able to explore spatial relationships among simulated brain areas. Second, we need to enable users to link low-level, neural activity to geometrical data and finally, a successful tool should seamlessly integrate techniques from the domain scientists' daily analysis workflow. Therefore, we implemented a visualization application that has been used to simultaneously visualize 32 vision related areas of a macaque brain. Its design is focused on enabling users to explore spatial relationship among simulated areas and see average neural activity of each area while being able to interactively browse the time-dependent simulation results. Furthermore, the user is given the ability to freely navigate around brain areas of interest, to see activity levels of simulated neurons, and to inspect dot plots of neural activity for corresponding brain areas. Additionally, the user can interactively select areas of interest in order to get fine-grained control over the visualization's focus and to help reduce information overload.



Textual annotations show anatomical area designators. Both, the color of each area and the width of the corresponding annotation's link are used to depict average neural activity.

Visualization of Multimodal Brain Data

Claudia Hänel

Joint work with the Institute of Neuroscience and Medicine (INM-1), Forschungszentrum Jülich

In cooperation with the Institute of Neuroscience and Medicine of the Forschungszentrum Jülich this project aims to give an interactive virtual view onto brains of patients with Alzheimer's disease (AD). Those show a reduction of brain volume over time. A hypothesis is that a well-directed placement of electrodes in the patient's brain can decrease this decay. Goal of the project is to visualize the placement of the electrodes in the brain with respect to the anatomy and functional regions.

Different kinds of data were acquired during a study. First an anatomic magnetic resonance imaging (MRI) was done. Afterwards, electrodes for deep brain stimulation were implanted to some of the AD patients. A computed tomography (CT) was acquired. One year later an MRI of all patients was done. A registration was applied to all acquired data. The main focus here is the combined visualization of different data types. We need to show enough context information without occluding the important structures within.

Additional to the acquired data we have segmented functional regions of a reference brain. Those are saved in a Maximum Probability Map. For each voxel we have a probability that it belongs to a desired region. The anatomy, the electrodes segmented from the CT scan and the functional regions are going to be visualized with the help of Importance Driven Volume Rendering. During ray casting the electrodes and regions are labeled with a higher priority than the anatomy. In this way the user will see a conical cut out in the brain context where a selected brain region would be occluded. In this way we preserve the context information and a precise location of important hidden structures is possible.

Furthermore, a visualization of the brain volume decay is planned. Therefore, the difference between the two MRI data sets needs to be visualized. In the virtual environment the user will get an improved visual impression of the relationship between electrodes, functional regions, anatomy and volume reduction.

GTECS3D: Graph-Theoretical Evaluation of Crystal Structures in 3D

Sven Porsche, Daniel Bündgens

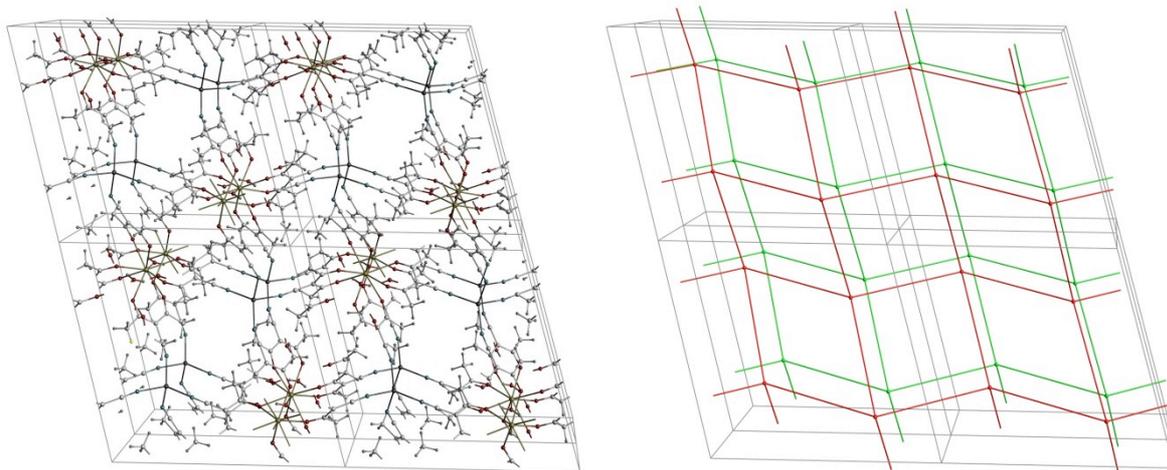
Joint work with the RWTH Section C for Mathematics and the RWTH Department of Inorganic Chemistry

Funded by Explorative Research Space within the Excellence Initiative

GTECS3D is an interdisciplinary project funded by the Excellence Initiative. The aim of this project was a tool for semi-automatic simplification and analysis of crystal structures.

The crystallography as a part of the inorganic chemistry is the study of crystals based on their geometry. The geometry itself is an extended, periodic network-structure. For the analysis of such structures, they have to be simplified, to get the underlying network of the crystal-structure. Afterwards it is possible to calculate topological indices which characterize a structure and allow comparison with others.

GTECS3D is a tool to accelerate the work process of analyzing and characterizing extended, periodic network-structures. Therefore the possibility is given to visualize crystal structures and simplify such structures with the usage of graph-theoretical algorithms. To allow users to intervene in the process of simplification, methods were adopted and developed to select substructures and manipulate them or execute algorithm-based simplification steps. For a clear representation the software was separated in two parts. The visualization part is based on the Virtual Reality Toolkit ViSTA and allows users the selection of substructures and a stereoscopic visualization. The other part is an additional user interface for the modification of network-structures



An example network-structure before any simplification step (left) and the same structure after simplification and recoloring (right).

VATSS - Virtual Air Traffic System Simulation

Sebastian Pick

joint work with multiple RWTH Institutes

BOOST-funded project within the Excellence Initiative

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.

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 (CAVE) 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.

In summer 2012, we have installed the “aixCAVE”. With a size of more than 5 x 5 m² for the rear floor projection, the system is not only one of the largest CAVEs worldwide, but raises the standards with respect to projection quality: by a sophisticated combination of high resolution, high brightness, brightness uniformity, specially coated screens, elaborate mechanical construction, and active stereo technology, a high level of immersion and an illusion of presence are achieved. The 24 HD-DLP projectors are driven by a 24-node visualization cluster with 48 GPUs.

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.

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.

Courses

Winter semester 2011/12

- Lecture on Virtual Reality

Summer semester 2012

- Seminar on Advanced Topics of Virtual Reality
- Practical Course (Lab) on Virtual Reality

Chair Holder’s scientific activities

Torsten Kuhlen is 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 served as Program Chair for the 2012 Eurographics Symposium on Parallel Graphics and Visualization.

Talks and Publications

Talks

S. Ullrich. *Haptic palpation for medical simulation in virtual environments*. IEEE Virtual Reality Conference, Orange County, USA.

T. Knott. *Stable and Transparent Bimanual Six-Degree-of-Freedom Haptic Rendering Using Trust Region Optimization*, EuroHaptics Conference, Tampere, Finland.

Y. Law. *Geometrical-Acoustics-based Ultrasound Image Simulation*. Eurographics Workshop on Visual Computing for Biology and Medicine, Norrköping, Sweden.

T. Kuhlen. *Virtuelle Realität in der Wissenschaftlichen Visualisierung*. DLR Workshop, Braunschweig, Germany.

Publications

S. Ullrich, T. Kuhlen (2012).: *Haptic palpation for medical simulation in virtual environments*. IEEE Transactions on Visualization and Computer Graphics 18 (4), pp. 617-625.

J. Hummel, R. Wolff, A. Gerndt, T. Kuhlen (2012). *Comparing three interaction methods for manipulating thin deformable virtual objects*. In Proceedings of the IEEE Virtual Reality Conference (IEEE VR 2012), pp. 139-140.

D. Bündgens, A. Hamacher, M. Hafner, T. Kuhlen, K. Hameyer (2012). *Bidirectional Coupling Between 3-D Field Simulation and Immersive Visualization Systems*. IEEE Transactions on Magnetics 48 (2), pp. 547-550.

T. Knott, Y. Law, Y., T. Kuhlen, (2012). *Stable and Transparent Bimanual Six-Degree-of-Freedom Haptic Rendering Using Trust Region Optimization*. In Proceedings of the 2012 EuroHaptics Conference, P. Isokoski, J. Springare (Eds.): Haptics – Perception, Devices, Mobility, and Communication, Springer Berlin/Heidelberg, pp. 270-281.

H. Childs, T. Kuhlen, F. Marton (eds.) (2012). *Parallel Graphics and Visualization 2012*. Eurographics Symposium Proceedings.

Y. Law, T. Knott, B. Hentschel, T. Kuhlen (2012). *Geometrical-Acoustics-based Ultrasound Image Simulation*. In Proceedings of the Eurographics Workshop on Visual Computing for Biology and Medicine (VCBM 2012), pp. 25-32.

J. Hummel, R. Wolff, T. Stein, A. Gerndt, T. Kuhlen (2012). *An Evaluation of Open Source Physics Engines for Use in Virtual Reality Assembly Simulations*. In Proceedings (Part II) of the 8th International Conference on Advanced in Visual Computing (ISVC 2012), LNCS 7432, pp. 346–357.

A. Bönsch, F. Graff, D. Bündgens, T. Kuhlen (2012). *CAVIR: Correspondence Analysis in Virtual Reality*. In: Virtuelle und Erweiterte Realität, 9. Workshop der GI-Fachgruppe VR/AR, Shaker Verlag, pp. 49-60.

B. Fimm, I.-A. Heber, T. Kuhlen, (2012). *Neuropsychologische Aufmerksamkeitsdiagnostik in virtueller Realität*. Zeitschrift für Neuropsychologie, 23, 160-161.

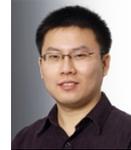
Parallel Programming



German Research School
for Simulation Sciences

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Overview

Anchored at the German Research School for Simulation Sciences in Aachen and affiliated with the Computer Science Department of RWTH Aachen University, the objective of the Laboratory for Parallel Programming is to develop tools that support simulation scientists in exploiting massive parallelism on modern architectures.

Driven by the increasing demand for computing power and accelerated by current trends in microprocessor design, the number of processor cores on supercomputers is growing from generation to generation, posing scalability challenges not only for applications but also for the whole software stack 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, parallel algorithms, 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. In addition to supercomputers, we also consider smaller shared-memory systems, for which we design tools that support parallelism discovery and correctness checking. 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.



IBM BlueGene/Q Juqueen at Forschungszentrum Jülich.

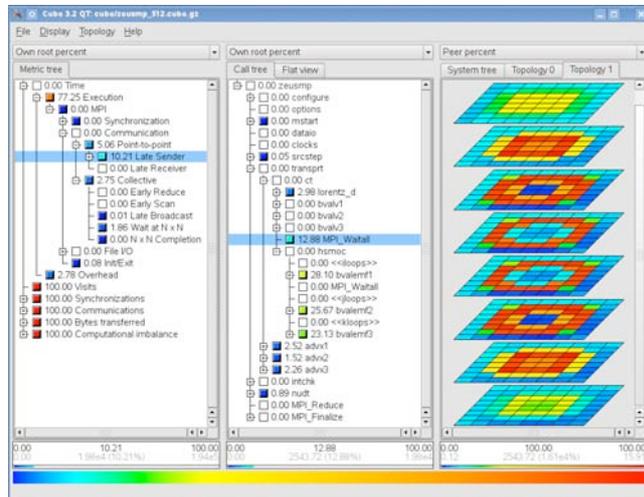
Research Activities

Scalable Performance Analysis of Large-Scale Parallel Applications (Scalasca)

*David Böhme, Alexandru Calotoiu, Marc-André Hermanns,
Daniel Lorenz, Monika Lücke, Amer Shah*

Carried out 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 XE, but is also well suited for small- and medium-scale HPC platforms. The analysis identifies potential performance bottlenecks – in particular those concerning communication and synchroni-zation – 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. Support for GPUs is in progress. The user of Scalasca can choose between two different analysis modes: (i) performance overview on the call-path level via profiling and (ii) in-



Interactive exploration of performance behavior using Scalasca.

formation of wait states even at very large scales. Wait states occur, for example, as a result of load imbalance. 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, Scalasca was ported to IBM BlueGene/Q, the successor of BlueGene/P, after the P system Jugene in Jülich was superseded by the Q system Juqueen. Moreover, a prototype of Scalasca now supports the new cross-tool measurement system Score-P. The prototype was already used in tutorials. Furthermore, we created hybrid versions of the delay and critical-path analysis, two novel trace-analysis methods aimed at the characterization of load and communication imbalance. We also developed new concepts for the performance analysis of task-based programs. Finally, based on Scalasca's replay-based trace analysis scheme, we devised a method to identify manual implementations of collective operations in message-passing programs, which are usually less efficient than their predefined counterparts, and therefore need to be replaced. Besides purely technical advancements, Scalasca was also presented to supercomputer users during hands-on workshops/tutorials.

European Exascale Software Initiative 2 (EESI 2)

Felix Wolf

Carried out in cooperation with fifteen European partners.

Funded by the EU.

The constant growth of generated data - Big Data - and computing capabilities of extreme systems lead to a new generation of computers composed of millions of heterogeneous cores, which is expected to provide exaflop performance around 2020. The successful first European Exascale Software Initiative (EESI 1) federated the European community, built a preliminary European cartography, vision and roadmap and served as the European voice on the international level. In the follow-up project, EESI 2, we go one step further towards implementation by establishing a European structure to gather the European community and by providing periodically cartography and roadmaps and dynamic synthesis and recommendations. The initiative started with a kickoff meeting on September 18th, 2012. Prof. Wolf leads the working group on scientific software engineering, software eco-system and programmability.

Dynamical Exascale Enabling Platform (DEEP)

Suraj Prabhakaran, Sebastian Rinke

Carried out in cooperation with Jülich Supercomputing Centre, Intel Corporation, Partec Cluster Competence Center, Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften, University of Heidelberg, Eurotech (Italy), Barcelona Supercomputing Center (Spain), Mellanox (Israel), École Polytechnique Fédérale de Lausanne (Switzerland), Katholieke Universiteit Leuven (Belgium), CERFACS (France), The Cyprus Institute (Cyprus), University of Regensburg, CINECA (Italy), and CGGVeritas (France).

Funded by the EU.

DEEP is an innovative European response to the exascale challenge. The DEEP consortium will develop a novel, exascale-enabling supercomputing architecture with a matching software stack and a set of optimized grand-challenge simulation applications. DEEP takes the concept of compute acceleration to a new level: instead of adding accelerator cards to cluster nodes, an accelerator cluster, called booster, will complement a conventional HPC system and increase its compute performance. Together with a software stack focused on meeting exascale requirements, comprising adapted programming models, libraries and performance tools, the DEEP architecture will enable unprecedented scalability. The cluster-level heterogeneity of DEEP will attenuate the consequences of Amdahl's law, allowing users to run applications with kernels of high scalability alongside kernels of low scalability

concurrently on different sides of the system, avoiding at the same time over and under subscription. An extrapolation to millions of cores would take the DEEP concept to an exascale level. Our group contributes in the areas of middleware, resource management, and performance tools. During the reporting period, we developed a concept for offloading computations using MPI-2 dynamic process management facilities. Extensions and optimizations of this approach are under investigation. Also, we are working on extensions to the Torque/Maui resource management system, which will enable the static and dynamic resource allocation of booster nodes to applications.

Performance Dynamics of Massively Parallel Codes (LMAC)

David Böhme, Marc-André Hermanns

Carried out in cooperation with Gesellschaft für numerische Simulation mbH, RWTH Aachen University (Center for Computing and Communication), TU Dresden, TU Munich, and University of Oregon (USA).

Funded by the BMBF.

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. During the reporting period, we hybridized two methods for the characterization of load imbalance and created a first version of the governance model for Score-P, a community-driven performance-measurement infrastructure.

Enabling Climate Simulation at Extreme Scale (ECS)

Monike Lücke

Carried out in cooperation with Barcelona Supercomputing Center (Spain), INRIA (France), National Center for Atmospheric Research (USA), Tokyo Tech (Japan), University of Illinois at Urbana-Champaign (USA), University of Tennessee at Knoxville (USA), University of Tsukuba (Japan), University of Victoria (Canada).

Funded by the DFG in the Interdisciplinary Program on Application Software towards Exascale Computing for Global Scale Issues as part of the G8 Research Councils Initiative on Multilateral Research.

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. Our group concentrates on scalability aspects of the Community Earth System Model (CESM), which is developed at the National Center for Atmospheric Research (NCAR) in the US. During the reporting period, we studied how load imbalance causes the formation and propagation of wait states in the sea-ice model of CESM. Together with NCAR, we are currently working on an improved partitioning mechanism based on space-filling curves that would increase performance by reconciling load with communication balance.

Holistic Performance System Analysis (HOPSA)

Aamer Shah, Marc-André Hermanns

Carried out 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. During the reporting period, we finished a prototype of a lightweight

measurement module designed to capture coarse-grained performance data across a larger number of jobs (i.e., applications) as a starting point for deeper investigations. A distinctive feature of the module is its ability to collect performance data separately for predefined intervals, which allows the detection of application interference.

**Performance Refactoring of Instrumentation, Measurement, and Analysis
Technologies for Petascale Computing (PRIMA)**

Daniel Lorenz

Carried out 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. During the reporting period, we developed a range of instrumentation options for Score-P, the measurement system now underlying both tools, and integrated the tools into the Eclipse development environment.

Virtual Institute – High Productivity Supercomputing (VI-HPS)

David Böhme, Marc-André Hermanns

*Carried out in cooperation with Barcelona Supercomputing Center (Spain),
Forschungszentrum Jülich, Lawrence Livermore National Laboratory (USA), RWTH Aachen
University (Center for Computing and Communication), Technical University of Dresden,
Technical University of Munich, University of Oregon (USA), University of Stuttgart,
University of Tennessee (USA), and Université de Versailles St-Quentin-en-Yvelines (France).*

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 Versailles and Garching near Munich. In addition, tutorials with and without hands-on exercises were held at International Supercomputing Conference 2012 and EuroMPI 2012. Finally, the virtual institute organized the 5th Workshop on Productivity and Performance (PROPER) in conjunction with the Euro-Par Conference 2012 (Rhodes Island, Greece) and the Workshop on Extreme-Scale Performance Tools in conjunction with the Supercomputing Conference (SC) 2012 (Salt Lake City, USA).

Other Activities

Courses

Winter semester 2011/12

- Parallel Programming I
- Simulation Sciences Laboratory
- Seminar Parallel Programming

Summer semester 2012

- Parallel Programming II

Workshop (Co)-organization

Workshop on Extreme-Scale Performance Tools held in conjunction with the Supercomputing Conference (SC'12), Salt Lake City, UT, USA, November 16, 2012.

5th Workshop on Productivity and Performance (PROPER) held in conjunction with the EuroPar 2012 Conference, Rhodes Island, Greece, August 28, 2012.

Workshop on Large-Scale Computer Simulation, Oak Ridge, TN, USA, April 25-27, 2012.

Tutorials and Short Courses

D. Böhme, M. Geimer, M. Gerndt, B. Krammer, V. Petkov, S. Shende, W. Spear, R. Tschüter, J. Weidendorfer: 10th VI-HPS Tuning Workshop, LRZ/TUM, Garching bei München, Oct 16-19, 2012.

W. Homberg, J. Kraus, J. Meinke, P. Philippen, S. Prabhakaran: GPU Programming, Jülich Supercomputing Centre, Germany, August 13–15, 2012.

D. Böhme, O. Lagrasse: Use of a Linux cluster and performance analysis. Linux Clusters Institute Summer School, HPC@LR, Montpellier, France, July 4, 2012.

W. Homberg, J. Kreutz, J. Meinke, P. Philippen, S. Prabhakaran: GPU Programming, Jülich Supercomputing Centre, Germany, March 19–21, 2012.

J. Meinke, J. Kreutz, W. Homberg, S. Prabhakaran: GPU Programming, Jülich Supercomputing Centre, Germany, December 12–14, 2011.

Talks and Publications

Talks

Aamer Shah, Felix Wolf: Holistic performance analysis of applications and systems, 2nd Sino-German Workshop on Cloud-based High Performance Computing, Hasso-Plattner Institute, University of Potsdam, October 24, 2012

A. Jannesari: Multicore and Parallel Programming, RWTH AICES Annual Workshop (Retreat), Monschau, Germany, October 4, 2012.

F. Wolf: Time - An Often-Neglected Dimension of Parallel Performance Analysis, TU Kaiserslautern, September 21, 2012.

D. Lorenz, P. Philippen, D. Schmidl, and F. Wolf: Profiling of OpenMP tasks with Score-P. PSTI 2012, Pittsburgh, PA, USA, September 11, 2012.

F. Wolf: Time - An Often-Neglected Dimension of Parallel Performance Analysis, Tokyo Institute of Technology, Tokyo, Japan, July 25, 2012.

F. Wolf: Scalable Performance Analysis of High-Performance Computing Applications, RIKEN Advanced Institute for Computational Science, Kobe, Japan, July 23, 2012.

F. Wolf: Time - An Often-Neglected Dimension of Parallel Performance Analysis, Goethe Center for Scientific Computing, Goethe University Frankfurt, June 28, 2012.

F. Wolf: Performance Engineering in HPC Application Development. Supercomputing Academy, Lomonosov Moscow State University, June 27, 2012.

D. Lorenz: Task analysis with Score-P. CScADS Tools Workshop, Snowbird, UT, USA, June 27, 2012.

D. Böhme, B. R. de Supinski, M. Geimer, M. Schulz, F. Wolf: Scalable Critical-Path based Performance Analysis. IPDPS 2012, Shanghai, China, May 24, 2012.

F. Wolf: Software Engineering in HPC – A Gap to be Closed. Perspectives Workshop on Co-Design of Systems and Applications for Exascale, Schloss Dagstuhl, Wadern, Germany, May 22, 2012.

M. Lücke: Simulationwissenschaften, Girls Day, Aachen, April 27, 2012.

D. Böhme: Scalable Trace Analysis with Scalasca. JICS/GRS Workshop on Large-scale Simulation, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 25, 2012.

A. Jannesari: Parallelism at node-level (multicore) systems, Siemens AG, Corporate Technology, Corporate Research and Technologies, Munich, Germany, April 10, 2012.

M. Lücke: Performance Analysis of the CESM CICE Model, G8 ECS Workshop, Aachen, March 6-7th 2012.

F. Wolf: Time - An Often-Neglected Dimension of Parallel Performance Analysis, University of Duisburg-Essen, Germany, February 3, 2012.

F. Wolf: Performance Dynamics of Massively Parallel Codes, HPC status conference of the Gauss Alliance, Darmstadt, Germany, December 5, 2011.

M. Lücke: Performance analysis of the CGPOP mini-application, G8 ECS Workshop, SC11 Seattle, USA, November 18, 2011

D. Böhme: The Scalasca Software Development Process, Workshop Entwicklung und Evolution von Forschungssoftware, Rolduc, NL, November 10, 2011.

Publications

Zoltán Szebenyi: Capturing Parallel Performance Dynamics. PhD thesis, RWTH Aachen University, volume 12 of IAS Series, Forschungszentrum Jülich, 2012, ISBN 978-3-89336-798-6.

Markus Geimer, Pavel Saviankou, Alexandre Strube, Zoltán Szebenyi, Felix Wolf, Brian J. N. Wylie: Further improving the scalability of the Scalasca toolset. In Proc. of PARA 2010: State of the Art in Scientific and Parallel Computing, Part II: Minisymposium Scalable tools for High Performance Computing, Reykjavik, Iceland, June 6–9 2010, volume 7134 of Lecture Notes in Computer Science, pages 463–474, Springer, 2012.

Dieter an Mey, Scott Biersdorff, Christian Bischof, Kai Diethelm, Dominic Eschweiler, Michael Gerndt, Andreas Knüpfer, Daniel Lorenz, Allen D. Malony, Wolfgang E. Nagel, Yury Oleynik, Christian Rössel, Pavel Saviankou, Dirk Schmidl, Sameer S. Shende, Michael Wagner, Bert Wesarg, Felix Wolf: Score-P: A Unified Performance Measurement System for Petascale Applications. In Proc. of the CiHPC: Competence in High Performance Computing, HPC Status Konferenz der Gauß-Allianz e.V., Schwetzingen, Germany, June 2010, pages 85–97. Gauß-Allianz, Springer, 2012.

Dominic Eschweiler, Michael Wagner, Markus Geimer, Andreas Knüpfer, Wolfgang E. Nagel, Felix Wolf: Open Trace Format 2 - The Next Generation of Scalable Trace Formats and Support Libraries. In Proc. of the Intl. Conference on Parallel Computing (ParCo), Ghent, Belgium, August 30 – September 2 2011, volume 22 of Advances in Parallel Computing, pages 481–490, IOS Press, 2012.

Andreas Knüpfer, Christian Rössel, Dieter an Mey, Scott Biersdorff, Kai Diethelm, Dominic Eschweiler, Markus Geimer, Michael Gerndt, Daniel Lorenz, Allen D. Malony, Wolfgang E. Nagel, Yury Oleynik, Peter Philippen, Pavel Saviankou, Dirk Schmidl, Sameer S. Shende, Ronny Tschüter, Michael Wagner, Bert Wesarg, Felix Wolf: Score-P – A Joint Performance Measurement Run-Time Infrastructure for Periscope, Scalasca, TAU, and Vampir. In Proc. of 5th Parallel Tools Workshop, 2011, Dresden, Germany, pages 79-91, Springer Berlin Heidelberg, September 2012.

Daniel Lorenz, Peter Philippen, Dirk Schmidl, Felix Wolf: Profiling of OpenMP tasks with Score-P. In Proc. of Third International Workshop on Parallel Software Tools and Tool Infrastructures (PSTI 2012), Pittsburgh, PA, USA, September 2012.

Sebastian Rinke, Daniel Becker, Thomas Lippert, Suraj Prabhakaran, Lidia Westphal, Felix Wolf: A Dynamic Accelerator-Cluster Architecture. In Proc. of the 41st International Conference on Parallel Processing Workshops (ICPPW 2012), Pittsburgh, PA, USA, September 2012.

Christian Siebert, Jesper Larsson Träff: Efficient MPI Implementation of a Parallel, Stable Merge Algorithm. In Recent Advances in the Message Passing Interface, volume 7490 of Lecture Notes in Computer Science, pages 204-213, Springer Berlin / Heidelberg, September 2012.

Marc-André Hermanns, Markus Geimer, Bernd Mohr, Felix Wolf: Scalable detection of MPI-2 remote memory access inefficiency patterns. Intl. Journal of High Performance Computing Applications (IJHPCA), 26(3):227–236, August 2012.

Alexandru Calotoiu, Christian Siebert, Felix Wolf: Pattern-Independent Detection of Manual Collectives in MPI Programs. In Proc. of the 18th Euro-Par Conference, Rhodes Island, Greece, volume 7484 of Lecture Notes in Computer Science, pages 28-39, Springer, August 2012.

Dirk Schmidl, Peter Philippen, Daniel Lorenz, Christian Rössel, Markus Geimer, Dieter an Mey, Bernd Mohr, Felix Wolf: Performance Analysis Techniques for Task-Based OpenMP Applications. In Proc. of the 8th International Workshop on OpenMP (IWOMP), Rome, Italy, volume 7312 of Lecture Notes in Computer Science, pages 196–209, Berlin / Heidelberg, Springer, June 2012.

David Böhme, Bronis R. de Supinski, Markus Geimer, Martin Schulz, Felix Wolf: Scalable Critical-Path Based Performance Analysis. In Proc. of the 26th IEEE International Parallel & Distributed Processing Symposium (IPDPS), Shanghai, China, IEEE Computer Society, May 2012.

David Böhme, Markus Geimer, Felix Wolf: Characterizing Load and Communication Imbalance in Large-Scale Parallel Applications. In Proc. of the 26th IEEE International Parallel & Distributed Processing Symposium (IPDPS) PhD Forum, Shanghai, China, IEEE Computer Society, May 2012.

Daniel Harlacher, Harald Klimach, Sabine Roller, Christian Siebert, Felix Wolf: Dynamic Load Balancing for Unstructured Meshes on Space-Filling Curves. In 2012 IEEE 26th International Parallel and Distributed Processing Symposium Workshops & PhD Forum, Shanghai, China, pages 1655-1663, IEEE computer society, May 2012, Workshop on Large-Scale Parallel Processing.

Advanced Studies in Computational Engineering Science



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- **Faculty**
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- **Postdoctoral associate**
Edoardo Di Napoli, Ph.D.
- **Team**
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- **Student Researcher**
Lucas Beyer
- **Guests**
Prof. Yurii Aulchenko, University Medical Center Rotterdam
Dr. Victor Eijkhout, Texas Advanced Computing Center
Prof. Robert van De Geijn, University of Texas at Austin
Prof. Enrique Quintana-Orti, Universidad Jaume I
Dr. Anton Duchkov, Russian Academy of Science



Overview

Paolo Bientinesi was appointed as Junior Professor in ‘Algorithm & Code Generation for High-Performance Architectures’ in 2008. He is also Young Research Leader, member of the steering committee, and deputy director of the Aachen Institute for Advanced Studies in Computational Engineering Science (AICES).

As leader of the “High-Performance and Automatic Computing” group, Bientinesi supervises research projects in different disciplines, including parallel eigensolvers, tensor operations, automatic algorithm & code generation, and performance modeling & prediction. The range of applications includes molecular dynamics, density functional theory, automatic differentiation, and genome analysis. Although diverse in nature, all these projects share one key aspect: The attempt of bridging the gap that separates the development of algorithms from both the computing platforms and the target applications.

In early 2012, Bientinesi received a small grant from the National Science Foundation (NSF), to work on ‘High-performance Computing in Seismic Data Processing’ in collaboration with Dr. Anton Duchkov, from the Russian Academy of Science.

Research

Computational Biology

Joint work with

Prof. Yurii Aulchenko (University Medical Center Rotterdam).

Generalized linear mixed-effects models in the context of genome-wide association studies (GWAS) represent a formidable computational challenge: the solution of millions of generalized least-squares problems, and the processing of terabytes of data. We develop high performance in-core and out-of-core algorithms for GWAS. By taking advantage of domain specific knowledge, exploiting multi-core parallelism, and handling data efficiently, our algorithms attain unequalled performance. When compared to GenABEL, one of the most widely used libraries for GWAS, we obtain speedups up to a factor of 50.

The variance component tests used in genomewide association studies of thousands of individuals become computationally exhaustive when multiple traits are analysed in the context of omics studies. We aim for high-throughput algorithm for multiple phenotype genome-wide association studies. The algorithm, generated with the help of an expert system, reduces the computational complexity to the point that thousands of traits can be analyzed for association with millions of polymorphisms in a course of days on a standard workstation.

Automation

We are working on a prototypical linear algebra compiler that automatically exploits domain-specific knowledge to generate high-performance algorithms. The input to the compiler is a target equation together with knowledge of both the structure of the problem and the properties of the operands. The output is a variety of high-performance algorithms to solve the target equation. Our approach consists in the decomposition of the input equation into a sequence of library-supported kernels. Since in general such a decomposition is not unique, our compiler returns not one but a number of algorithms. The potential of the compiler is shown by means of its application to a challenging equation arising within the genome-wide association study. As a result, the compiler produces multiple "best" algorithms that outperform the best existing libraries.

Performance Modeling

It is well known that the behavior of dense linear algebra algorithms is greatly influenced by factors like target architecture, underlying libraries and even problem size; because of this, the accurate prediction of their performance is a real challenge. We are not interested in creating accurate models for a given algorithm, but in correctly ranking a set of equivalent algorithms according to their performance. Aware of the hierarchical structure of dense linear algebra routines, we approach the problem by developing a framework for the automatic generation of statistical performance models for BLAS and LAPACK libraries. This allows us to obtain predictions through evaluating and combining such models. Our approach is successful in both single- and multi-core environments, not only in the ranking of algorithms but also in tuning their parameters.

Eigensolvers

We introduced a new collection of solvers EleMRRR for large-scale dense Hermitian eigenproblems. EleMRRR solves various types of problems: generalized, standard, and tridiagonal eigenproblems. Among these, the last is of particular importance as it is a solver on its own right, as well as the computational kernel for the first two; we developed a fast and scalable tridiagonal solver based on the Algorithm of Multiple Relatively Robust Representations (PMRRR). Like the other EleMRRR solvers, PMRRR is part of the freely available Elemental library, and is designed to fully support both message-passing (MPI) and multithreading parallelism (SMP). As a result, the solvers can equally be used in pure MPI or in hybrid MPI-SMP fashion. We conducted a thorough performance study of EleMRRR and ScaLAPACK's solvers on two supercomputers. Such a study, performed with up to 8,192 cores, provides precise guidelines to assemble the fastest solver within the ScaLAPACK framework; it also indicates that EleMRRR outperforms even the fastest solvers built from ScaLAPACK's components.

Analysis of the FEAST eigensolver.

Joint work with

Prof. Bruno Lang, Bergische Universitaet Wuppertal.

We analyze the FEAST method for computing selected eigenvalues and eigenvectors of large sparse matrix pencils. After establishing the close connection between FEAST and the well-known Rayleigh-Ritz method, we identify several critical issues that influence convergence and accuracy of the solver: the choice of the starting vector space, the stopping criterion, how the inner linear systems impact the quality of the solution, and the use of FEAST for computing eigenpairs from multiple intervals. We complement the study with numerical examples, and hint at possible improvements to overcome the existing problems.

Improved Accuracy for the MRRR algorithm.

Joint work with

Prof. Enrique Quintana-Orti, Universidad Jaume I.

A number of algorithms exist for the dense Hermitian eigenproblem. In many cases, MRRR is the fastest one, although it does not deliver the same accuracy as Divide&Conquer or the QR algorithm. We demonstrate how the use of mixed precisions in MRRR-based eigensolvers leads to an improved orthogonality, even surpassing the accuracy of DC and QR. Our approach comes with limited performance penalty, and increases both robustness and scalability.

Computational Physics

Joint work with

Prof. Stefan Blügel, Forschungszentrum Jülich.

Density Functional Theory (DFT) is one of the most used ab initio theoretical frameworks in materials science. It derives the ground state properties of multi-atomic ensembles directly from the computation of their one-particle density. In DFT-based simulations the solution is calculated through a chain of successive self-consistent cycles; in each cycle a series of

coupled equations (Kohn-Sham) translates to a large number of generalized eigenvalue problems whose eigenpairs are the principal means for expressing. A simulation ends when has converged to the solution within the required numerical accuracy. This usually happens after several cycles, resulting in a process calling for the solution of many sequences of eigenproblems. We found evidence showing unexpected correlations between adjacent eigenproblems within each sequence and suggest the investigation of an alternative computational approach: information extracted from the simulation at one step of the sequence is used to compute the solution at the next step. The implications are multiple: from increasing the performance of material simulations, to the development of a mixed direct-iterative solver, to modifying the mathematical foundations of the DFT computational paradigm in use, thus opening the way to the investigation of new materials.

Other Activities

Teaching

Winter semester 2011/12

- 11ws-14775: Introduction to Scientific Computing Languages
- 11ws-29563: Seminar Languages for Scientific Computing (Simulationstechnik I)

Summer semester 2012

- 12ss-38045: Automatic Generation & Analysis of Algorithms

Services

Bientinesi serves as member of the AICES steering committee, and as AICES deputy scientific director. In 2012, he was in the Program Committee of the 15th IEEE International Conference on Computational Science and Engineering" (IEEE CSE 2012), October '12, Cyprus.

He also organized the following events:

- Minisymposium on "High-Performance Linear Algebra on GPUs". GAMM Annual Meeting 2012, Darmstadt.
- Regional school "PETSc tutorial", AICES, 2012.

Talks and Publications

Talks & Lectures

"Automating the Generation of Algorithms for Generalized Least-Squares Problems". Speaker: Diego Fabregat-Traver. The 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012). Vienna, Austria, September 2012.

"A Compiler for Linear Algebra Operations". Speaker: Paolo Bientinesi - Invited speaker. Workshop on Libraries and Autotuning for Extreme-Scale Systems (CScADS '12). Snowbird, Utah, August 2012.

"A Domain-Specific Compiler for Linear Algebra Operations". Speaker: Diego Fabregat-Traver. The 7th Intl Workshop on Automatic Performance Tuning (iWAPT), 10th Intl Meeting on High-Performance Computing for Computational Science (VECPAR 2012). Kobe, Japan, July 2012.

"Automatic Modeling and Ranking of Algorithms". Speaker: Paolo Bientinesi - Invited speaker. The Seventh International Workshop on Automatic Performance Tuning (iWAPT 2012). Kobe, Japan, July 2012.

"Orthogonality in the Hermitian Eigenproblem and the MRRR Algorithm". Speaker: Matthias Petschow. International Workshop on Parallel Matrix Algorithms and Applications (PMAA 2012). London, England, June 2012.

"High-throughput Algorithms for Genome-Wide Association Studies". Speaker: Diego Fabregat-Traver. The 8th International Conference on Bioinformatics of Genome Regulation and Structure/Systems Biology (BGRS/SB 2012). Novosibirsk, Russia, June 2012.

"Block Iterative Eigensolvers for Sequences of Dense Correlated Eigenvalue Problems". Speaker: Edoardo Di Napoli. International Workshop on Parallel Matrix Algorithms and Applications (PMAA 2012). June 2012.

"High Performace Genome Studies". Speaker: Lucas Beyer. 2012 SIAM Conference on Applied Linear Algebra. SIAM Conference on Applied Linear Algebra. Universitat Politecnica de Valencia, Spain, June 2012.

"Performance Modeling for Ranking Blocked Algorithms". Speaker: Elmar Peise. Parallel Matrix Algorithms and Applications (PMAA) 2012. Birkbeck University of London, June 2012.

"Eigenproblems and Eigensolvers in Density Functional Theory". Speaker: Edoardo Di Napoli. Invited talk at the Argonne Leadership Computing Facility. May 2012.

"Block Iterative Solvers and Sequences of Eigenproblems arising in Electronic Structure Calculations". Speaker: Edoardo Di Napoli. Twelve Copper Mountain Conference on Iterative Methods. Copper Mountain, Colorado, USA, March 2012.

"Sequences of Generalized Least-Squares for Genome-Wide Association Studies". Speaker: Diego Fabregat-Traver. The 83rd Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM 2012). Darmstadt, Germany, March 2012.

"Fast and Scalable Eigensolvers for Multicore and Hybrid Architectures". Speaker: Paolo Bientinesi - Plenary speaker. 40th SPEEDUP Workshop on High-Performance Computing. Basel, Switzerland, February 2012.

Publications

Edoardo Di Napoli, Stefan Blügel and Paolo Bientinesi, "Correlations in Sequences of Generalized Eigenproblems Arising in Density Functional Theory", *Computer Physics Communications (CPC)*, volume 183, number 8, 1674--1682, Aug 2012.

Paolo Bientinesi, John Gunnels, Margaret Myers, Enrique Quintana-Orti, Tyler Rhodes, Robert van de Geijn and Field Van Zee, "Deriving Dense Linear Algebra Libraries", *Formal Aspects of Computing*, 1--13, Jan 2012.

José Aliaga, Paolo Bientinesi, Davor Davidovic, Edoardo Di Napoli, Francisco Igual and Enrique Quintana-Orti, "Solving Dense Generalized Eigenproblems on Multi-Threaded Architectures", *Applied Mathematics and Computation*, volume 218, issue 22, 11279--11289.

Roman Iakymchuk and Paolo Bientinesi, "Modeling Performance through Memory-Stalls", *ACM SIGMETRICS Performance Evaluation Review*, volume 40, number 2, 2012.

Diego Fabregat-Traver and Paolo Bientinesi, "A Domain-Specific Compiler for Linear Algebra Operations", *Proceedings of VECPAR 2012*, 2012.

Matthias Petschow and Paolo Bientinesi, "MR3-SMP: A Symmetric Tridiagonal Eigensolver for Multi-Core Architectures", *Parallel Computing*, Volume 37, Number 12, Dec 2011.

Roman Iakymchuk and Paolo Bientinesi, "Execution-Less Performance Modeling", *Proceedings of the Second International Workshop on Performance Modeling, Benchmarking and Simulation of High-Performance Computing Systems (PMBS11)* held as part of the Supercomputing Conference (SC11), Seattle, USA, Nov 2011.

Technical Reports

Matthias Petschow, Enrique Quintana-Orti and Paolo Bientinesi, "Improved Orthogonality for Dense Hermitian Eigensolvers based on the MRRR algorithm", Aachen Institute for Computational Engineering Science, RWTH Aachen, AICES-2012/09-1, Sept 2012.

Elmar Peise and Paolo Bientinesi, "Performance Modeling for Dense Linear Algebra" Aachen Institute for Computational Engineering Science, RWTH Aachen, <http://arxiv.org/abs/1209.2364> Sept 2012.

Diego Fabregat-Traver, Yurii Aulchenko and Paolo Bientinesi, "High-Throughput Genome-Wide Association Analysis for Single and Multiple Phenotypes", Aachen Institute for Computational Engineering Science, RWTH Aachen, AICES-2012/07-1, July 2012.

Diego Fabregat-Traver, Yurii Aulchenko and Paolo Bientinesi, "Fast and Scalable Algorithms for Genome Studies", Aachen Institute for Computational Engineering Science, RWTH Aachen, AICES-2012/05-1, May 2012.

Lukas Krämer, Edoardo Di Napoli, Martin Galgon, Bruno Lang and Paolo Bientinesi "Dissecting the FEAST Algorithm for Generalized Eigenproblems" Aachen Institute for Computational Engineering Science, RWTH Aachen, <http://arxiv.org/abs/1204.1726>.

Diego Fabregat-Traver and Paolo Bientinesi, "A Domain-Specific Compiler for Linear Algebra Operations" Aachen Institute for Computational Engineering Science, RWTH Aachen, AICES-2012/01-2, Jan 2012.

José Aliaga, Paolo Bientinesi, Davor Davidovic, Edoardo Di Napoli, Francisco Igual and Enrique Quintana-Orti, "Solving Dense Generalized Eigenproblems on Multi-Threaded Architectures", Aachen Institute for Computational Engineering Science, RWTH Aachen, AICES-2011/11-3, Nov 2011.

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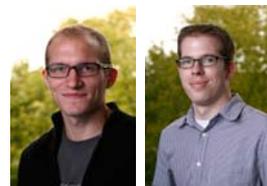
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Georg Wicherski
David Sosnitza



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 2012 eight research assistants were working towards a PhD in the IT-Security Research Group. In the reporting period eleven 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.

In 2012 Prof. Meyer received an offer for a Full Professorship at University of Mannheim.

Research Projects

ASMONIA

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. Here, we particularly work on the detection of malicious traffic within a mobile provider's network.

Anomaly-based Malware Detection on Mobile Devices

Dominik Teubert

funded by B-IT-Research School

The goal of this project is the development of a mobile malware detection system that operates on a mobile device directly and detects mobile malware with the help of machine learning techniques. In particular, we investigate the use of Hidden Markov Models trained with system call sequences as features.

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

Siemens AG

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

Nokia Siemens Networks

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

funded 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.

Security in Wireless Mesh Networks

Andre Egners

funded by UMIC Research Centre

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 behaviour is the current focus of our study.

Other Activities

rwthCTF 2011

In fall 2011 the Research Group IT-security organized the Capture the Flag hacking contest rwthCTF. More than 50 participating teams were competing in the contest. These teams were supplied with a Linux virtual computer image containing five services, implemented in a variety of programming languages which exhibited various security weaknesses. 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 manoeuvres did not matter for the final ranking, but could be used to buy access to a challenge network which ultimately culminated in physical control over a small robot which had to be steered through a maze 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. Due to the success of the event the Research Group will organize the rwthCTF 2012 in late November.



Courses

Winter semester 2011/12

- Lecture: IT-Security 1

Summer semester 2012

- Lecture: Security in Mobile Communication
- Seminar: Selected Topics in IT-Security and Cryptography
- Lab: Security Lab, the practical hacking lab held every summer term.

Chair Holder's scientific activities

Prof. Meyer served as member of the program committee for the following conferences

- SICK 2012
- LCN 2012

In addition she served as reviewer for the IEEE Journal for Wireless Personal Communications as worked as reviewer for the BMBF as well as the DFG.

Talks and Publications

Talks and Workshops

All of the publications listed below were presented in form of a talk at the respective conference or workshop. In addition the following talks were given by researchers from the IT-Security Research Group:

- Ericsson Workshop, “Make or break for the networked society”, January 25th 2012
- Russian Student Group Visit, Talks and practical challenges for a group of 15 graduate and undergraduate students from a Russian CTF-Team, April 2012
- Ulrike Meyer, Florian Weingarten, Junior Akademie, “Kryptographie – Grundlagen und Anwendungen”, August 6th 2012
- Mark Schlösser, „Computerviren, Malware, Botnetze - Dürfen wir uns wehren?“ RWTH Wissenschaftsnacht, November 11th 2012

Publications

J. Barnickel, U. Meyer, *A Privacy Preserving Range Extension for Commercial WLANs with User Incentives*, The Second International Conference on Mobile Services, Resources, and Users (MOBILITY 2012), Venice, Italy, October 2012 - to appear

P. Schoo, M. Schäfer, A. Egners, H. Hofinger, S. Wessel, M. Kühnel, S. Todt and M. Montag: *Collaboration Between Competing Mobile Network Operators to Improve CIIP*, 7th Conference on Critical Information Infrastructures Security (CRITIS 2012), Lillehammer, Norway, September 2012 - to appear

J. Gilger, J. Barnickel, U. Meyer: *GPU-acceleration of block ciphers in the OpenSSL cryptographic library*, 15th Information Security Conference (ISC 2012), Passau, Germany, September 2012 - to appear.

A. Egners, B. Marschollek, U. Meyer: *Hackers in Your Pocket: A Survey of Smartphone Security Across Platforms*, RWTH Aachen University, Technical Report, AIB-2012-07, May 2012.

A. Egners, B. Marschollek, U. Meyer: *Messing with Android's Permission Model*, IEEE International Conference on Trust, Security and Privacy in Computing and Communications (IEEE TrustCom-12), June 2012 (Liverpool, United Kingdom)

J. Barnickel, J. Wang, U. Meyer: *Implementing an Attack on Bluetooth 2.1+ Secure Simple Pairing in Passkey Entry Mode*, IEEE International Conference on Trust, Security and Privacy in Computing and Communications (IEEE TrustCom-12), June 2012 (Liverpool, United Kingdom).

A. Egners, H. Fabelje, U. Meyer: *FSASD: A Framework for Establishing Security Associations for Sequentially Deployed WMN*, IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks (WoWMoM), June 2012 (San Francisco, USA)

A. Egners, D. Gatzen, A. Panchenko, U. Meyer: *Introducing SOR: SSH-based Onion Routing*, 26th International Conference on Advanced Information Networking and Applications (AINA), March 2012 (Fukuoka, Japan)

Dissertations

Algorithms for Coordination and Competition in Networks

Habilitation Thesis

Martin Hoefer

This thesis describes our recent contributions to algorithmic game theory in the areas computation of equilibria, inefficiency of equilibria and mechanism design. The main topic are algorithms for resource allocation in networks with strategic agents. Our treatment first concentrates on aspects of systems without centralized control and the complexity of equilibria. We consider protocols and convergence of dynamics in congestion, load balancing, and neighborhood interaction games. Furthermore, we study the effects of agent cooperation on the structure and computational complexity of (coalitional) equilibrium concepts in congestion games, anonymous games, routing games over time, and cost sharing games.

In the second part of the thesis we treat social cost and the inefficiency of equilibria in congestion games. In addition, we also concentrate on reducing the inefficiency and study means to manipulate agent incentives to optimize social cost. We propose an extension of the price of anarchy to average-case analysis in load balancing games. We study agent heterogeneity and consider games with selfish and altruistic agents that optimize social cost. Finally, we study a restricted version of the classic taxing problem and propose and analyze a new means for social cost reduction in routing games.

In the third part we further explore social welfare maximization and study questions in the area of algorithm and mechanism design. We focus on the prominent application of throughput maximization in wireless networks in more detail and consider two approaches to this problem. Our first approach incorporates rational decisions of network participants. Here we design a truthful mechanism for the throughput optimization problem. Our second approach models the dynamic nature of the problem and is grounded in competitive analysis and online algorithms. Equivalently, we can view the problem as finding a good strategy in a 2-player zero-sum game against a malicious adversary.

Finally, the last part treats revenue maximization in a variety of network pricing scenarios with rational and approximately rational buyers. The study of pricing algorithms is closely connected to mechanism design, albeit with the objective of optimizing revenue for the auctioneer.

Evaluators: Prof. Dr. Rolf Möhring (TU Berlin)

Prof. Dr. Artur Czumaj (University of Warwick)

Habilitation Colloquium: 25 October 2011

Exploiting Wireless Link Dynamics

Muhammad H. Alizai

We address the challenge of link estimation and routing over highly dynamic and bursty wireless links that rapidly shift between reliable and unreliable periods of transmission. To this end, we propose unconventional yet efficient approaches of link estimation, routing and addressing in multi-hop wireless networks to exploit wireless link dynamics instead of bypassing them for the sake of stability and reliability. The goal is to maximize routing performance parameters, such as transmission counts and throughput, by exploiting the burstiness of wireless links while, at the same time, preserving the stability and reliability of the existing mechanisms.

The contributions of this work are as follows:

Firstly, we develop relevant link estimation metrics to estimate link burstiness and identify intermediate links that can enhance the routing progress of a packet at each hop. Secondly, we propose adaptive routing extensions that enable the inclusion of such long-range intermediate links into the routing process. Thirdly, we devise a resilient addressing scheme to assign stable locations to nodes in challenging network conditions. Our evaluation highlights the key achievements of this work when compared to the state-of-the-art: The proposed metrics identify bursty links in the network with high accuracy, the routing extensions reduce the transmission count in the network by up to 40%, and the addressing scheme achieves 3-7 times more stable addressing even under challenging network conditions.

Evaluators: Prof. Dr. Klaus Wehrle
Prof. Dr. Bernhard Rump

Date of oral exam: 7 March 2012

On the Projection Problem in Active Knowledge Bases with Incomplete Information

Vaishak Belle

The problem of projection has been identified as a fundamental reasoning concern in dynamical domains, where we are to determine whether or not some conditions will hold after a sequence of actions has been performed starting in some initial state. Solving the problem requires, at the very least, effectively reasoning about how actions transform the world, and inferring the logical consequences of the initial knowledge base (KB). For various reasons, tractability one of them, applications often make the closed-world assumption, thereby limiting the scope of these systems for the real world.

In this thesis, using the language of the situation calculus, we investigate the computational properties of a number of unsolved reasoning tasks in the context of projection with incomplete information. We first look at inherently incomplete KBs, where the information provided to the agent may not determine every fact about the world. Projection, then, may involve reasoning about what is believed and also, about what is not believed. We then look at physical agents with unreliable hardware, as a result of which actions lead to certain kinds of incomplete knowledge. Intuitively, beliefs should be (periodically) synchronized with this noise. Finally, we consider the presence of other agents in the environment, whose beliefs may differ arbitrarily, and the formalism should incorporate what others sense and learn during actions.

To enable a precise mathematical treatment of incomplete KBs, we appeal to a seminal proposal by Levesque, called only knowing. Building on existing work, we investigate projection wrt extensions to the situation calculus for only knowing, noisy hardware and multiple agents. Our central contribution will be to show that, in spite of the additional expressivity, reasoning about knowledge and action reduces to non-epistemic non-dynamic reasoning about the initial KB. More precisely, we show that when the initial KB is an arbitrary first-order theory, we are able to identify conditions under which projection can be solved by progressing the KB to a sentence reflecting the changes due to actions that have already occurred. Moreover, when effectors are unreliable, we allow the system to maintain probabilistic beliefs and then show how projection can be addressed by means of updating these beliefs. Finally, when there are many agents in the picture, we show that queries about the future can be resolved by regressing the query backwards to a formula about the initial KB. Only knowing comes with a significant result that allows us to reduce queries about knowledge to first-order theorem-proving tasks, which is then made use of when solving projection.

Evaluators: Prof. Gerhard Lakemeyer, Ph.D.

Prof. Hector J. Levesque, Ph.D. (University of Toronto)

Date of oral exam: 8 June 2012

Uncertainty Handling in Mobile Community Information Systems

Yiwei Cao

:Current mobile community information systems handle vast amounts of multimedia, various operations on multimedia processing, and diverse user communities using different mobile devices. Imprecise or even false GPS information, users' false semantic description about a multimedia artifact, or different interpretations of multimedia content in different user communities lead to data uncertainty. Some research work has been conducted in advanced uncertainty databases with probabilistic theories, data lineage, and fuzzy logic. However, these approaches deal with “conventional” data uncertainty problems at the database level. Multimedia content as well as user and community factors are not paid much attention, which is important for data management in prevalent web and mobile community information systems. Hence, this dissertation deals with data uncertainty problems addressed with the emerging and advanced development of Web 2.0 and mobile technologies. In my research I identify the new uncertainty problem perspectives in context, multimedia semantics, and community in mobile community information systems, namely *uncertainty 2.0*.

To deal with this uncertainty 2.0 problem, I have developed a model with a combination of the aspects of context management, semantics management, and community of practice realization. Collaborative tagging for multimedia content and community-based storytelling are the key approaches to handling uncertainty problems and engineering mobile community information systems. This model is established with two foci. First, interactions and conversions between multimedia semantics and multimedia context are crucial for mobile and Web data management in mobile community information systems. Second, development of the concept *community of practice* has great potentials to reduce uncertainty 2.0 problems. The *practices* taken by communities consist of multimedia tagging and multimedia storytelling. Amateurs are able to develop their knowledge and experiences in communities of practice. Uncertainty is reduced via this cultivation of expertise with the help of community of practice. A set of mobile community information system applications have been realized in the domains of cultural heritage management and technology enhanced learning, which validates the models and approaches to uncertainty 2.0 handling.

Examiners: Prof. Dr. Matthias Jarke
Baltasar Fernandez-Manjon (University of Madrid)
Ralf Klamma

Date of oral examination: 22 March 2012

Supporting Diversity and Evolvability in Communication Protocols

Stefan Götz

Internet communication has become very heterogeneous: typical use cases include web browsing, mobile communication, cloud and data-center networking, and sensor networks. However, today's communication protocols are still developed with significant manual effort for supposedly generic or average use cases. As a result, protocols are not custom-tailored to the requirements of users, applications, or services and are not as fast, flexible, secure, or reliable as they could be. Also, advances in protocol engineering and research are adopted only very slowly.

This talk presents an evolvable protocol platform, EPP, which illustrates a step in this direction of greater flexibility. It aims at assembling protocol stacks semi-automatically from software components, so that they can adapt gracefully to the constant evolution of communication protocols and their usage scenarios.

At its core, EPP describes the functionality of and interaction between individual software components. It then composes them into complete protocol stacks by evaluating these descriptions along with a set of communication requirements, as specified by the network, device, application, and user.

The main contributions of our approach consist of a concise protocol component meta-model, a composition algorithm for protocols, and an efficient ranking method where a single protocol stack needs to be selected from multiple alternatives. Together, these mechanisms can contribute to adapting protocols automatically to the increasing heterogeneity of communication scenarios and challenges.

Evaluators: Prof. Dr. Klaus Wehrle
Prof. Dr. Christian Becker (U. Mannheim)

Date of oral exam: 23. Februar 2012, 14.00 Uhr

Subspace Clustering for Complex Data

Stephan Günnemann

The increasing potential of storage technologies and information systems has opened the possibility to conveniently and affordably gather large amounts of complex data. Going beyond simple descriptions of objects by some few characteristics, such data sources range from high dimensional vector spaces over imperfect data to network data describing relations between the objects.

Data Mining is the task of automatically extracting previously unknown and useful patterns from such data. One of the most prominent mining tasks is clustering, which aims at grouping similar objects while separating dissimilar ones. Since in today's applications usually many characteristics for each object are recorded, one cannot expect to find similar objects by considering all attributes together. As a general solution to this problem, the paradigm of subspace clustering has been introduced, which aims at detecting clusters hidden in subspace projections of the data.

In this talk, we discuss novel methods for effective subspace clustering on various types of complex data. Our methods tackle major open challenges for clustering in subspace projections. We study the problem of redundancy in subspace clustering results and propose models whose solutions contain only non-redundant and, thus, valuable clusters. Since different subspace projections represent different views on the data, often several groupings of the objects are reasonable. Thus, we propose techniques that are not restricted to a single partitioning of the objects but that enable the detection of multiple clustering solutions. Besides tackling these challenges of subspace clustering for the case of vector data, we study the task of subspace clustering on two further data types: imperfect data and network data. We propose integrated mining techniques directly handling errors in the data and simultaneously mining different information sources. Overall, for the first time, meaningful subspace clustering results can be obtained for these types of complex data.

Evaluators: Prof. Dr. Thomas Seidl, RWTH Aachen

Prof. Martin Ester, PhD, Simon Fraser University, Burnaby, British Columbia,
Canada

Date of oral exam: 15 March 2012

Direct End-to-Middle Authentication in Cooperative Networks

Tobias Heer

Cooperative networks rely on user cooperation at the network layer to provide services, such as packet forwarding and shared access to other network resources like storage or Internet access. Examples of such networks are decentralized wireless mesh networks and wireless Internet access sharing networks. However, cooperation also creates new attack possibilities for malicious and selfish users. For example, wireless multi-hop networks are particularly susceptible to attacks based on flooding and the interception of, tampering with, and forging of packets. Thus, reliable communication in such networks often depends on mechanisms to allow on-path devices, such as middleboxes, to verify the authenticity of network traffic and the identity of the communicating end-hosts.

In this talk, we present, analyze, and evaluate novel end-to-middle authentication protocols. Thereby, we address the fundamental tension between security, performance, and lack of central control in cooperative networks. We show different design options that enable middleboxes to efficiently verify the source and/or the integrity of forwarded packets at different transmission speeds. With such a capability, middleboxes can shelter against resource misuse and protect end-hosts against DoS attacks that leverage the middleboxes as a weak spot.

Evaluators: Prof. Dr. Klaus Wehrle
Prof. Dr. Sarsu Tarkoma (U. of Helsinki)

Date of oral exam: 14 December 2011

Prozessanalyse und Ontologieevolution in kreativen, dynamischen Domänen

Jessica Huster

Today, whole work processes consist of the processing of information – both from internal and from external sources. Adequate information systems support requires the understanding of these often very complex processes and their underlying information. The semantic structures of this information are traditionally regarded as stable descriptions of a domain. But in the fashion industry sector, designers and marketers consciously cause changes in these ontologies every season. Only if they convince customers of these new ontologies, they were able to sell their products successfully. For information systems supporting fashion-based enterprises, this requires constant radical evolution of the underlying ontologies.

This work first introduces a process analysis technology and modeling procedure, to capture the work processes in such dynamic, creative domains. Based on their knowledge transformation and conversion processes, a method is developed to support the evolution of the underlying semantic models. A substantial part of the methodology concerns the integration of this ontology evolution into the user work processes. The proposed method is validated in a case study setting of the European home textile industry.

Evaluators: Prof. Dr. Matthias Jarke
Prof. Mareike Schoop Ph.D. (Uni Hohenheim)

Date of oral exam: 10 February 2012

Performance Modeling and Prediction for Linear Algebra Algorithms

Roman Iakymchuk

The dissertation incorporates two research projects: performance modeling of dense linear algebra algorithms, and high-performance computing on clouds.

The first project is focused on dense matrix computations, which are often used as computational kernels for numerous scientific applications. To solve a particular mathematical operation, linear algebra libraries provide a variety of algorithms. The algorithm of choice depends, obviously, on its performance. Performance of such algorithms is affected by a set of parameters, which characterize the features of the computing platform, the algorithm implementation, the size of the operands, and the data storage format. Because of this complexity, predicting algorithmic performance is a challenging task, to the point that developers are often forced to rely on extensive trial-and-error technique. We approach this problem from a different perspective. Instead of performing exhaustive tests, we introduce two techniques for modeling performance: one is based on measurements and requires a limited number of sampling tests, while the other needs neither the execution of the algorithms nor parts of them. Both techniques employ a bottom-up approach: we first model the performance of the BLAS kernels. Then, using these results we create models for higher-level algorithms, e.g. the LU factorization, that are built on top of the BLAS kernels. As a result, by using the hierarchical and modular structure of linear algebra libraries, we develop two techniques for hierarchical performance modeling; both techniques yield accurate predictions.

The second project is concerned with high-performance computing on commercial cloud environments. We empirically study the computational efficiency of compute intensive scientific applications in such an environment, where resources are shared under high contention. Although high performance is occasionally obtained, contention for the CPU and cache space degrades the expected performance and introduces significant variance. Using the matrix-matrix multiplication kernel of BLAS and the LINPACK benchmark, we show that the underutilization of resources substantially improves the expected performance. For instance, for a number of cluster configurations, the solution is reached considerably faster when the available resources are underutilized.

Evaluators: Prof. Paolo Bientinesi
Prof. Enrique Quintana-Orti'

Date of oral exam: 30 August 2012

Approximation Algorithms for Spectrum Allocation and Power Control in Wireless Networks

Thomas Kesselheim

Wireless networks have to operate despite the effects of interference. Therefore, it is a vital prerequisite to have algorithms that suitably manage wireless spectrum accesses. We design and analyze such algorithms from a theoretical perspective, striving for provable performance guarantees. In contrast to most previous studies in algorithmic theory, interference constraints are stated based on the signal-to-interference-plus-noise ratio (SINR). This way, our interference model allows to take power control into account. That is, transmit powers are individually adjusted with the purpose of minimizing the effects of interference.

In the first part, we consider the very fundamental combinatorial optimization problems. In the capacity-maximization problem, given a set of n possible communication requests, the task is to select a maximum feasible subset of these requests. Transmit powers are either given in advance or they are chosen by our algorithm. For both variants, we present constant-factor approximations. In the latency-minimization problem, the task is to compute a schedule serving all of the requests using as few time slots as possible. The capacity-maximization algorithms directly yield centralized $O(\log n)$ -approximation algorithms. In the second part, we deal with two advanced problem scenarios. By using suitable abstractions, we are able to reuse the insights of the first part. At the same time, our results are more general because they do not only apply to SINR-based models but also to a number of further models previously studied in algorithmic research.

The first setting we consider are auctions for secondary spectrum markets. In these markets licenses allowing secondary-usage of currently unused parts of the spectrum are being sold. Licenses are valid for short terms and in local areas. Thus, they have to take interference into account. We devise approximation algorithms whose guarantees are almost optimal under standard complexity-theory assumptions. Furthermore, we are able to turn them into truthful-in-expectation mechanisms ensuring that no bidder can benefit from lying about his true valuation.

The other advanced problem we study deals with dynamically arising communication requests within a network. By introducing a stochastic and an adversarial injection model, we are able to quantify and to bound the amount of arising requests. Furthermore, we present a general technique to transform latency-minimization algorithms built for the respective static problem into stable protocols guaranteeing delivery in the dynamic setting. Approximation factors are preserved in this transformation. Depending on the applied static algorithm, the obtained protocol also works in a distributed way.

Evaluators: Prof. Dr. Berthold Vöcking

Prof. Magnus M. Halldorsson, PhD (Reykjavik University)

Date of oral exam: 6 August 2012

Constraint-driven Schema Integration

Xiang Li

Schema integration occurs in many scenarios such as database design, data integration from independently created sources, data warehousing, and schema evolution in long-lived databases. To make the integrated schema useful for querying and data interoperability, mappings between the integrated schema and the sources have to be created as well. Information preservation and minimization of the integrated schema are key requirements to schema integration methods whose automation, however, is not sufficiently addressed by previous research.

The thesis proposes a new approach to schema merging using tuple-generating and equality-generating dependencies in the two base scenarios of design-time view integration and a posteriori data integration. It provides a well-founded semantics for these tasks, and an integrated schema minimization approach which simultaneously automates the generation of query or data exchange code, while guaranteeing information preservation. We study the theoretical complexity as well as the actual performance in well-known ontology integration and data integration benchmarks, and offer adapted support for important practical special cases such as incremental schema integration.

Evaluators: Prof. Dr. Matthias Jarke
Prof. Dr. Sonia Bergamaschi (University of Modena)

Date of oral exam: 23 October 2012

Automotive Software – Processes, Models and Variability (in German)

Cem Mengi

Software takes an important role in the development of cars. It opens new potentials und is a primary driver for innovation. At the same time, it is also an extensive complexity and cost factor. A major reason for this is the insufficient use of adequate methods and concepts for systematically capturing and handling software variants.

The ambition to design software in a way that it is adaptable for different variants requires proper measures in all phases of a software development process: (1) variability (commonalities, differences) must be explicitly captured, (2) dependencies between variable entities must be formulated, and (3) variants must be bound. In this context, this thesis proposes different solutions and applies them on three development levels.

The basis forms a variability model, which can be used to explicitly model and structure any kind of variability. Dependencies are formulated by a constraint language. Finally, variants are bound by a configuration activity followed by a generation process. This variability model is used on all regarded development levels.

For the conceptual design with function nets a top-down modeling process is proposed. Reusable properties are initially modeled in a classified domain library. These properties can then be instantiated out of the library in order to model function nets. To capture variants explicitly and formally, a variability mechanism is introduced. This variability mechanism is connected to the variability model, so that function variants can be handled completely.

In the architectural design with Simulink models an incremental variant development by copy & paste is assumed. Therefore, a bottom-up approach is recommended in order to explicitly identify common and variable model parts. By applying adequate variability mechanisms all model variants can be transformed into a family model. A connection to the variability model completes the approach for this phase.

For the implementation (with the programming language C) an approach is proposed, which supports a monitored variant implementation with a link to the variability model. Modifications in the source code are done on variant-specific views. With appropriate variability mechanisms these modifications are transferred into the original source code.

All approaches of the different levels are characterized such that, in principle, they both can be applied on all development levels and in combination. For the above described solutions a set of tools have been developed and applied. This forms a proof-of-concept for the described approaches.

Evaluators: Prof. Dr.-Ing. Dr. h.c. Manfred Nagl
Prof. Dr.-Ing. Stefan Kowalewski

Date of oral Exam: 26 June 2012

Konzepte für eine virtuelle Integration von AUTOSAR-konformer Fahrzeug-Software in frühen Entwicklungsphasen

Alexander Michailidis

Die stetig steigende Anzahl und Komplexität elektronischer Fahrzeugfunktionen erfordert neue Herangehensweisen an den Entwurf und die Qualitätssicherung von Steuergeräte-Software. Um diesen Herausforderungen zu begegnen, hat sich in der Automobilindustrie mittlerweile der Ansatz des modellbasierten Entwurfs etabliert. Durch den Einsatz simulationsfähiger Modelle können Software-Modultests vorgezogen und die Software-Qualität bereits in frühen Phasen gesteigert werden. Komponenten- und Systemintegrationsaspekte werden allerdings bei den frühen Modelltests bisher nur beschränkt betrachtet. Hauptgrund dafür ist die Vielfalt der proprietären Software-Architekturen, die bei den Steuergerätelieferanten bisher eingesetzt werden.

Mit der Standardisierung der Steuergeräte-Software-Architektur durch AUTOSAR ergeben sich neue Potenziale bei der frühzeitigen Absicherung von modellbasiert entwickelter Fahrzeug-Software. Es ist erstmalig mit vertretbarem Aufwand möglich, die verschiedenen funktionalen Software-Anteile gemeinsam mit der Hardware-nahen Software auf eine „virtuelle“ Plattform zu integrieren. Durch die Verwendung von derartigen „AUTOSAR-Integrationsplattformen“ können zukünftig Teile der Komponenten- und Systemtests bereits vor Verfügbarkeit der Ziel-Hardware durchgeführt werden. Eine Steigerung der Qualität von Systemspezifikationen und Funktionsmodellen kann somit bereits in frühen Entwicklungsphasen erzielt werden.

Im Rahmen der vorliegenden Arbeit wird ein neuartiges Konzept zur virtuellen Integration von AUTOSAR-konformer Fahrzeug-Software vorgestellt. Den zentralen Baustein bildet hier die Beschreibung einer formalen AUTOSAR-Integrationsplattform, in der insbesondere Aspekte zur Stimulation und Auswertung für Software-Tests früher Entwicklungsphasen analysiert werden. Durch die Aufzeichnung von Anwendungsfällen und Testszenarien werden Testziele von Komponenten- und Systemtests adressiert sowie allgemeine Testmuster für eine virtuelle Software-Absicherung hergeleitet. Anschließend folgt ein Vorschlag zur Eingliederung des Konzepts der virtuellen Integration in die derzeitige Software-Entwicklung im Fahrzeug. Dabei werden sowohl aktuelle Entwicklungsprozesse als auch die unterschiedlichen Entwicklungsrollen, -artefakte und -werkzeuge berücksichtigt. Das neue Konzept wird letztlich prototypisch umgesetzt und durch mehrere Fallstudien begleitend zur Serienentwicklung für Body- und Comfort-Funktionen der Daimler AG bewertet. Mit einer Aufwand-/Nutzenanalyse wird neben den technischen Vorteilen auch die Tauglichkeit des Konzepts für einen Serieneinsatz dargestellt.

Evaluators: Prof. Kowalewski
Prof. Rumpe

Date of oral exam: 19 December 2011

Applied Timed Testing: Testautomatisierung in industriellen Testprozessen von eingebetteten Systemen

Ralf Mitsching

Die Reduktion des Testaufwands bei gleichzeitiger Beibehaltung der Qualität und des Umfangs der Testaktivitäten ist ein zentrales Anliegen bei der Entwicklung von zeitkritischen eingebetteten Systemen in industriell geprägten Testprozessen. Aufgrund ihres Potenzials zur Automatisierung von Testfallgenerierung und -ausführung eignen sich modellbasierte Testmethoden (=MBT) zur Reduktion des Testaufwands. Zusätzlich erlauben modellbasierte Testmethoden, Änderungen an Testmodellen lokal vorzunehmen sowie eine konsistente Übertragung der Änderungen an weitere Prozessdokumente im Testprozess. Des Weiteren stellen bestimmte Formen des MBT ein theoretisches Fundament zur Sicherstellung der Konformanz zwischen Anforderungen und Systemverhalten beim Testen zur Verfügung.

Das Timed Testing, als eine Ausprägung des MBT, bietet die Möglichkeit, Testfallgenerierung und -ausführung zusätzlich um die Betrachtung der Zeit zu erweitern. Somit besitzt das Timed Testing ideale Voraussetzungen, um innerhalb eines industriell geprägten Testprozesses zur Reduktion des Testaufwandes von echtzeitkritischen eingebetteten Systemen beizutragen.

Während für andere modellbasierte Testmethoden verschiedene Arbeiten bzgl. der Integration der Methoden und Werkzeuge innerhalb eines Testprozesses bereits vorliegen und somit Methodik und Werkzeuge für den Einsatz im industriellen Umfeld angepasst wurden, stand eine Arbeit mit diesem Fokus für den Bereich des Timed Testings noch aus. In der vorliegenden Arbeit wurden daher systematisch die Bedürfnisse eines industriellen Anwenders bei der Applikation des Timed Testings innerhalb eines industriell geprägten Testprozesses untersucht, neue Modellierungskonzepte und entsprechende Werkzeuge entwickelt und im Rahmen einer industriellen Fallstudie untersucht.

Evaluators: Prof. Kowalewski
Prof. Lichter

Date of oral exam: 18 September 2012

Games on Dynamic Networks: Routing and Connectivity

Frank G. Radmacher

Infinite games are a strong model for analyzing dynamic networks that encounter continuous topological changes during operation. In this framework, the players represent the contrary forces which modify the network. In particular, this thesis deals with three different two-player games which focus on guaranteeing routing and connectivity properties in dynamic networks. In each model, one player has to establish the proper operation of the network, while the adversary produces failures and demands that occur during operation.

In the first part, we study *sabotage games*, which van Benthem introduced in 2002. In these games, a *Runner* traverses a graph and tries to reach a set of goal vertices, while a *Blocker* removes edges. We refine this game in two ways; namely we consider a more general winning objective expressed in linear temporal logic, and we study the variant in which Blocker is replaced by a probabilistic player. We show that in both cases the problem to decide whether Runner wins remains PSPACE-complete.

In the second part, we develop a routing game in which a *routing agent* has to deliver packets to their destinations, while a *demand agent* continuously generates packets and blocks connections for a certain amount of time. We show general limitations for obtaining routing strategies but also point to algorithmic solutions. The results depend on both the desired routing property and the coarseness of the model. For certain scenarios we develop feasible routing algorithms, each of which guarantees a routing property against any behavior of the demand agent.

In the third part, we introduce a connectivity game between a *Constructor* and a *Destructor*. While Destructor deletes nodes, Constructor can restore or even create new nodes under certain conditions. Also, we model information flow through the network by allowing Constructor to change labels of adjacent nodes. Constructor either has a reachability or a safety objective, i.e., Constructor has to either establish a connected network or guarantee that the network always stays connected. We show under what conditions the solvability of these games is decidable and, in this case, analyze the computational complexity. The results depend on the abilities of Constructor and differ for the reachability and the safety version.

Examiners: Prof. Dr. James Gross
Prof. Dr. Ir. Joost-Pieter Katoen
Prof. Dr. Horst Lichter
Prof. Dr. Dr.h.c. Wolfgang Thomas
Prof. Dr. Berthold Vöcking

Date of oral exam: 24 February 2011

Model-based Development of Automotive Control-Systems in Small and Medium Enterprises

Michael Reke

Small and medium enterprises (SME) are the innovation leaders of the industry and especially for the technology-oriented automotive industry. Because of the major structural and cultural differences to large-scale enterprises, many obstacles have to be overcome for a more extensive integration of SME into the software development process. In bigger companies the development is organized by tightly regulated development processes and often long-term decision making processes. In contrast to that the advantage of SME is their big flexibility, which appears in creative solutions, fast decisions and customer oriented work.

The approach in this thesis introduces a development process, which is based on interfaces and methods from large-scale enterprise processes. But the processes itself are simplified, combined and weighted in a different way. The goal is to skip the elements, which were introduced to organize the massive parallel work of engineers, but to keep those elements, which ensure a high software quality. It is shown that especially model-based development is best suited to support this goal. Additionally, a development tool is presented, that fits to the new process approach and enables model-based software development.

The introduced processes were implemented and evaluated in a small development company. The processes were successfully approved by the assessment method Automotive SPICE. Requirements were defined for the development tool and the architecture is presented. The main design element is an abstraction layer, which separates the configuration from the modeling-tool and integrates the parameters for simulation and code generation. This enables a flexible adaption of the tool to various tool-chains used in different projects. For evaluation several case studies are presented, which show and discuss the usage of the tool and the methods in developing electronic control units for automotive applications. The interface to different external software tools was evaluated and is also discussed in the thesis.

In summary, the thesis presents an approach, how small and medium enterprises give a beneficial contribution to the development of automotive control-systems by processes and tools that support the individual advantages of these enterprises.

Evaluators: Prof. Dr.-Ing. Stefan Kowalewski

Prof. Dr. Thomas Rose

Date of oral exam: 3 July 2012

Interactive Tracing of RadioWaves and Neuronal Fiber Pathways for Exploratory Visualization in Virtual Reality

Tobias Rick

Exploratory visualization of physical simulations in virtual environments greatly benefits from interactively changing parameters with real-time feedback. The present thesis addresses two specific research questions by problem reformulation and implementation on the Graphics Processing Unit's many-core architecture towards a simulation and interaction in real-time: (1) simulating and manipulating wireless radio networks and (2) estimating and disambiguating neuronal fiber connectivity in the living human brain.

This work assists in the exploratory scientific analysis by directly coupling simulation input and output with visual feedback and natural interaction via an interactive Virtual Reality (VR) interface. The user becomes an integral part of the workflow in order to observe computation results in real-time and to react appropriately. An interactive manipulation is enabled by decomposing and re-formulating the domain specific algorithms into parallel sub tasks. Their scalability is demonstrated in the presence of a huge number of cores as available on current graphics hardware. The work uses VR interfaces to put the user in more control of the computing pipeline in order to exploit the full potential of a human-in-the-loop to see patterns and structures arise.

Evaluators: Prof. Dr. Torsten Kuhlen
Prof. Dr. Leif Kobbelt
Prof. Dr. Katrin Amunts

Date of oral exam: 9 May 2012

Eine Werkzeuginfrastruktur zur agilen Entwicklung mit der UML/P

Martin Schindler

One of the most promising approaches for handling the increasing complexity of software development projects is the abstraction using modeling for which the UML has been established during the last years. With the UML/P this rather heavyweight and partly redundant family of modeling languages got reduced to essential core notations and optimized according to the requirements of agile, model-driven development processes. Adding Java as action language, the UML/P allows entire modeling and quality assurance of software systems whereas the technical realization is derived from the models using generators.

With this work the practical application of the agile concepts and modeling techniques of the UML/P are supported by a tooling infrastructure for the first time. Summarized the main results are as follows:

- The *modeling* of structure, behavior, and quality assurance of software systems is supported by a Java-like textual notation for the UML/P. This offers a compact, efficient, and tooling-independent model creation, a structuring of models in packages, a support of language profiles and explicit model relations using qualified name references and imports.
- The *context analysis* allows model- and language-crossing consistency checks of the models and is flexibly adaptable and extendable for language profiles or different model abstractions. Particularly the context analysis interprets Java against the models so that Java is raised to the model-level as abstract action language.
- The *code generation* is realized using templates as central artifact for development, configuration, and execution of generators in a modular manner concerning languages and models. Tracing of generated code and its sources, optimizations for readable templates, automatic derivation of the data model, and invoking of Java code simplifies the adaption and extension of the generators within a development project. In addition, a method for a stepwise development of generators from exemplary source code is defined. The approach is complemented by concepts for production and test code generation from UML/P-models as well as by a technique for a language-independent calculation of test coverage on models. This demonstrates how a compositional, extendable, and testable architecture can be derived from models for the target system.
- The *tooling infrastructure* is implemented as a modular and lightweight framework. Each language is realized as a self-contained component, which combines the grammar-based language definition, language processing, context conditions and generators independently from other languages. This allows a flexible extension and variable composition of the UML/P languages in a modular manner.

To conclude, this work offers a comprehensive tooling infrastructure for the agile model-driven development with the UML/P which is flexibly extendable and adoptable to technology as well as to domains.

Evaluators: Prof. Dr. rer. nat. Bernhard Rumpe
Prof. Dr. rer. nat. Albert Zündorf (University of Kassel)

Date of oral Exam: 23 December 2011

A File System for Wireless Mesh Networks

Benjamin Schleinzer

Over the last years, research has focused on Wireless Mesh Networks (WMNs) to bridge the gap between cellular networks, Mobile Ad-hoc Networks and Wireless Local Area Networks. The evaluation of existing file systems showed a lack of important features to perform well in WMNs. Therefore, this talk presents a new approach for a distributed file system---the Wireless File System (WFS). The approach is based on a new architecture that introduces three different data types: First, containers that store the metadata and the security information for the file system, every directory and every file. Second, cell trees that combine Merkle-trees and B+-trees to provide a dynamic data structure that stores the content of the different file system items. Third, the inode tree, which stores a link to the latest version of each file system item.

A critical aspect of the file system is to secure cell trees against unauthorized access or manipulation and to still allow users to share access to containers and cell trees with other trusted users. At the same time, the inode tree stores important information about the status of the file system and must be readable by everyone while still being resilient against manipulation. The solution to this problem is a new cryptographically enforced access control system, which includes a user management system and a key distribution scheme.

Evaluators: Prof. Dr. Oto Spaniol
Prof. Dr. Matthias Jarke

Date of oral exam: 20 June 2012

Infinite Regular Games in the Higher-Order Pushdown and the Parametrized Setting

Michaela Slaats

Higher-order pushdown systems extend the idea of pushdown systems by using a “higher-order stack” (which is a nested stack). More precisely on level 1 this is a standard stack, on level 2 it is a stack of stacks, and so on. We study the higher-order pushdown systems in the context of infinite regular games.

In the first part, we present a k -EXPTIME algorithm to compute global positional winning strategies for parity games which are played on the configuration graph of a level- k higher-order pushdown system. To represent those winning strategies in a finite way we use a notion of regularity for sets of higher-order stacks that relies on certain (“symmetric”) operations to build higher-order stacks. The construction of the strategies is based on automata theoretic techniques and uses the fact that the higher-order stacks constructed by symmetric operations can be arranged uniquely in a tree structure.

In the second part, we study the solution of games in the sense of Gale and Stewart where the winning condition is specified by an MSO-formula $\varphi(P)$ with a parameter $P \subseteq \mathbb{N}$. This corresponds to a three player game where the i -th round between the two original players is extended by the choice of the bit 1 or 0 depending on whether $i \in P$ or not. We consider the case that the parameter can be constructed by some deterministic machine, a “parameter generator”. We solve the parametrized regular games for parameters P given by two kinds of such generators, namely: higher-order pushdown automata and collapsible pushdown automata.

In the third part, we study higher-order pushdown systems and higher-order counter systems (where the stack alphabet contains only one symbol), by comparing the language classes accepted by corresponding automata. For example, we show that level- k pushdown languages are level- $(k+1)$ counter languages.

Examiners: Dr. habil. Didier Caucal
Prof. Dr. Erich Grädel
Prof. Dr. Ir. Joost-Pieter Katoen
Prof. Dr. Thomas Seidl
Prof. Dr. Dr.h.c. Wolfgang Thomas

Date of oral exam: 23 November 2011

Bimanual Interaction for Medical Virtual Environments: Palpation and Needle Intervention

Sebastian Ullrich

While medicine and surgery evolved significantly in the last century and past decade, the teaching methods have not changed in the same manner. The apprenticeship model "See one, do one, teach one" is still common practice and bears risks in patient safety. Traditional training methods are often constrained and limited, e.g., puppets and artificial material deteriorate from repeated usage, training on corpses or animals is expensive, tissue behavior differs and the usage is ethically questionable. Most of these issues can be addressed by virtual reality-based training simulators.

In this thesis we focus on bimanual interaction for medical simulation. More specifically, novel approaches for simultaneous palpation and needle insertion are researched. To apply and validate these techniques on a specific medical procedure, we choose the femoral block technique from regional anesthesia.

The major contributions of this thesis are a real-time capable software architecture that allows for haptic bimanual interaction in a finite element-based medical simulation environment, novel methods for palpation with tissue dragging, simulated anatomical landmarks and haptic pulse rendering, and methods for haptic needle insertion with multiple tissue layers. Simulator prototypes are described that utilize the aforementioned algorithms and combine these for medical training scenarios with plausible anatomical datasets, produced with the content creation tools. Finally, the algorithms are in part assessed with time measurements for performance, force logging for analysis of simulation results and the prototypes are validated with medical experts in user studies.

Evaluators: Prof. Dr. Torsten Kuhlen
Prof. Dr. Rolf Rossaint,
Prof. Dr. Uwe Naumann

Date of oral exam: 22 December 2011

Exploitation of Structural Sparsity in Algorithmic Differentiation

Ebadollah Varnik

The background of this thesis is algorithmic differentiation (AD) of in practice very computationally expensive vector functions given as computer programs. Traditionally, most AD software provide forward and reverse modes of AD to calculating the Jacobian matrix accurately at a given point on some kind of internal representation kept on memory or hard disk. In fact, the storage is known to be the bottleneck of AD to handle larger problems efficiently, especially, in reverse mode. The forward mode AD can be implemented very cheaply in terms of memory by single forward propagation of directional derivatives at runtime. However, the reverse mode needs to store some data in the so-called forward sweep to allow the data flow reversal needed for backward propagation of adjoints. The latter is recently the focus of ongoing research activities of the AD community for scalar functions as a single application of reverse mode is enough to accumulate the entire gradient of the target function. To handle the memory bottleneck, checkpointing schedules e.g. revolve have been developed for time-dependent problems. However, they require user's knowledge in both the function as well as the reverse mode AD. In this context, we aim to provide a tool, which minimizes non-AD user's effort in application of the reverse mode AD on their problems for large dimensions. Moreover, we investigate methods to improve the exploitation of structural sparsity of in general derivative tensors such as Jacobians and Hessians. Existing methods are based on the knowledge of the nonzero pattern of target derivative structures, where a compression is usually achieved by the application of some coloring algorithms to a graphical representation. We consider partial distance-2 coloring and star/acyclic coloring of the bipartite and adjacency graph of Jacobians and Hessians, respectively, provided by the coloring package ColPack. To achieve better compression, we distinguish between variable and constant nonzeros, where the latter is supposed to be unchanged at all those points of interest with fix flow of control. Hence, only the former is needed to be computed at runtime. Therefore, general runtime algorithms are provided to compute the variable pattern and the constant entries. We test also their performance in both runtime and achieved colors in the process of sparse Jacobian and Hessian computation. Furthermore, we present an algorithm to overestimate the Hessian sparsity pattern that is referred to as the conservative Hessian pattern estimation. It is gained by exploiting the partial separability of the underlying function. We present numerical results on the computational cost as well as the coloring performance in terms of runtime and achieved colors of the conservative pattern and compare them with those of the exact (nonzero) Hessian pattern. The computational complexity of the latter is known to be quadratic. Finally, the conservative algorithm is refined to a recursive version that is referred to as the recursive Hessian pattern estimation. The recursive algorithm is supposed to converge to the exact one in both runtime and the resulting pattern for sufficiently large recursion level. Thereby, the recursion level one yields exactly the same pattern as the conservative one.

Evaluators: Prof. Dr. rer. nat. Uwe Naumann

Prof. Dr. rer. nat. Andrea Walther (Paderborn University)

Date of oral exam: 9 November 2011

Generierung domänenspezifischer Transformationssprachen

Ingo Weisemöller

Domain specific languages (DSLs) have recently become increasingly important in software engineering. These languages allow domain experts to model parts of the system under development in a problem-oriented notation that is well-known in the respective domain. Thus, they can substantially improve the involvement of domain experts into software engineering processes. The introduction of a DSL is accompanied by the need to transform models or programs in this language. In doing so, frequently used transformations are formalized as transformation rules for computer aided or even automatic repeated execution.

Describing transformation rules is of interest not only for language developers, but also for language users. For instance, they can describe specific analysis and editing operations or sequences of such operations in macros, and execute them again as needed.

The results presented in this thesis include a transformation language that reuses the concrete syntax of a given textual modeling language (base language), which allows experts for the base language to describe both models and model transformations in a notation familiar to them. The usage and development of the transformation language are illustrated based on the rather complex example of simplifying hierarchical statecharts, a semantics preserving transformation that can be used as a step of a code generation process.

The domain specific transformation language and the transformation engine consist of three main components, each of which is presented in a separate chapter of this thesis. First, the language contains rule language with the domain specific notation mentioned above. These rules can be translated to rules in a different, generic transformation language; this second language uses a notation based on UML object diagrams, which can in turn be translated to Java. Third, a control flow language allows to combine rules in either of these languages to complex transformation modules.

As a unique and novel innovation, the results presented here allow to automatically derive the domain specific transformation language from the description of the base textual DSLs. From the language developers' perspective, introducing such a language therefore causes very little effort, because it is generated automatically from previously existing artifacts.

Hence, domain specific transformation languages are substantially valuable for the users of domain specific modeling languages, and they comes with negligible additional efforts for the language developer.

Evaluators: Prof. Dr. rer. nat. Bernhard Rumpe
Prof. Dr. rer. nat. Andy Schürr (TU Darmstadt)

Date of oral Exam: 5 May 2012

Bringing Haptic General-Purpose Controls to Interactive Tabletops

Malte Weiss

Interactive tabletops are large horizontal displays that allow multiple users to simultaneously and directly interact with digital content by touching the surface, manipulating physical objects, or conducting gestures above the surface. In the last decade, these devices have aroused much interest in the research community, and first commercial products have been released. Interactive tabletops combine a dynamic graphical user interface, a natural way of input, and a platform that is suitable for collocated collaboration. However, they provide only limited haptic feedback. In contrast to physical controls that guide the users' motion, visual on-screen controls cannot be felt and require visual focus when being operated. Also, due to the large contact area of fingers, input by touch is less precise than by conventional controls, such as mice or keyboards.

This thesis addresses the issue of limited haptic feedback on interactive tabletops, while focussing on precise input for productivity tasks. We introduce physical general-purpose controls that combine the benefits of haptic feedback with the dynamic nature of interactive tabletops. Our controls are passive, untethered, low-cost, and easy to prototype. Made of transparent materials and using the table's back projection, they can change their visual appearance on the fly and become versatile controls for various applications. Furthermore, we describe how to turn these controls into malleable user interfaces by employing an electromagnetic actuation mechanism. This allows to move a control or parts of it, to maintain the consistency between its physical and virtual state, and to change physical properties via software at run time. Finally, we present an output method that creates haptic feedback near the surface and only requires a minimal equipment worn by the user.

The thesis provides an introduction to the field of interactive tabletops and embeds our contributions into the context of related work. We explain our design and interaction concepts, the underlying hardware engineering, and software technologies. We evaluate our contributions in user studies and measurements and provide evidence for the usefulness of our techniques. We also describe potential applications with focus on productivity tasks. Finally, we illuminate implementation challenges, discuss limitations, and provide a perspective on recent developments as well as future trends in the field of haptic feedback on interactive tabletops.

Evaluators: Univ.-Prof. Dr.rer.nat. Jan Borchers
Prof. James D. Hollan, Ph.D.

Date of oral exam: 23 August 2012

Das Transmission Control Protocol – Neue Wege einer modernen Loss Recovery

Alexander Zimmermann

Mehr als drei Jahrzehnte nach seiner Standardisierung ist das Transmission Control Protocol (TCP) nach wie vor das am häufigsten eingesetzte Transportprotokoll im Internet. Kernpunkt der TCP-Spezifikation ist die Congestion Control, die es ermöglicht, die Senderate entsprechend der im Netzwerk wahrgenommenen Überlast anzupassen. Mangels eines expliziten Feedbacks durch das Netzwerk wertet TCP traditionell den Verlust von Segmenten als implizites Anzeichen einer Überlast. Eine der Möglichkeiten für TCP, den Verlust von Segmenten festzustellen, ist der Empfang von Duplicate Acknowledgments. Leider liefert diese Heuristik nicht immer korrekte Resultate, insbesondere dann nicht, wenn Segmente in einer anderen Reihenfolge empfangen werden als sie gesendet wurden: das Problem des Packet Reordering. Motiviert durch die negativen Auswirkungen des Reordering auf TCP, wird mit TCP-aNCR ein senderseitiger Algorithmus vorgestellt, der die TCP-Spezifikation standardkonform erweitert. Auf Basis einer Erkennungs- und Quantifizierungskomponente werden TCP's Congestion Control und Loss Recovery adaptiv an das im Netzwerk präsente Reordering angepasst, so dass sich das Standardverhalten des Protokolls nicht ändern, falls kein Reordering im Netzwerk vorkommt.

Evaluators: Prof. Dr. Otto Spaniol
Prof. Dr. Ulrike Meyer
Dr. Lars Eggert, Nokia Research Center

Date of oral exam: 8 March 2012

Solving Infinite Games with Bounds

Martin Zimmermann

We investigate the existence and the complexity of computing and implementing optimal winning strategies for graph games of infinite duration. Parameterized linear temporal logics are extensions of Linear Temporal Logic (LTL) by temporal operators equipped with variables for time bounds. In model-checking, such specifications were introduced as “PLTL” by Alur et al. and as “PROMPT-LTL” by Kupferman et al. We show how to determine in doubly-exponential time, whether a player wins a game with PLTL winning condition with respect to some, infinitely many, or all variable valuations. Hence, these problems are not harder than solving LTL games. Furthermore, we present an algorithm with triply-exponential running time to determine optimal variable valuations that allow a player to win a game. Finally, we give doubly-exponential upper and lower bounds on the values of optimal variable valuations.

In Muller games, we measure the quality of a winning strategy using McNaughton’s scoring functions. We construct winning strategies that bound the losing player’s scores by two and show this to be optimal. This improves the previous best upper bound of $n!$ in a game with n vertices, obtained by McNaughton. Using these strategies, we show how to transform a Muller game into a safety game whose solution allows to determine the winning regions of the Muller game and to compute a finite-state winning strategy for one player. This yields a novel antichain-based memory structure and the first definition of permissive strategies for Muller games. Moreover, we generalize our construction by presenting a new type of game reduction from infinite games to safety games and show its applicability to several other winning conditions.

Examiners: Prof. Dr. Ir. Joost-Pieter Katoen
Prof. Dr. Jean-François Raskin
Prof. Dr. Thomas Seidl
Prof. Dr. Dr.h.c. Wolfgang Thomas

Date of oral exam: 27 February 2012

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
- **Student Workers**
René Birekoven
Sebastian Kaufmann
Christian Königs
Kevin Möllering
Behnam Nikzad
Heiner Oßwald

Overview

Since 1985 the System Administration Group (Rechnerbetrieb Informatik, RBI) operates several computer labs and provides technical support for the Department of Computer Science at RWTH Aachen University. The principal task of the RBI is to install, maintain, and evolve the local network and several central services, including file servers, a database server, mail server, and web server. Students, faculty, and staff have free unlimited access to the computer labs operated by the RBI.

The computer labs are used in computer science courses and for student and faculty research projects. Especially for novice users a user helpdesk is offered during business hours. The labs are provided with PCs running the Debian GNU/Linux operating system. The computers are equipped with various hardware extensions and software to support the students in doing their exercises and projects. All computers are part of the local area network and provide unrestricted access to the campus backbone and the internet.

Equipment

Computer Laboratories

The RBI operates five labs in the basement of the E1 and E2 building. The labs are particularly intended for practical courses and student research projects. A user helpdesk is located next to the labs in both locations and provides support for lab users and installation support for students. The labs offer a total number of 52 networked computers based on Intel and AMD CPUs and running the Debian GNU/Linux operating system, additional workplaces for 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. file servers 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.

Computer Science Library RWTH Aachen



Staff

- **Head**
Dipl.-Bibl. Renate Eschenbach-Thomas
- **Team**
Birgit Willms
Birgit Zagolla
- **Students** (as of September 2012)
Katarina Braun
Kim Kerger
Christina Nieradzik
Matthias Nöbel
Tatjana Repenko
René Scherer
Anna Storz



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>

What you can find in our library

- 60,000 monographs and conference proceedings recorded in an online public access catalogue (OPAC).
- “Handapparate”: Required readings for the courses, compiled by professors for their students, accessible on special shelves.
- All Diploma, Bachelor and Master 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-Space 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. Transfer of 23000 books from St. Augustin to Aachen

In summer 2011 we received the news from Prof. Jarke, Director of Fraunhofer FIT, that the library of the Fraunhofer Institutes in St. Augustin (IZB) would be closed. In order to prevent that many books and journals from the magnificent stock of that library would be lost, a plan was devised to transfer parts of the IZB to the computer science library in Aachen. As a result,

23000 out of 77000 volumes were selected as relevant for the stock of our library. The project took a lot of effort and went over about 12 months starting in November 2011. The process was organized in the following stages:

1. Several professors and members of staff and the librarian went through the lists of the 77000 IZB volumes and marked those entries that would be useful for the Aachen computer science library.
2. In a remarkable effort, the staff of IZB (Mr. Greschek and Mrs. Kragl-Besse) managed to extract these books from their stock and organized a transport of them from St. Augustin to Aachen, just before Christmas 2011.
3. The 1200 boxes of books were stored in four rooms of the computer science library. Over Christmas, the librarian developed a strategy how to transport the content of these 1200 boxes to the magazine of the library in correct order.
4. After about two weeks, the books had been placed into the magazine in a roughly correct order (respecting the various signatures, but in each signature not yet in alphabetic order by author's name).
5. In a tedious operation lasting several months the "fine-sorting" was accomplished. Also the electronic data on the new books were sent from IZB and integrated into the library data base in Aachen.



As a result, the stock of the computer science library increased from about 37000 volumes by further 23000 volumes (to nearly 60000 altogether), including many precious items and several journals and conference proceedings series that were so far missing in Aachen.

2. A new kitchen unit (sponsored by ASCOM)

By a generous sponsoring of the IT company ASCOM (Aachen), our library was given a small beautiful kitchen unit, accompanied by a set of cups and plates. This opens many possibilities to serve our students better: For example, they will be offered (for a very moderate price covering the expenses) fresh coffee and tea during all times when the university cafeteria is closed.



3. An open-air umbrella for the “Lesegarten” (sponsored by GENERALI Deutschland Informatik Services)

By another generous sponsoring action, our open-air reading space (Lesegarten) was extended by a very attractive item: The company GENERALI Informatik Services paid a beautiful sun umbrella (of 3m diameter) to protect readers from the sun (or even rain) when working in the open air.



4. Waffelfest

In November 2011, our Waffelfest was held for the third time: Many students and staff turned up (altogether more than 400) for having chats, drinking “Glühwein” and enjoying waffles. A lottery gave additional excitement, and at the book fleemarket one could search for old but interesting literature.



5. The Colloquium Receptions

The receptions were adapted to the new schedule in which “premium talks” of the “Informatik-Kolloquium” take place on Wednesdays at 3 pm. After each such talk, a reception is held in the library, where discussions with the invited speaker can be continued in a relaxed atmosphere, with sherry, coffee, tea, mineral water, or juice, accompanied by cookies.

6. Lesegarten

After a long time of waiting, our Lesegarten could be re-opened: It had been closed due to a complete scaffolding of the building E2, which blocked the entrance to our open-air area for reading. Although most of the scaffolding is still present (which gives our visitors impressions that are far from charming), the area can now at least be reached again, giving our students the possibility to do their studies in the open air.

7. KiWi - Children's Room

The KiWi service of the library is an offer to student and staff member parents who can take their small children to a special KiWi room in the library (“KiWi” = “Kinder und Wissenschaft”) with lots of play material and a place for cleaning babies and breastfeeding. This offer was accepted by more and more student parents over the last year and helped many of them to combine their family duties with their study work in the library.



8. New Sponsors? New Sponsors!

Many journal volumes will be shifted to the library magazine over the coming year. This provides a lot of space that will be used to open more places for studying and reading in the library. A special reading room with comfortable seats (rather than desks) and whiteboard is part of this plan. We are looking for sponsors that help to equip this room with the appropriate furniture. Sponsors are welcome to contact the librarian for further details.



Fachschaft I/1

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.

In the last year we were forced to implement an access restriction (*numerus clausus*) to our Bachelor programme. We were very successful in making these restrictions as light as possible, thereby guaranteeing all interested students of this year's winter semester a place in the programme. This wouldn't have been possible without the extensive constructive collaboration with the rest of the computer science department, which we also practice in many other areas.

Aside from our committee participation, 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. Additionally 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, which is now finally happening after years of waiting.

All these activities are only made possible by the numerous students who work voluntarily and without pay for the Fachschaft. We want to thank all the active members of the past year, namely:

*Aleksandr Grinspun
André Goliath
Björn Guth
Christoph Rackwitz
Gereon Kremer
Gesche Gierse
Heiner Oßwald
Holger Weber
Inga Herber
Jakob Breier
Jan Bergner
Julian Meichsner
Marlin Frickenschmidt
Martin Bellgardt
Matthias Heinrichs
Mauricio Cattaneo
Nadine Friesen
Niklas Fischer
Patrick Hallen
Svenja Schalthöfer
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)

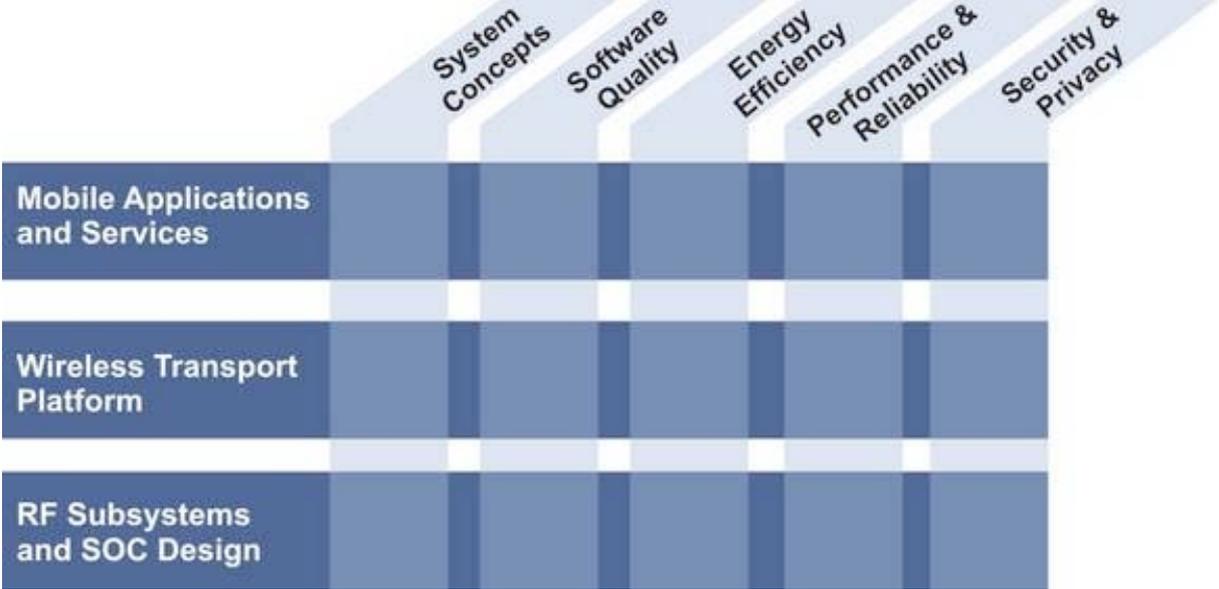
Overview

"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.

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

In addition, there are a number of cross-disciplinary projects:

- Routing over Dynamic Networks: A Game-Theoretic Approach
- Approaches, Decentralized Algorithms and Convergence Theory
- Energy Awareness of Applications
- The Impacts of Next Generation Wireless Networks on Transport Protocols
- Analysis of Dynamical Networks in the Framework of Model Checking
- Design and Analysis of Self-Regulating Protocols for Spectrum Assignment

- Adaptive Protocol Stacks and Model Checking
- Analyzing QoS Aspects in Ad-Hoc Network Protocols by Model Checking
- UMIC Simulation Framework
- UMIC Software Quality Initiative
- Ultra Fast Radio Wave Propagation Prediction by Cell Processor Architectures
- Applying Formal Methods for QoS Provisioning in Mobile Architectures

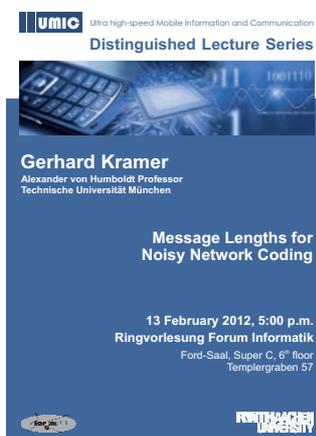
UMIC Day 2011

The fifth UMIC Day took place on 18 October 2011, at RWTH's SuperC building. This year the first keynote Speech was given by an old acquaintance, Prof. Dr.-Ing. Adam Wolisz from TU Berlin's Chair of Telecommunication Networks. It was entitled 'Do we have a Vision of the Future Wireless Networks?'. Subsequently, two members of the UMIC team talked about their respective lines of work: Prof. Dr.-Ing. Rudolf Mathar discussed 'Coding on a Façade'; Prof. Dr. rer.nat. Berthold Vöcking's talk was entitled 'Algorithmic Aspects of Spectrum Allocation in the Physical Model'. The formal presentations were concluded by a talk from industry held by Dr. Stephan ten Brink of Alcatel Lucent Deutschland AG: 'Trends in Wireless Communications'.

In parallel, a number of demos showcased recent work going on in the UMIC context and offered hands-on experiences

After the formal part of the programme the Whirling Wheels gave some samples of their art, and the Get-Together-cum-Bufferet concluded the event in a friendly and relaxed atmosphere.

UMIC Distinguished Lecture



Prof. Dr. Gerhard Kramer, who holds an Alexander von Humboldt Professorship at the Technical University of Munich (TUM), gave this year's Distinguished Lecture on 13 February 2012. It was entitled 'Message Lengths for Noisy Network Coding'. The talk was based on joint work with Jie Hou of TUM and looked at Quantize-map-forward (QF) or Noisy Network Coding (NNC) that is a compression-based relaying strategy that has several nice information-theoretic properties. For example, the method properly extends random network coding from classic networks without interference to wireless relay networks, and it achieves rates within a reasonable gap of a cut upper bound. This talk reviewed the historical development of the strategy and presents some recent results concerning random coding and decoding.

The Bad News

Sadly, based on the verdict of the evaluators, UMIC will be discontinued in

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.

On Friday, June 15, 2012, the German Research Foundation announced that AICES will be funded for the second time by the German Excellence Initiative; thus fostering AICES's innovative aims and scientific concepts for another five years (2012 - 2017). Involving three more faculties, the AICES Graduate School will now be able to realize its visions even more intensively. In order to cover further promising research fields, the number of junior research groups and doctoral candidates will be nearly doubled. This enables a more extensive and top-class promotion of young scientists on the basis of outstanding research in the field of computational engineering science - including undergraduates and doctoral candidates as well as junior professors and junior research group leaders.

From computer science, Prof. Bientinesi, Prof. Kobbelt, Prof. Naumann, and Prof. Wolf are involved, with Prof. Bientinesi leading one of the junior research groups. During the reporting period, both Prof. Bientinesi and Prof. Wolf served on the steering committee of AICES.

More information

www.aices.rwth-aachen.de

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Virtual Institute – High Productivity Supercomputing (VI-HPS)

The Virtual Institute - High Productivity Supercomputing is a joint initiative of Barcelona Supercomputing Center, Forschungszentrum Jülich, German Research School for Simulation Sciences, Lawrence Livermore National Laboratory, RWTH Aachen University (Center for Computing and Communication), Technical University of Dresden, Technical University of Munich, University of Oregon, University of Stuttgart, University of Tennessee, and Université de Versailles St-Quentin-en-Yvelines. 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/Q 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



IBM Blue Gene/Q Jugene in Jülich.

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 Versailles and Garching near Munich. In addition, tutorials with and without hands-on exercises were held at International Supercomputing Conference 2012 and EuroMPI 2012. Finally, the virtual institute organized the 5th Workshop on Productivity and Performance (PROPER) in conjunction with the Euro-Par Conference 2012 (Rhodes Island, Greece) and the Workshop on Extreme-Scale Performance Tools in conjunction with the Supercomputing Conference (SC) 2012 (Salt Lake City, USA).

More information

www.vi-hps.org

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German Research School for Simulation Sciences (GRS)

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.



GRS building in Aachen (Schinkelstr. 2a).

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 solutions that support simulation scientists in exploiting massive parallelism on modern architectures.

More information

www.parallel.grs-sim.de

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B-IT: Bonn-Aachen International Center for Information Technology

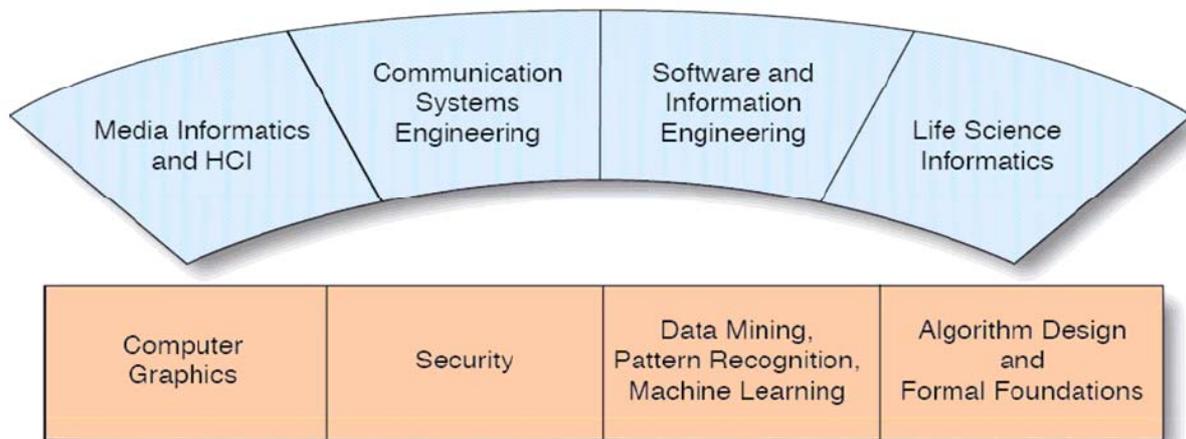


Since 2003, the B-IT has been pioneering the brain gain of much needed IT specialists from all over the world by offering top-level international master programs in applied informatics. In a unique cooperation between RWTH Aachen University, the University of Bonn, the Bonn-Rhein-Sieg University of Applied Sciences, and the Fraunhofer Center Birlinghoven Castle, these master programs address Media Informatics, Life Science Informatics, and Autonomous Systems, respectively. Currently, students from over 40 countries worldwide are studying in the beautiful B-IT Building on the Rhine River in Bonn-Bad Godesberg. The B-IT is directed by Professors Armin B. Cremers (Bonn), Matthias Jarke (RWTH Aachen and Fraunhofer FIT), and Kurt-Ullrich Witt. Eight endowed professorships are funded from proceeds of the B-IT Endowment, plus matching funds by NRW State.

In the academic year 2011-2012, a record number of 66 master degrees were awarded, thirty of them in the Media Informatics program which is under the responsibility of RWTH Aachen University. Since 2010, the program is coordinated by Prof. Jan Borchers, one of the endowed professorship holders, and supported by study advisor Dr. Jürgen Rapp. 42 new students were accepted into the program from almost 200 applicants, ten of them with prestigious scholarships e.g. by Erasmus-Mundus or DAAD. We were also happy to observe that many of our early B-IT graduates have by now already completed a doctorate in one of the participating universities or elsewhere. One example is Xiang Li who joined B-IT from Tsinghua University / China in late 2004, and recently completed his doctorate at RWTH Aachen University with a topic of constraint-based schema integration in databases with distinction.

Careful placement tracking of the B-IT graduates show that the dual goal of strengthening German business and science by young promising international graduates, and of improving further the linkages to their home countries by returning well-educated graduates for their local commercial and scientific job markets, has been impressively reached. The quality of the program was confirmed in 2011-2012 by re-accreditation of all B-IT Master programs until 2018, which covered not only the German ASIIN but also the new European accreditation label EurInf, which the B-IT programs were the first to achieve within all of Europe. Full details can be found in the B-IT Annual Report 2012 published in www.b-it-center.de.

The B-IT Research School aims to augment the B-IT by structured doctoral education in eight research fields of Computer Science where RWTH Aachen University, Bonn University, and the institutes FIT, IAIS, and SCAI at Fraunhofer Center Birlinghoven Castle have demonstrated critical mass in research excellence. The School is partially funded by the NRW State Research School Program for the period 2008-2013, with matching funds from the participating universities and third-party funding e.g. from industry. Professors Matthias Jarke (speaker, RWTH Aachen) and Armin B. Cremers (co-speaker, Uni Bonn) coordinate the B-IT Research School, supported by operational managers Getraud Peinel (Fraunhofer FIT) and Alexandra Reitelmann (B-IT Bonn).



In total, 32 scholarships have been awarded by the B-IT Research School, most in 2009 and 2010. About 56% come from 12 countries outside Germany, about one third are women. By now, eight scholarship holders have successfully defended their dissertations (three by women), several more theses have been already submitted.

The training program of the B-IT Research School consists of domain-specific as well as soft skill compact courses, individually tailored for doctoral candidates. Practice phases in the participating Fraunhofer institutes or in industry are also encouraged. The participants in the courses and seminars do not just include the scholarship holders but also other doctoral students within the eight mentioned areas.

Much of the training takes place in the B-IT Building in Bonn, but since early 2012, remodeling of former library space at RWTH Aachen's Informatikzentrum has also been completed, such that the B-IT Research School can now also offer courses in Aachen. The facilities were opened in spring 2012 with the General Assembly of the B-IT Research School.

Graduiertenkolleg (Research Training Group)

General Information

A Graduiertenkolleg (Research Training Group) is a university graduate training programme established at a centre of scientific excellence in a specific field. It is designed for up to 15 PhD students by several faculty members. The students work on their theses within the framework of a coherent and often interdisciplinary research programme; they participate in an accompanying study programme organised by the faculty members and to some extent by the students themselves.

The concept of “Graduiertenkolleg” (short: GK) was established in 1990 to improve the quality of doctoral training in Germany and to substantially reduce the average time necessary to complete a PhD thesis. This time is generally considered as overly high and should, ideally, be reduced to three years while keeping the scientific quality at the highest possible level.

Helen Bolke-Hermanns links the GK together: she is responsible for management and coordination.

AlgoSyn Graduiertenkolleg AlgoSyn

The Graduiertenkolleg “AlgoSyn” is a highly interdisciplinary research project led by a group of ten professors representing five different faculties in our university. The aim is to develop methods for the automated design of software and hardware, and its main challenge is to make progress in integrating quite diverse approaches from computer science and engineering disciplines.

While methods of software validation and verification are by now well established, based on adequate formal models and tested in practical applications, the approach of automatic synthesis of software (and hardware) is as yet only developed in quite rudimentary form. On the other hand, in theoretical computer science as well as in engineering disciplines a rapidly increasing stock of techniques for the development of algorithmic synthesis is emerging, triggered by the demand to decrease development costs by invoking algorithmic procedures based on adequate formal models. The approach of program synthesis is only applicable in restricted scenarios, in particular in control systems and in reactive (multi-agent-)systems with low data complexity. Central issues in the area are the establishment of system models which allow an algorithmic solution of the synthesis problem, the combination of discrete and continuous parameters in hybrid systems (as this is also familiar from verification), and the exploration of the potential of applications. The aim of the Research Training Group is to unify the expertise from computer science, mathematics, and four engineering disciplines and to push forward the desired integration of methods.

There is a unit working on foundations comprising two branches, a central unit supplying methodological interfaces for implementations, and a range of application areas from four engineering disciplines. In a little more detail, the areas are:

- Algorithmic for agent-based, probabilistic, and hybrid systems
- Formal methods of reactive systems and game-theoretic methods

- Software development and modeling languages and
- Applications and demonstrators, in the fields of processor architectures, automatic control, process control engineering and train traffic systems..

The actual research activities always touch more than one of these subject areas, and a central objective is to intensify the interaction, by tuning models towards applications, and by making practical case studies accessible to a treatment in the existing formal and algorithmic frameworks.

For a full version of the proposal (in German language) please see: <http://www.algosyn.rwth-aachen.de/>

AlgoSyn has 12 positions for PhD students position. There are also collegiates and research students who are attached to the Research Training Group. You can find the complete list of people involved on the website www.algosyn.rwth-aachen.de.

All positions have been taken by highly qualified students. The grant holders 2011/2012 are the following:

- Namit Chaturveri, M.Sc, Chair Informatik 7, Prof. Dr. Thomas
- Dipl.-Inform. Diana Fischer, Chair Informatik 7 Lab, Prof. Dr. Grädel
- Dipl.-Inform. Marcus Gelderie, Chair Informatik 7, Prof. Dr. Thomas
- Dipl.-Inform. Oliver Göbel, Chair of Computer Science 1, Prof. Dr. Vöcking
- Dipl.-Inform. Friedrich Gretz, Chair of Computer Science 2, Prof. Dr. Katoen
- Dipl.-Inform. Sten Grüner, Chair of Process Control Engineering, Prof. Dr. Epple
- Dipl.-Inform. Paul Hänsch, Chair of Computer Science 11, Prof. Dr. Kowalewski
- Dipl.-Inform. Simon Lessenich, Mathematical Foundations of Computer Science
- Dipl.-Inform. Ulrich Loup, Hybrid Systems Group, Prof. Dr. Abraham
- Alexandru Mereacre, M.Sc., Chair Computer Science 2, Prof. Dr. Katoen
- Dipl.-Inform. Johanna Nellen, Hybrid Systems, Prof. Dr. Abraham
- Dipl.-Inform. Stefan Repke, Chair Computer Science 7, Prof. Dr. Thomas
- Dipl.-Inform. Oliver Ringert, Chair Computer Science 3, Prof. Dr. Rumpe
- Dipl.-Inform. Thomas Ströder, Research Group Computer Science 2 , Prof. Dr. Giesl
- Dipl.-Inform. Sabrina von Styp-Rekowski, Chair Computer Science 2, Prof. Dr. Katoen
- Dipl.-Inform. Melanie Winkler, Chair Computer Science 1, Prof. Dr. Vöcking



*(Happy) Members of Gk AlgoSyn
after a successful Workshop in Rolduc
2011*

GUtech – German University of Technology in Oman



Since 2008, RWTH Aachen University helps setting up the first private technical university in the Arabic Gulf region, the German University of Technology (GUtech) in Muscat/Oman. Starting with four bachelor programs in fields of particular interest to the region (geosciences, sustainable tourism, architecture, and applied information technology), GUtech is now expanding by further programs in the engineering sector, including the important issues of water management and chemical process engineering. GUtech is led by former RWTH Aachen Rector Burkhard Rauhut.

For the period 2008-2012, Professor Matthias Jarke (Information Systems, RWTH Aachen) has been Inaugural Dean at GUtech, first for Applied IT, since 2010 for Engineering in general. The main role is quality control and hiring of new faculty using joint search committees between RWTH Aachen University and GUtech, initially also other tasks of a department chair until sufficiently experienced new faculty could be hired.

The academic years 2010-2012 were focused on the successful completion of the AQUIN accreditation of the Applied IT study program, and on the hiring of three additional faculty members, with strong academic and in part industrial background as well as international experience. Therefore, the department leadership was transferred in late 2011 from Prof. Jarke to a local colleague.

Due to rapid growth, GUtech had already moved to an intermediate building near Muscat Airport in 2010. In late 2012, the main building of the final GUtech building complex with facilities and housing for over 2000 planned students will be opened. On this occasion, the first batch of Bachelor students from all four early study programs will celebrate their graduation achieved in summer 2012. From the IT graduates, two will continue master studies abroad, one of them with RWTH Aachen University.

REGINA e.V. – Competence Network Information and Communication Technology Aachen



KARRIERE
per Klick

1 BEWERBUNG - 100 EMPFÄNGER

- 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)
- Dipl.-Ing. M. Bayer, Chamber of Industry and Commerce Aachen
- Dr.-Ing. J. Mansfeld, DSA GmbH (former chairman)
- Prof. Dr. St. Kowalewski, Chair of CS 11, Software for embedded systems, RWTH Aachen



Activities in 2011-2012

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 2011/2012:

- Management Get-togethers: Green(by) IT, , IT-project management, Augmented Reality, IT-project management, Kinect
- Round-table Discussion: Alternatives to the gross domestic product
- Coaching by experienced managers & scientists
- Recruiting Support
- Social Events

International Activities

The opportunity to exchange experience and to establish contacts offers many advantages to all concerned. The close cooperation with the regional group of GESELLSCHAFT FÜR INFORMATIK, the Dutch partner organization REGITEL, the Belgium partner organization Multi Valley Flandern and the FORUM INFORMATIK of Aachen University of Technology contributes to this process.

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.

- **Career Portal:** **karriere.ac**
Karriere.ac is an internet-based job placement exchange for high tech jobs in the Aachen region. REGINA member companies run a chance to offer their vacancies for free.
- **Career by Click!**
1 Application – 100 Recipients
Applicants send their applications to REGINA and we forward them to our member-companies. In this way applicants reach with only one application more than 100 recipients.
- **Night of the Companies**
If you have finished university and are looking for a new job then catch the bus and visit your prospect employers. Once a year, in November, we organize for students and graduates the so called Night of the Companies. There are 5 bus lines which carry the participants to companies in the region of Aachen and give them the opportunity to get to know interesting job offers. Further information:
www.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).

The **Cooperation Systems Department** (Prof. Wolfgang Prinz, PhD) builds on its long CSCW experience and social computing concepts the Cooperation Systems department to develop and evaluate novel groupware, community and knowledge management systems for distributed organizations and teams. We also provide personalized and collaborative learning environments and investigate methods to infer the goals, tasks and preferences of their users, based on precise observations of teachers and learners.

The department enriches work environments with novel forms of interaction that use mixed reality technology. Multi-touch panels, gesture control and Augmented Reality are among the technologies in our idea of the workplace of the future. We investigate pervasive games, exciting new computer-based games that use the players' real vicinity as their playing field. Our scientific and technological expertise in these fields enables us to build custom-tailored systems for the needs of real organizations.

The **Life Science Informatics Department** (Prof. Dr. Thomas Berlage) develops new approaches to produce highly specific information on diseases and individual patients.

After the sequencing of the human genome had been successfully completed, automatic instruments and computerized data analysis moved into the focus of biotechnology and medicine. On all levels, from molecular interaction to cellular function, tissue or organ structure, and the course of a disease in an individual patient, new instruments can produce information about the processes involved in a disease and can help to improve diagnosis and therapy.

This potential motivates our R&D in the field of information-intensive instruments using optical and electronic detection methods. We develop novel components, like fluidic microsystems to study cells and molecules, smart scanning microscopes and software for image analysis and object detection. We test and validate complete applications in cooperation with their users. We use our components to build application-specific systems that provide seamless integration in state-of-the-art network infrastructures and mobile access.

The Risk Management And Decision Support Department (Prof. Dr. Thomas Rose) addresses methods and measures for risk preparation and mitigation, response in crisis situations, and recovery from emergencies. Our prime focus is the development of integrated risk management systems, specifically the support of decision-making by different tools and formal methods. The scope of decisions includes the planning and coordination of resources for fire brigades, the design of novel pieces of equipment for relief services, or the assessment of alternatives in drafting financial legislation.

In October 2011, FIT opened a new project group on Finance informatics at the University of Augsburg, supported by a EUR 5 Mio starting grant from the State of Bavaria. The group is led by Prof. Dr. Hans Ulrich Buhl and particularly concentrates on the integration of the two research areas Finance & Information Management (FIM) and Operations & Information Management (OIM).

The User-Centered Computing Department (Dr. Markus Eisenhauer) develops IT systems and technologies that focus on their users throughout their complete life cycle. We aim for systems that provide effective personalized support for the task at hand and fit perfectly into the work environment. Our expertise from more than 20 years of R&D on Human-Computer-Interaction and adaptation to context enables us to build intelligent environments and IT systems that satisfy the requirements of usability, Web compliance and accessibility in their individual context.

Our wide repertoire of design methods lets us combine appropriate test-oriented methods from User-Centered Engineering with ethnographic and participatory approaches, so we can involve the users from the start in the planning, design and evolution of their systems. The range of our activities includes usability engineering of products and systems, support for the design of standard-compliant Web and desktop applications as well as the use of sensor technologies and embedded systems in industrial environments.

List of Technical Reports

- 2012-01 Annual Report
- 2012-02 Thomas Heer
Controlling Development Processes
- 2012-03 Arne Haber, Jan Oliver Ringert, Bernhard Rumpe
MontiArc - Architectural Modeling of Interactive Distributed and Cyber-Physical Systems
- 2012-04 Marcus Gelderie
Strategy Machines and their Complexity
- 2012-05 Thomas Ströder, Fabian Emmes, Jürgen Giesl, Peter Schneider-Kamp, and Carsten Fuhs
Automated Complexity Analysis for Prolog by Term Rewriting
- 2012-06 Marc Brockschmidt, Richard Musiol, Carsten Otto, Jürgen Giesl
Automated Termination Proofs for Java Programs with Cyclic Data
- 2012-07 André Egners, Björn Marschollek, and Ulrike Meyer
Hackers in Your Pocket: A Survey of Smartphone Security Across Platforms
- 2012-08 Hongfei Fu
Computing Game Metrics on Markov Decision Processes
- 2012-09 Dennis Guck, Tingting Han, Joost-Pieter Katoen, and Martin R. Neuhäuser
Quantitative Timed Analysis of Interactive Markov Chains
- 2012-10 Uwe Naumann and Johannes Lotz
Algorithmic Differentiation of Numerical Methods: Tangent-Linear and Adjoint Direct Solvers for Systems of Linear Equations
- 2012-12 Jürgen Giesl, Thomas Ströder, Peter Schneider-Kamp, Fabian Emmes, and Carsten Fuhs
Symbolic Evaluation Graphs and Term Rewriting --- A General Methodology for Analyzing Logic Programs
- 2012-15 Uwe Naumann, Johannes Lotz, Klaus Leppkes, and Markus Towara
Algorithmic Differentiation of Numerical Methods: Tangent-Linear and