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**UNIVERSITÄT
BERN**

Institut für Informatik und
angewandte Mathematik
Universität Bern

www.iam.unibe.ch

IAM Annual Report 11/12



IAM Annual Report
Academic Year 2011/2012

August, 2012

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1 Institute of Computer Science and Applied Mathematics (IAM)

1.1 Address

Neubrückestrasse 10, CH-3012 Bern, Switzerland
Telephone: +41 31 631 86 81, Telefax: +41 31 631 32 62
www: <http://www.iam.unibe.ch>

1.2 Personnel

Members

I. Alyafawi; C. Anastasiades; M. Anwander; S. Beffa; P. Brambilla; Prof. Dr. T. Braun; G. Budweiser; S. Bucheli; B. Choffat; A. Caracciolo; D. Dhillon; Dr. D. Dimitrova; D. Donatsch; S. Eberhard; D. Esser; Prof. Dr. P. Favaro; D. Flumini; R. Goetschi; P. Hurni; Prof. Dr. G. Jager; Dr. A. Jamakovic; A. Kashev; I. Keller; C. Knaus; J. Kurš; Dr. R. Kuznets; P. Leimer; Z. Li; D. Lima do Rosario; W. Lo; Dr. M. Lungu; T. Macicas; M. Manzi; Dr. R. McKinley; B. Mosler; Dr. T. Nemoto; Prof. Dr. O. Nierstrasz; I. Noppen; B. Nyffenegger; S. Ott; T. Papadimitri; F. Perin; D. Perrone; Dr. D. Probst; F. Ranzi; J. Ressia; F. Rousselle; Dr. K. Sato; Dr. Y. Savateev; D. Schroth; N. Schwarz; Dr. A. Sellent; Dr. T. Staub; Dr. M. Sorel; Prof. Dr. Th. Strahm; PD Dr. Th. Studer; Dr. N. Thomos; T. Verwaest; G. Wagenknecht; J. Werner; E. Wernli; Z. Zhao; R. Zumbrennen; Prof. Dr. M. Zwicker

Board of directors

Prof. Dr. Torsten Braun; Prof. Dr. Paolo Favaro; Prof. Dr. Gerhard Jäger;
Prof. Dr. Oscar Nierstrasz; Prof. Dr. Matthias Zwicker

Managing director

Prof. Dr. Gerhard Jäger

Director of studies

Prof. Dr. Matthias Zwicker (August 2011 - January 2012)

PD. Dr. Thomas Studer (February 2012 - July 2012)

Administration

Bettina Choffat; Dragana Esser; Iris Keller; Daniela Schroth.

Technical staff

Peppo Brambilla; Markus Anwander.

2 Teaching Activities

2.1 Courses for Major and Minor in Computer Science

Autumn Semester 2011

- Bachelor 1st Semester

Einführung in die Informatik (Die Dozenten der Informatik, 5 ECTS)

Grundlagen der technischen Informatik (Th. Studer, 5 ECTS)

Programmierung 1 (Th. Strahm, 5 ECTS)

- Bachelor 3rd Semester

Diskrete Mathematik und Logik (G. Jäger, 5 ECTS)

Computernetze (T. Braun, 5 ECTS)

Einführung in Software Engineering (O. Nierstrasz, 5 ECTS)

- Bachelor 5th Semester

Mensch-Maschine-Schnittstelle (Th. Strahm, 5 ECTS)

Künstliche Intelligenz (K. Riesen, 5 ECTS)

Computergrafik (M. Zwicker, 5 ECTS)

Anleitung zu wissenschaftlichen Arbeiten (5 ECTS)

Proseminare (5 ECTS)

- Master Courses

Software Design and Evolution (M. Lungu, Prof. O. Nierstrasz, 5 ECTS)

Software Composition (O. Nierstrasz, 5 ECTS)

Sensor Networks (T. Braun, 5 ECTS)

Computer Networks and Distributed Systems (T. Braun, 5 ECTS)

Computational Photography (M. Zwicker, 5 ECTS)

Epistemic Logics (G. Jäger, R. Kuznets, 5 ECTS)

Graduate Seminar Logic and Information (G. Jäger, G. Metcalfe, K. Stoffel, U. Ultes-Nitsche, 5 ECTS)

Seminar: Computer Graphics (M. Zwicker, 5 ECTS)

Seminar: Logic and Algebra (G. Jäger, G. Metcalfe, 5 ECTS)

Seminar: Logic and Computer Science (G. Jäger, 5 ECTS)

- Service Course

Anwendungssoftware (P. Brambilla, 3 ECTS)

Spring Semester 2012

- Bachelor 2nd Semester

Datenbanken (K. Stoffel, 5 ECTS)

Datenstrukturen und Algorithmen (P. Brambilla, 5 ECTS)

Rechnerarchitektur (Th. Studer, 5 ECTS)

Programmierung 2 (O. Nierstrasz, 5 ECTS)

- Bachelor 4th Semester

Betriebssysteme (T. Braun, 5 ECTS)

Berechenbarkeit und Komplexität (Th. Strahm, 5 ECTS)

Automaten und formale Sprachen (K. Riesen, 5 ECTS)

Praktikum Software Engineering (Th. Studer, 5 ECTS)

- Bachelor 6th Semester

Anleitung zu wissenschaftlichen Arbeiten (5 ECTS)

Proseminare (5 ECTS)

- Master Courses

Programming Languages (O. Nierstrasz, 5 ECTS)

Multimedia Communications (T. Braun, 5 ECTS)

Computability Theory (T. Strahm, 5 ECTS)

Lambda-Calculus and Applicative Theories (G. Jäger, 5 ECTS)

Graduate Seminar Logic and Information (G. Jäger, G. Metcalfe, K. Stoffel, U. Ultes-Nitsche, 5 ECTS)

Seminar: Computer Graphics (5 ECTS)

Seminar: Software Composition (O. Nierstrasz, 5 ECTS)

Seminar: Computer Networks and Distributed Systems (T. Braun, 5 ECTS)

Seminar: Logic and Algebra (G. Jäger, G. Metcalfe, 5 ECTS)

Seminar: Logic and Computer Science (G. Jäger, 5 ECTS)

- Service Course

Anwendungssoftware (Th. Strahm, 3 ECTS)

2.2 Colloquium in Computer Science

- 02/08/2011 Prof. Dr. Karl Lieberherr
College of Computer and Information Science Northeastern
University Boston
A Crowdsourcing Platform for Driving Innovation
- 21/09/2011 Prof. M. Milinkovitch
University of Geneva
United living colours
- 22/12/2011 Dr. Thiemo Voigt
Swedish Institute of Computer Science (SICS)
Multi-Channel Two-way time of Flight Sensor Network Ranging

2.3 Students

- Major Subject Students: AS 2011: 249, SS 2012: 231
- Minor Subject Students: AS 2011: 130, SS 2012: 110
- Ph.D. Candidates: AS 2011: 30, SS 2012: 31

2.4 Degrees and Examinations

- Ph.D.: 8
- Master: 16
- Bachelor: 9
- Completion of Minor Studies: 22 (90 E: 1, 60E: 6, 30E: 9, 25E: 0, 15E: 6 (810 ECTS))
- Semester Examinations AS 2011: 528 (1984 ECTS)
- Bachelor/Master Theses AS 2011: 4 (75 ECTS)
- Semester Examinations SS 2012: 420 (1572 ECTS)
- Bachelor/Master Theses SS 2012: 12 (400 ECTS)

2.5 Activities

- Contributing to the "Fit in IT - Roadshow", Alte Kantonsschule Aarau, September 14, 2011
- Contributing to the "Fit in IT - Roadshow", Kantonsschule Olten, November 8, 2011
- Contributing to the Nationaler Zukunftstag, Bern, November 10, 2011
- Contributing to the "Fit in IT - Roadshow", Kanti Rychenberg Winterthur, November 22, 2011
- Contributing to the "Fit in IT - Roadshow", Kantonsschule Zug, December 1, 2011
- Visitor program, Gymnasium Bern Kirchenfeld, Bern, May 30, 2012
- Visitor program, Gymnasium Thun-Schadau, Bern, July 2, 2012

2.6 Awards

- IAM Alumni Prize 2011 for Philipp Hurni's Ph.D. thesis "Traffic-Adaptive and Link-Quality-Aware Communication in Wireless Sensor Networks"
- IAM Alumni Prize 2011 for Ulrich Bürgi's Master's thesis "Performance Optimization for TCP-based Wireless Sensor Networks"
- IAM Alumni Prize 2011 for Max Leske's Bachelor's thesis "The Genesis of Pharo: The Complete History of Pharo with Git"

3 Research Group on Communication and Distributed Systems

3.1 Personnel

Head:	Prof. Dr. T. Braun	Tel.: +41 31 511 2631 email: braun@iam.unibe.ch
Office Manager:	R. Bestgen	Tel.: +41 31 511 2630 email: bestgen@iam.unibe.ch (until 31.12.2011)
	D. Schroth	Tel.: +41 31 511 2630 email: schroth@iam.unibe.ch (since 01.08.2011)
Scientific Staff:	I. Alyafawi*	Tel.: +41 31 511 7631 email: alyafawi@iam.unibe.ch (since 01.09.2011)
	C. Anastasiades*	Tel.: +41 31 511 2635 email: anastasi@iam.unibe.ch
	M. Anwander*	Tel.: +41 31 511 2634 email: anwander@iam.unibe.ch
	S. Beffa*	email: beffa@iam.unibe.ch (01.02.2012 - 31.05.2012)
	Dr. D. Dimitrova*	Tel.: +41 31 511 2633 email: dimitrova@iam.unibe.ch
	P. Hurni*	email: hurni@iam.unibe.ch (until 31.01.2012)
	Dr. A. Jamakovic*	Tel.: +41 31 511 2637 email: jamakovic@iam.unibe.ch (since 01.01.2012)
	P. Leimer	email: leimer@iam.unibe.ch (01.04.2012 - 31.07.2012)
	Z. Li*	Tel.: +41 31 511 2638 email: li@iam.unibe.ch (since 16.04.2012)
	D. Lima do Rosario*	Tel.: +41 31 511 2632 email: rosario@iam.unibe.ch (since 01.04.2012)
	T. Macicas*	Tel.: +41 31 631 8681 email: macicas@iam.unibe.ch (since 01.07.2012)

B. Mosler*	email: mosler@iam.unibe.ch (01.01.2012 - 31.03.2012)
I. Noppen	email: mail@ivonoppen.nl (15.09.2012 - 31.12.2011)
B. Nyffenegger*	email: nyffeneg@iam.unibe.ch (until 31.01.2011)
S. Ott*	Tel.: +41 31 631 8681 email: ott@iam.unibe.ch (since 01.10.2011)
Dr. T. Staub*	email: staub@iam.unibe.ch (until 31.01.2011)
Dr. N. Thomos*	Tel.: +41 31 511 76 45 email: thomos@iam.unibe.ch (since 01.10.2011)
G. Wagenknecht*	email: wagen@iam.unibe.ch (until 30.06.2012)
Z. Zhao*	Tel.: +41 31 511 2639 email: zhao@iam.unibe.ch

External**Ph.D. Students:**

A. Antonescu	email: antonescu@iam.unibe.ch
M. Thoma	email: thoma@iam.unibe.ch

**Guests BNF -
Swiss qualification
program:**

A. Vedat*	email: vedat@iam.unibe.ch (01.09.2011 - 30.06.2012)
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Guests:

V. Bernardo	University of Coimbra, Faculty of Science and Technology, Portugal February 2012
Prof. Dr. V. Siris	Athens University of Economics and Business, Grece June 2012

* with financial support from a third party

3.2 Overview

The research group for Communication and Distributed Systems (formerly: Rechnernetze und Verteilte Systeme, RVS) has been active since 1998 in several areas of computer communications and distributed systems. We are investigating how multimedia applications and services with high demands on the quality, reliability, and energy efficiency of communication systems and networks can be supported. The current focus of the research group are wireless networks with special emphasis on wireless mesh and sensor networks. Management architectures as well as protocols on link, routing, and transport layer are being investigated.

3.3 Research Projects

Traffic Adaptivity in Wireless Sensor Networks

Energy efficiency is a major concern in the design of Wireless Sensor Networks (WSNs) and their communication protocols. Today's energy-efficient (E^2) MAC protocols are able to deliver little amounts of data with a low energy footprint, but introduce severe restrictions with respect to throughput and latency. Regrettably, they yet fail to adapt to varying traffic loads and changing requirements of the imposed traffic load.

We intend to bridge this gap with the Traffic Adaptivity in Wireless Sensor Networks (TRAWSN) project, which started in October 2009 and successfully ended in January 2012. Within TRAWSN, we have developed MaxMAC, an energy-efficient MAC protocol for WSN scenarios with varying traffic conditions. While MaxMAC operates similarly as existing E^2 -MAC protocols in low traffic situations, it is able to maximally adapt to changes in the network traffic load at run-time. We have published simulation-based results of the MaxMAC protocol and have since then been working on a) software-based energy estimation mechanisms as well as b) the real-world prototype implementation of MaxMAC and its evaluation on our indoor WSN testbed. This evaluation was again conducted on the distributed testbed facilities set up within two buildings on the Engehalde Campus, which are operated by our management infrastructure TARWIS.

Another activity pursued within TRAWSN is our study on the potential of Forward Error Correction (FEC) mechanisms and dynamic/run-time adaptive FEC variants in WSNs. We implemented eight different Error Correction Codes (ECCs) and have made them available in a publicly available ECC library. The implemented codes range across four different classes,

from simple bit-repetition schemes via Hamming codes to complex and powerful Bose-Chaudhuri-Hocquenghem codes. They further contain our three proposed run-time adaptive FEC schemes, which adapt the correctional power of ECCs to the current link quality. We have thoroughly evaluated the computational costs and the resulting benefits with respect to packet delivery rate (PDR) of the static and adaptive FEC schemes under real-world conditions in a wide range of experiments on our distributed WSN testbed laboratory which is operated by our management infrastructure TARWIS.

Moreover, we implemented and evaluated a WSN network stack supporting energy efficient and robust packet-oriented radio modules. We performed simulations and conducted experiments in real world testbeds. Packet-oriented radio modules require several times less energy and time to forward data than bit/byte-oriented radio modules that are used by common energy efficient MAC protocols. Our new WSN network stack implements a novel traffic load measuring technique, called traffic prediction, to enhance the adaptivity of the radio sleep cycles to the current traffic load. We developed a congestion detection mechanism, which is able to identify and correctly handle intra-flow and inter-flow interferences as well as congestion. To enhance network connectivity and reusability of our protocols, the WSN network stack supports IEEE 802.15.4, IP, UDP and TCP.

FEC codes that showed promising results on bit/byte-oriented radio modules deliver only low reliability performance and low energy efficiency on packet-oriented radio modules. Therefore, we additionally evaluated the impact of the Hamming (12,8) FEC code and the Reed-Solomon (255,225) FEC code to packet-oriented radio modules. We compared the performance of both FEC codes on a bit/byte bit/byte-oriented radio module and on a packet-oriented radio module. We added the FEC codes to our energy efficient and reliable WSN network stack based on a packet-oriented radio module. Although both FEC codes are able to reduce the required transmission attempts, they can neither reduce the energy usage nor enhance the reliability of our real world WSN network stack supporting energy-aware reliability mechanisms on a packet-oriented radio module.

Finally, we have worked on optimizing TCP performance in WSNs on top of several MAC protocols such as X-MAC, LPP, and ContikiMAC. Since the appearance of downsized and simplified TCP/IP stacks, single nodes in Wireless Sensor Networks (WSNs) have become directly accessible from the Internet with commonly used networking tools and applications (e.g., Telnet or SMTP). However, TCP has been shown to perform poorly in wireless networks, especially across multiple wireless hops. Our TCP performance optimizations are based on distributed caching and local retrans-

mission strategies of intermediate nodes in a TCP connection. We also developed extended techniques to these strategies. We studied the impact of different radio duty-cycling MAC protocols on the end-to-end TCP performance when using the proposed TCP optimization strategies in an extensive experimental evaluation on a real-world sensor network testbed.

Research staff: Philipp Hurni, Markus Anwander, Sebastian Barthlomé, Torsten Braun, Ulrich Bürgi

Financial support: Swiss National Foundation Project No. 200021-126718/1

Energy-efficient Management of Heterogeneous Wireless Sensor Networks

Wireless sensor networks consist of wireless sensor nodes, which host different applications for the purposes of event detection, localization, tracking, monitoring. These applications run on different types of sensor nodes. This results in a heterogeneous WSN. Furthermore, an application needs to be configured and continuously updated throughout the lifetime of the network. Such tasks can occur rather frequently, especially during the deployment phase. There are several challenges to the configuration and update process. Configuration and updating should be done over the air. We developed a novel management architecture for heterogeneous wireless sensor networks (WSNs) called MARWIS. It supports common management tasks such as monitoring, (re)configuration, and updating program code in a WSN. MARWIS considers specific characteristics of WSNs and restricted physical resources of the nodes such as battery, computing power, memory or network bandwidth as well as link quality. To handle large heterogeneous WSNs we propose to subdivide the sensor network into smaller sensor subnetworks. Each subnetwork contains sensor nodes of one type. A wireless mesh network (WMN) operates as backbone and builds the communication gateway between the different sensor subnetworks. The mesh nodes operate also as a communication gateway between the different sensor subnetworks and perform management tasks. All management tasks are controlled by a management station located in the Internet.

In contrast to the predominant multipoint-to-point communication in WSNs for data retrieval, management traffic, especially for code updates, follow a point-to-multipoint pattern. Using multicast communication in WSNs is

an efficient way to disseminate code updates to multiple sensor nodes. For this purpose a multicast protocol has to support bulky traffic (typical traffic pattern for code updates) and end-to-end reliability. In addition, we are interested in energy-efficient operations due to the limited resources of sensor nodes. We proposed the SNOMC (Sensor Node Overlay Multicast) protocol, an overlay multicast protocol, which supports reliable, time-efficient, and energy-efficient data dissemination of bulky data from one sender to many receivers. The protocol performance in terms of transmission time, number of totally transmitted packets and energy consumption is compared to other data dissemination protocols. Our results show superior performance of SNOMC independent of the underlying MAC protocol.

Research staff: Gerald Wagenknecht, Torsten Braun

Authentication, Authorization, Accounting and Auditing in Wireless Mesh Networks

The Authentication, Authorization, Accounting and Auditing in Wireless Mesh Networks (A⁴-Mesh) project has been carried out as part of the AAA/SWITCH-e-Infrastructure for e-Science programme. It is an interdisciplinary collaboration between SWITCH and two networking research groups, UniBE IAM and UniNe IIUN, plus several potential WMN users, namely the environmental researchers from UniBE GIUB and the IT services from UniBE IT and UniNe SITEL. The goal of the project is to develop a fully functional wireless mesh network supporting the authentication, authorization, accounting and auditing (A⁴) functionalities.

To successfully use Wireless Mesh Networks (WMNs) in the area of Swiss higher education, WMNs have to support authentication, authorization, accounting, and auditing functionalities. To be able to do that, a WMN must be seamlessly integrated into the organizations' authentication and authorization infrastructure (AAI), like SWITCHaai. Furthermore, as there are usually multiple concurrent users of the network, a WMN has to support accounting to enable charging and network management. Finally, for a successful operation of a wireless mesh network, inconsistent and erroneous states in the network have to be detected and resolved. This requires constant auditing of network state and configuration. The auditing function may then trigger alarms or even perform self-healing of the network.

In the course of the first year of the project together with UniNe, we have designed and implemented a) a fully functional innovative machine au-

thentication and authorization mechanisms based on SWITCHaai, and b) a short-term accounting and monitoring mechanism based on Net-flow. Moreover, we have set up a wireless mesh network in the area of Crans-Montana in the Swiss Alps where the project has demonstrated the great potential of wireless mesh networking for environmental research. Our application scenario in the Swiss Alps considers an extensive hydro-meteorological monitoring network that has been set up for estimating and modeling water availability under present and future conditions. This hydro-meteorological monitoring network consists of different measurement devices and these all produce a large amount of data, which needs to be transferred from the different remote sites to the university campus, preferably in near real-time. A wireless communication mesh network serves accordingly the purpose of a (temporary) measurement infrastructure, giving researchers low-cost broadband network access in virtually any remote area.

The current setup of the wireless mesh network in the Swiss Alps consists of seven wireless mesh nodes interconnecting the hydrological sensors to the university campus network. For the future we plan to work on the integration of the authentication, authorization, accounting and auditing (A⁴) mechanisms into this hydro-meteorological monitoring wireless mesh network, and to use the gained experience to deploy another outdoor test beds at the University of Bern. This outdoor testbed aims use wireless mesh networking to easily extend the campus WLAN network coverage.

Research staff: Markus Anwander, Torsten Braun, Almerima Jakmakovic, Sandro Beffa, Teodor Macicas, Benjamin Nyffenegger, Thomas Staub

Financial support: AAA/SWITCH Project UNIBE.6

Integral Indoor 3D Guidance and Access-Control System

The key innovation of the project is a method for uniquely identifying mobile phones without actually decrypting their transmissions and using this information for enabling location-based and access control services.

The central idea of the project in technical terms is to develop a system running on a software defined radio (SDR) system that is able to intercept traffic from both base stations and mobile devices, independently of a subscriber, in order to enable localisation algorithms based on the time difference of arrival (TDOA). The main challenge in this aspect is to capture

transmissions on the uplink (from mobile devices) and to be able to identify the devices. Concerning the former most if not all available software only deals with the downlink; concerning the latter network operators take special measures to protect the identity of their users, which aggravates the problem.

In the first months of the project we have focussed on two tasks, namely, the development of the GSM sensor that is able to intercept GSM signals and testing the hardware ability to support TDOA approach. For the preparation of the GSM sensor we have performed detailed analysis of the GSM specification to gain insights about signal processing during system design. In parallel we investigated several available solutions towards GSM sniffing such as GNU Radio plus Airprobe or OpenBTS. It was decided to reuse as many available elements as possible but develop additional functionality that we may need. For the preparation of the TDOA approach we performed tests to establish the time synchronisation discrepancies among the sensors that may affect the approach.

We are using the USRP N110 and E110 equipment from Ettus Research. An embedded Linux system built with the Administration and Deployment Adhoc Mesh (ADAM) framework, developed at the University of Bern, has been ported to the devices. On top of that the GNUradio software package was integrated and several other modules, borrowed from the Airprobe project, were incorporated into it for processing and interpretation of the GSM signals. The current version of the system is able to capture signals on the downlink and interpret the messages allowing us to derive valuable information for the processing of the uplink. The system was extended to allow multiple-channel reception.

Research staff: Desislava Dimitrova, Islam Alyafawi, Zan Li, Stefan Ott, Torsten Braun

Financial support: Eurostars E!6429, BBT Vertragsnummer INT.2011.0035

Location Based Analyser

The main goal of the Location Based Analyser (LBA) project was to develop a practical solution - from the design to deployment phase - which is able to locate and track Bluetooth and WiFi modules, embedded in personal devices, e.g., mobile phones. The solution is based on low cost wireless sensor networks (WSNs) and collects statistical information for

personal devices on the (indoor) premises. These statistics can be used, for example, by network operators to adapt capacity provisioning or by businesses to improve their services. Privacy is protected since the system is passive and does not retrieve any data with which the phone owner may be identified.

LBA is a technology transfer project in cooperation with DFRC AG and Wellness Telecom as industry partners. DFRC provides feedback on implementation and deployment issues and tries to bring the product to the market. In order to ensure the product quality and improve the development, DFRC provided us realistic measurements from already deployed networks in Singapore, Sevilla (Spain), Tel Aviv (Israel) and Zug (Switzerland).

The project targets the evolving market of business intelligence based on location data and statistics on customers behaviour (in time and space).

The technological problem that LBA is trying to solve is a designing a scalable, low-cost system that is at the same time able to locate subjects with sufficient accuracy. Moreover, the system should not interfere with the customers privacy.

In the scope of the project a test-bed based on Gumstix Overo sensors was deployed first in a single space and later over several rooms on a single or multiple floors of the IAM building. The sensor nodes were running an in-house developed embedded Linux distribution (ADAM), which accommodates all functionality necessary to enable signal capturing. The system was also successfully tested on other sensor platforms such as Panda and Beagle boards.

Series of measurements were performed to gain insights on the environment, in which the system should operate and on the system performance. In the first group of measurements the impact of various factors such as manufacturer, device orientation and obstacles was investigated. In the second group several approaches towards the localisation algorithm were considered, e.g., fingerprinting, propagation model-based, etc. It was decided to focus on two directions, namely, adaptive propagation models and advanced proximity algorithms. An adaptive propagation model makes use of regular readings on channel propagation (between two sensor nodes) to derive more accurate information of the path loss. An enhanced proximity algorithm does not only consider the node closest to the target sensor node but combines feedback from several sensor nodes to improve the precision of the system. For both directions measurements were collected to evaluate the feasibility of the proposal and to test the system performance.

In addition, we also addressed several practical issues in the deployment

of an indoor localisation system such as accessibility, visualisation (done by DFRC) and scalability. For the latter we developed intelligent filtering and aggregation approaches.

Research staff: Desislava Dimitrova, Islam Alyafawi, Thomas Staub, Torsten Braun, Ivo Noppen

Financial support: Eurostars E!5533, BBT Vertragsnummer INT.2010.0027

Enhanced Mobile Communication with Content-Centric Networks

Content-Centric Networking (CCN) as a new paradigm for the Future Internet is a promising approach for mobile communication, because routing is not based on specific forwarding nodes but content names. If an individual forwarder becomes unavailable, any node in the vicinity that has overheard the content transmission or holds the corresponding content may replace the former forwarder's functionality.

In this project, we focus our research on resource constrained wireless mesh nodes that transmit content over IEEE 802.11 WLANs. The research work is divided into three areas: memory management, energy efficient operation and content discovery/delivery. Memory management is required since wireless mesh nodes have only a limited amount of RAM. Caching mechanisms need therefore to be extended to secondary storage on flash memory. Efficient caching strategies and tradeoffs, e.g., availability vs. reliability, are required. Energy-efficient operation is important for resource constrained devices to extend the battery lifetime. We aim to improve the communication efficiency by adaptively address messages via unicast or multicast communication. If only one node is interested in a content object, it is not required to broadcast and process it all nodes. Additionally, we plan to exploit the inherent bidirectional Interest-Data message exchange to employ duty cycles and synchronize activity periods. Finally, efficient content discovery and delivery mechanisms are required to enable mobile (multi-hop) communication. We aim to develop suppression mechanisms that reduce the number of unnecessarily transmitted duplicates without significantly decreasing connectivity. Additionally, dynamic routing mechanisms are required that quickly adapt to changing node connectivity due to mobility.

Since Content-Centric Networking is a new communication paradigm, no standard evaluation tools exist. In the past year, we developed and refined a CCN framework for the OMNeT++ network simulator, which is based on an accurate implementation of the CCN daemon in CCNx, the open source implementation of CCN. In the future, the simulator will allow us to quickly evaluate new processing and routing algorithms in arbitrary environments. We are currently implementing an extension applying network coding. One crucial aspect of CCN is naming. Knowledge of available content names is required to express Interests in these. We therefore developed two opportunistic discovery algorithms and implemented it using the original CCNx open source implementation. The evaluation was performed with VirtualMesh, a hybrid emulation tool for wireless ad hoc networks that is based on the emulation of CCNx and the simulation of the wireless communication. A project goal is also the deployment of our mechanisms on wireless mesh nodes. We therefore extended our embedded operating system by CCNx and performed first communication tests. Since mesh nodes have limited RAM, we implemented a resume capability, which transfers data in case of disruptions from volatile cache to persistent storage and resumes the communication at the next opportunity.

Research staff: Carlos Anastasiades, Arian Uruqi, Tobias Schmid, Jürg Weber, Alexander Striffeler, Torsten Braun

Financial support: Swiss State Secretariat for Education and Research (SER), SER No. C10.0139

Wireless Networking for Moving Objects

The Future Internet will incorporate a large number of autonomous wireless objects moving with diverse patterns and speeds while communicating via several radio interfaces. Examples of such objects may include humans, cars or unmanned aerial vehicles, with every object acting as a networking device generating, relaying and/or absorbing data. The Future Internet will require global interoperability among objects/devices. To overcome current shortcomings, a number of research challenges have to be addressed in the area of networking, including protocol engineering, development of applications and services, as well as realistic use-cases. The COST Action IC0906 coordinates research efforts of national and international projects in the area of Wireless Networking for Moving Objects

(WiNeMO). For this purpose, we have contributed to two white papers on Content-Centric Architectures for Moving Objects and on Joint Modeling for Networks of Moving Objects. In the context of the former white paper, two Short Term Scientific Missions (STSMs), one at Xanthi and one at Bern, have been funded by the COST Action. Another STSM at Barcelona was performed to investigate Localization strategies for moving objects. Other related activities include our ongoing work on Enhanced Mobile Ad-hoc Communication with Content-Centric Networks and Routing for highly Mobile Ad-hoc Networks.

In the Delay Tolerant Communication with Content-Centric Networks (CCN) STSM (Carlos Anastasiades at Demokritus University of Thrace, Greece), the application of CCN in intermittently connected terrestrial mobile ad-hoc networks was investigated. In distributed environments, CCN communication may improve scalability of mobile ad-hoc communication and the relevance of requested information. Three reference scenarios were identified based on which the investigation was performed. The scenarios included location-based information collection, message ferrying and alarming. Since naming is essential in all three scenarios, a naming scheme was defined to support efficient location-based communication. Another central requirement for location-based communication is adaptivity. Various existing adaptive mechanisms and their potential for CCN communication were identified. These build a basis for further investigations. To support intermittent communication in environments, where no end-to-end connectivity can be achieved, agent-based collection protocols and notification mechanisms have been defined. These protocols help collecting information by delegating tasks to other nodes and obtaining user-awareness immediately when new content becomes available.

Prof. Dr. Vasilis Siris visited the CDS group for an STSM on Content-Centric Networking Architectures for Moving Objects. The visit focused on two main topics: source mobility and service support in information-centric networks (ICN). In source mobility, two issues were identified: finding a mobile source's location and supporting session continuity to avoid data loss and to enable seamless mobility. During the STSM several source mobility approaches and scenarios were investigated and characterized. Source mobility solutions depend on multiple aspects including duration and types of mobility, scenarios and ICN architectures. Location independent naming facilitates caching while identity-locator splits support flexible mobility support. Based on the considered scenarios, limitations and tradeoffs were identified. Within the second topic, requirements and architectures to support service-centric networking (SCN) were investigated. The SCN concept, which has been developed at the CDS group, is a gen-

eralization of content-centric networking enabling requesting nodes to ask for services and not only content. As a result, the flexibility of requests is increased.

In October 2011 Desislava Dimitrova made a research visit to the Universidad Polytechnica de Catalunya, Spain. The two main purposes of the STSM were (1) to share knowledge and experience in the field of localization of indoor applications and (2) to identify research topics of common interest, which will trigger cooperation among the parties. Meetings with researchers at UPC but also CTAE (Aerospace Research and Technology Centre) were held. As result two research initiatives were started - (1) measurements in the CDS test-bed to estimate the feasibility of a dynamic adaptation of path loss readings; and (2) a combined effort towards evaluating the usability of fingerprinting mechanisms, which can work with RTT measurements, for localization.

Research staff: Torsten Braun, Carlos Anastasiades, Desislava Dimitrova, Zhongliang Zhao

Financial support: European Science Foundation

Energy Efficiency in Large Scale Distributed Systems

The COST Action IC0804 proposes realistic energy-efficient solutions to share distributed information technology resources. As large scale distributed systems gather and share more and more computing nodes and storage resources, their energy consumption is exponentially increasing. While much effort is nowadays put into hardware specific solutions to lower energy consumptions, the need for a complementary approach is necessary at the distributed system level, i.e., middleware, network and applications. The Action characterizes the energy consumption and energy efficiencies of distributed applications. Our research group is contributing to the Action's Focus Group on Energy-efficient Wireless Networking, which aims to investigate energy efficient concepts for wireless communication. Related work in this area has been performed in our research project on Authentication, Authorization, Accounting and Auditing in Wireless Mesh Networks and Traffic Adaptivity in Wireless Sensor Networks. In a joint research activity together with the Universities of Würzburg and Coimbra, we have investigated tradeoffs of energy efficiency and Quality-of-Experience for video transmission over wireless networks.

Research staff: Torsten Braun, Markus Anwander, Philipp Hurni

Financial support: European Science Foundation

Service-Centric Networking

Content-centric networking is a novel paradigm for the Future Internet. We argue that content-centric networking should be generalized towards a service-centric networking (SCN) scheme. We propose a service-centric networking design based on an object-oriented approach, in which content and services are considered objects. Service-centric networking can be beneficial for saving network resources and reducing response time for service invocation as well as supporting location-based services. A first prototypical implementation of SCN has been realized. As an example service we used a still image format conversion service, which enables CCN routers to convert bitmap images into JPEG encoding, if a requested JPEG image is not available but only the bitmap image.

Research staff: Torsten Braun, Elham Cheriki

Opportunistic Routing for highly Mobile Ad-hoc Networks

In the first project year of the Opportunistic Routing for highly Mobile Ad-hoc Networks (ORMAN) project, we proposed and developed a simulation framework for evaluating different opportunistic routing protocols in the OMNeT++ simulator. In the second project year, we targeted on the development and evaluation of various routing protocols using the framework. We implemented and performed a systematic performance analysis of representative opportunistic routing protocols, namely ExOR and MORE. The goal is to investigate under which situations the opportunistic routing approach may achieve better results than traditional mobile ad-hoc networks routing protocols. Our simulation results show that opportunistic routing may achieve significant performance gain in lossy wireless network environments, and it will reach a better improvement under high bit rate traffic scenarios. Also the number of potential forwarders has strong influence on the performance of the protocols. A high number of forwarders may introduce collisions that will eliminate the benefits it brings.

We also analyzed topology control issues in the highly mobile environment, i.e. Unmanned Aerial Vehicle (UAV) swarms. UAVs are usually flying within a certain formation. The relative positions of all UAVs are important

for information sharing between each other and for collision avoidance. We proposed an agent-based topology control approach which is faster and more efficient than the centralized solution. We take into account both the distance between flying UAVs, via the GPS module embedded within the UAVs, and communication link signal quality, via the received signal strength indicator (RSSI). Our proposal will make a joint decision based on both the distance and RSSI value between UAVs to control the movement of the UAV swarm and the relative movement of each UAV within the swarm.

Moreover, we developed UAVNet, a framework focusing on the autonomous deployment of a flying wireless mesh network (WMN), using small quadcopter UAVs. Every UAV carries a lightweight wireless mesh node, which is directly connected to the flight electronic of the UAV via a serial interface. The flying wireless mesh nodes are automatically interconnected to each other and are building an IEEE 802.11s WMN. Every wireless mesh node works as an Access Point (AP) and provides access for regular IEEE 802.11g wireless devices, such as notebooks, smart-phones, and tablets. UAVNet includes a concept and a prototype implementation of an autonomously deployable flying WMN. Additionally, an iPad or iPhone, with a customized software running on it, can be used to simplify the configuration, deployment, and monitoring of UAVNet. Our evaluations have shown that UAVNet can optimize network performance. They have proven that the performance of a flying network is much better than a ground-based approach, due to the better network coverage.

Research staff: Zhongliang Zhao, Simon Morgenthaler, Markus Anwander, Torsten Braun, Thomas Staub

Financial support: Swiss National Foundation Project No. 200021-130211

Mobile Multi-Media Wireless Sensor Networks

Wireless sensor network technology is becoming more and more mature and sensors are being used in many applications in the area of security, environment monitoring and e-health. Sensor networks include both discrete sensor data (e.g., temperature, passive infrared levels, and sound levels) and continuous multi-media flows (e.g., continuous audio and video flows). Moreover, in future wireless sensor networks, the issue of mobility becomes more important. First, objects to be monitored (cars, persons)

might be mobile. Second, these objects might carry sensors such that sensors become mobile. Third, the objects or special mobile devices such as robots or unmanned aerial vehicle may carry base stations to collect multimedia sensor data in order to provide them to processing elements, e.g., in a cloud computing environment, for further processing. This project proposes to build an experimental research platform including both the communication in wireless sensor networks (University of Bern, Swiss partner) and processing sensor data in cloud computing environments (University of Science and Technology of China, Chinese partner). The research platform will be based on existing solutions developed and used in previous projects at both partner-sides.

The research platform will then be used by researchers to support their experimental research work on mobile multi-media sensing. First, we investigated and designed a general scalable network architecture for mobile multi-media wireless sensor networks. Second, we investigated a multi-media sensor system for object detection and tracking based on steerable cameras that are triggered and steered based on discrete sensor data. Third, we will investigate how opportunistic forwarding can be used to support the delivery of multi-media sensor data, when sensors are mobile. Last, we will investigate mobile base stations visiting sensors for collecting multi-media sensor data. In this case, energy consumption at the sensors should be decreased by minimizing the activation of the transceivers used for communication between sensors and base stations.

Research staff: Zhongliang Zhao, Denis Lima do Rosario, Gerald Wagenknecht, Torsten Braun, Björn Mosler

Financial support: Joint research project of Nano-Tera.ch and the Sino Swiss Science and Technology Cooperation (SSSTC)

Low-Cost Network Coding for Collaborative Video Streaming

The widespread deployment of wireline/wireless communication systems and the proliferation of digital media created the recent surge in multimedia streaming research. With emerging applications such as wireless low-power surveillance, multimedia sensor networks, and portable devices with multimedia coding and communication capabilities, the traditional multimedia coding and streaming architectures are being challenged. For efficient multimedia streaming in overlay networks many often contradictory

tools as video coding, channel coding, coding strategies at intermediate network nodes and network protocols should be considered. Specifically, video coding aims at removing data redundancy to reduce the volume of the transmitted data, while channel coding adds some redundancy to the stream to make it more resilient to errors. Network protocols offer efficient transmission mechanisms to cope with the best-effort nature of networks which does not guarantee any quality of services. However, such protocols demand for knowledge of the end-to-end network statistics and are difficult to be maintained due to network dynamics. To this aim, coding at peers such as network coding becomes popular as it assists communications systems to improve network throughput, reduce delay and eliminate the need for reconciliation among peers. Essentially network coding is a special class of channel codes that permits on-the-fly adaptation of the added redundancy. Despite the appealing features of network coding, its efficient application is not straightforward and many challenging problems should be still addressed.

This project focuses on the deployment of low-cost network coding methods for video streaming in overlay networks. It is the follow up work of the Ambizione project with reference number PZ00P2-121906. In that project, we have proposed among others low complexity network coding schemes, prioritized network codes to address clients heterogeneity, inter-session network codes, and techniques for approximate network codes decoding. In detail, we have already presented a low-cost network coding method based on Raptor codes that first achieves close to linear decoding and encoding times. For decentralized systems, we have proposed another system that employs randomized network coding and restricts the coding operations in selective positions. It is shown that few network coding nodes in large overlay networks are enough to notice large gains in terms of throughput and delay. To keep the computational complexity low all other nodes are store-and-forward. We have defined a game that decides about the network coding positions based on the willingness of network nodes to perform network coding. We have coped with the problem of clients receiving an insufficient number of packets to fully recover the transmitted data. Thus, we have developed a method that uses data correlation to enhance data reconstruction. This scheme is the only one that provides a systematic framework for data recovery in case of severe losses that is applicable to various types of data. We have also considered the case of multiple concurrent streams that compete for the network resources and first present a general methodology that scales to any arbitrary number of sources. Finally, we have designed a receiver driven protocol based on network coding for video communication. This distributed system solves a

simple optimization algorithm to find the optimal coding strategy at nodes. It allows system users to improve their experience and exploit better their resources.

The developed randomized network coding method for multiple concurrent streams requires centralized knowledge about network topology and statistics. We aim to extend this technique to distributed systems. For low complexity, we will also consider the application of Raptor network coding. Novel source and channel rate allocation algorithm will be devised to take into account the multiple concurrent sources and remove the need for resource allocation algorithms that pre-allocate the bandwidth to the concurrent streams. We have shown that in many cases the sparse application of network coding is very efficient. Here, to further improve resiliency of the developed network coding techniques to network dynamics we will apply online learning methods. This will enable on-the-fly decision about the optimal coding operations and provide maximal quality streams with minimal delay. The designed approximate decoding techniques have made apparent that for rank deficient systems and correlated sources, decoding is possible by taking into account the correlation. To further enhance the performance of systems employing approximate decoding, we propose to benefit from the data correlation at encoding. For example, in wireless communication nodes can exploit overheard data from other nodes and the fact that they interfere with each other.

Research staff: Nikolaos Thomos

Financial support: Ambizione award from Swiss NSF (PZ00P2-137275)

Testbed for Mobile and Internet Communications

Our research group maintains its own comprehensive and heterogeneous network testbeds for various purposes. A wired testbed is used to build networks of experimental routers and end systems to be able to evaluate the behavior of new networking protocols and architectures in realistic environments. The testbed also forms a productive network of Linux PCs and provides the storage capacity and CPU power for many of our research group's projects. An educational laboratory network for students' training is also connected and has been used for teaching in the Bachelor program. Our research group also takes part in PlanetLab (<http://planet-lab.org>) and GpENI (<https://wiki.ittc.ku.edu/gpeni/>). PlanetLab is an open platform for

developing, deploying, and accessing planetary-scale services. For this purpose we are hosting three PlanetLab nodes in our testbed network. GpENI is a distributed set of sites, interconnected at layer 2 (or layer 2 tunnels) to enable experimentation at layers 3 and higher. For this purpose we are hosting three GpENI nodes, two GpENI routers and one GpENI controller node in our testbed network. Moreover, we have installed three Cisco routers. Each of them is terminating a L2TP connections to provide a major European GpENI concentrator point. We are connected to the University of Kansas, the ETH Zürich and the University of Zürich.

Moreover, our research group runs wireless testbeds. The research group owns a number of sensor nodes: Embedded Sensor Board (ESB), Modular Sensor Board (MSB), tmote SKY nodes, BTnodes, TelosB nodes, and micaZ nodes. Some of these nodes are operated as part of the Wisebed infrastructure. Another testbed consisting of multiple wireless mesh nodes (17 x PCEngines WRAP, 10 x Meraki Mini, 6 x PCEngines ALIX) has been deployed throughout the building and work environment of the research group. In this testbed, multi-channel communication, multi-path routing and the management framework ADAM have been evaluated. The testbed is currently used by several Ph.D. theses and student projects.

Research staff: All members of the CDS research group

3.4 Ph.D. Thesis

- Philipp Hurni: Traffic-Adaptive and Link-Quality-Aware Communication in Wireless Sensor Networks, December 22, 2011

3.5 Master's Theses

- Ulrich Bürgi: Performance Optimization for TCP-based Wireless Sensor Networks, August 2011
- Simon Morgenthaler: UAVNet: A Prototype of a Highly Adaptive and Mobile Wireless Mesh Network Using Unmanned Aerial Vehicles (UAVs), July 2012
- Elham Cheriki: Design and Implementation of a Conversion Service for Content Centric Networks, Master Thesis at FH Bern, January 2012

3.6 Bachelor's Theses

- Björn Mosler: Opportunistic routing algorithm implementation for OMNeT++ 4.0, March 2012

3.7 Awards

- IAM Alumni award for outstanding PhD work to P. Hurni on Traffic-Adaptive and Link-Quality-Aware Communication in Wireless Sensor Networks

3.8 Further Activities

Memberships

Torsten Braun

- Chair of ERCIM working group on eMobility
- Erweitertes Leitungsgremium Fachgruppe "Kommunikation und Verteilte Systeme", Gesellschaft für Informatik
- Vice President of SWITCH foundation
- SWITCH Stiftungsrat
- SWITCH Stiftungsratsausschuss
- Kuratorium Fritz-Kutter-Fonds
- Expert for Diploma Exams at Fachhochschule Bern
- Expert for Matura Exams at Gymnasium Hofwil
- Expert for Matura Exams at Gymnasium Thun-Schadau
- Management committee member of the COST Action IC 0804 Energy-Efficiency In Large Scale Distributed Systems
- Management committee member of the COST Action IC 0906 Wireless Networking for Moving Objects (WiNeMO)
- External Advisory Board Member of Space Internetworking Center (SPICE) at Democritus University of Thrace, Greece

- Board Member (Gesellschafter) of VGU Private Virtual Global University, Berlin, Germany

Editorial Boards

Torsten Braun

- Editorial Board Member of Elsevier's Computer Communications Journal
- Editorial Board Member of Informatik Spektrum, Springer-Verlag
- Editorial Board Member of Journal of Internet Engineering (Editor in Chief)
- Guest Editorial Board Member of Special Issue on "Recent Advances in the Design of MAC Protocols for WSNs" in Hindawi's International Journal of Distributed Sensor Networks

Conference Chairs

Torsten Braun

- Local Co-Chair of ACM EuroSys 2012, April 10-13, 2012, Bern
- Program Co-Chair of IEEE/ACM IWQoS 2012, 20th International Workshop on Quality-of-Service, June 4–5, 2012, Coimbra, Portugal
- General Chair of 6th Joint ERCIM eMobility and MobiSense Workshop, co-located to WWIC 2012, June 8, 2012, Island of Santorini, Greece, June 8, 2012
- General Co-Chair of 1st International Workshop on Novel approaches to Energy Measurement and Evaluation in Wireless Networks, June 15, Ottawa, Canada

Conference Program Committees

Torsten Braun

- 11th International Conference on Telecommunications for Intelligent Transport Systems, St. Petersburg, Russia, August 23 - 25, 2011

- 4th International Workshop on Multiple Access Communications, Trento, Italy, September 11-13, 2011
- 36th IEEE Conference on Local Computer Networks, Bonn, Germany, October 4-7, 2011
- 3rd International Congress on Ultra Modern Telecommunications and Control Systems, Budapest, Hungary, October 5-7, 2011
- 5th IEEE International Workshop on Enabling Technologies and Standards for Wireless Mesh Networking, Valencia, Spain, October 17, 2011
- 7th International Conference on Network and Service Management, Paris, France, October 24-28, 2011
- 1st IEEE Symposium on Network Cloud Computing and Applications, Toulouse, France, November 21-23, 2011
- 7th IEEE Broadband Wireless Access Workshop, co-located with IEEE GLOBECOM 2011, Houston, Texas, USA, November 2011
- 2nd IEEE Workshop on Pervasive Group Communication, held in conjunction with IEEE GLOBECOM 2011, Houston, TX, USA, December 9, 2011
- IEEE Global Communications Conference, in Houston, Texas, USA, December 5-9, 2011
- 10th IEEE Consumer Communications and Networking Conference, Las Vegas, USA, January 14-17, 2012
- 26th ACM Symposium On Applied Computing, Taichung, Taiwan, March 21-24, 2011
- 1st Workshop on Emerging Design Choices in Name-Oriented Networking, co-located with IEEE Infocom, Orlando FL, USA, March 25-30, 2012
- 27th Symposium On Applied Computing, Riva del Garda (Trento), Italy, March 26-30, 2012
- IEEE Wireless Communications and Networking Conference, Paris, France, April 1-4, 2012

- IEEE/IFIP Network Operations and Management Symposium, NOMS 2012, Maui, Hawaii, USA, April 16-20, 2012
- 2nd Baltic Congress on Future Internet Communications, Vilnius, Lithuania, April 25-27, 2012
- 11th IFIP Networking, Prague, Czech Republic, May 21-25, 2012
- 6th International Conference on Autonomous Infrastructure, Management and Security (AIMS 2012), University of Luxembourg, Luxembourg, June 4-8, 2012
- 10th International Conference on Wired/Wireless Internet Communications, Santorini Island, June 6-8, 2012
- 6th Joint ERCIM eMobility and MobiSense Workshop, co-located to WWIC 2012, Island of Santorini, Greece, June 8, 2012
- IEEE International Conference on Communications, Ottawa, Canada, June 10-15, 2012
- 4th IEEE International Workshop on Hot Topics in Mesh Networking, San Francisco CA, USA, June 25, 2012
- 5th International Workshop on Sensor Networks, co-located with ICCN, Munich, July 30-August 2, 2012

Desislava Dimitrova

- W3 workshop, 2011, University of Twente, The Netherlands
- WISH seminar, 2012, University of Bern, Switzerland
- Joint ERCIM eMobility and MobiSense workshop, 2012, Santorini, Greece

Ph.D. Jury Memberships

Torsten Braun

- Krzysztof Piotrowski, Brandenburgische Technische Universität Cottbus, November 2011
- Christian Hübsch, Karlsruhe Institute of Technology, June 29, 2012

Project and Person Reviewing Activities

Torsten Braun

- Education Assessment Exercise at KTH Stockholm, Chair of Review Panel for School of Electrical Engineering
- Evaluation Committee for Research in Information and Communication Technology at Norwegian Universities, University Colleges and Selected Research Institutes
- Project Reviewer for 7th Framework Programme of the European Community for research, technological development and demonstration activities
- Hasler Foundation
- Swiss National Science Foundation

Journal Article Reviewing Activities

Torsten Braun

- ACM Transactions on Embedded Computing Systems
- Elsevier Journal of Network and Computer Applications
- EURASIP Journal on Wireless Communications and Networking
- IEEE Communications Magazine
- IEEE Communications Letters
- IEEE Transactions on Computers
- IEEE Wireless Communications Magazine
- IEEE Transactions on Network and Service Management
- IEEE Transactions on Wireless Communications
- International Journal of Network Management
- International Journal of Distributed Sensor Networks
- Journal of Communications and Networks

- Simulation: Transactions of the Society for Modeling and Simulation International
- Springer Journal of Medical Systems

Desislava Dimitrova

- Elsevier Computer Communications
- Elsevier Computer Networks

Almerima Jamakovic-Kapic

- Elsevier, the Transportation Research Part C Journal
- Elsevier, The International Journal of Critical Infrastructure Protection (IJCIP)
- IEEE Transactions on Reliability

Invited Talks and Tutorials

Carlos Anastasiades

- Evaluation of CCNx in Mobile Environments using VirtualMesh, CCNx Community Meeting, Palo Alto, CA, USA, September 9, 2011

Torsten Braun

- Experimental Research on Reliability and Energy-Efficiency in Wireless Sensor Networks, Keynote Talk at 3rd Workshop on Pervasive Applications of Wireless Technologies, Enschede, The Netherlands, September 27, 2011
- Delay Tolerant Networking and Content/Service-Centric Networking, Invited Talk at Workshop at Space Internetworking Center (SPICE), Xanthi, Greece, September 6, 2011
- Development and Evaluation of Energy-Efficient and Adaptive Protocols for Wireless Sensor Networks, Keynote Talk at IEEE 3rd Latin-American Conference on Communications - LATINCOM 2011, Belem, October 24, 2011
- Soziale Netze-Einsatzmöglichkeiten der Zukunft, Invited Talk at Entrepreneur Clubabend, Solothurn, October 27, 2011

- Telematiknetze, Kaderkurs Telematik, Bundesamt für Bevölkerungsschutz, Schwarzenburg, Switzerland, November 22, 2011
- A4-Mesh: Authentication, Authorization, Accounting, and Auditing in Wireless Mesh Networks, AAA/SWITCH Info-Day, January 19, 2012, Bern
- Research Challenges in Networked Systems, Keynote Talk at the 5th VERDIKT Conference, Oslo, Norway, April 25, 2012
- Energy Consumption and Energy Efficiency On Hardware and Software Approaches to Monitor Wireless Mesh and Sensor Networks, Round Table on "Monitoring of energy consumption - are our tools sufficient?", organized by COST Action IC 0804 on Energy Efficiency in Large Scale Distributed Systems, Working Group 2: Characterization of energy consumption and energy efficiency, May 8, 2012, Madrid
- Content-Centric Networking in Delay/Disruption-Tolerant Networks, Invited Talk at WWIC 2012 Panel on Internetworking with Challenging Conditions, Santorini Island, June 7, 2012
- Reliable and Energy-Efficient Communication in Wireless Sensor Networks, Computer Science Colloquium, Western Michigan University, Kalamazoo MI, USA, June 13, 2012
- MobileCloud - Future Mobile Telecommunication Networks Using Cloud Technologies, Invited Talk at Open Cloud Day, Bern, June 19, 2012
- A4-Mesh: Authentication, Authorization, Accounting, and Auditing in Wireless Mesh Networks, 28th TERENA TF-Mobility and Network Middleware Meeting, Zürich, June 26, 2012

Thomas Staub

- Telematiknetze, Kaderkurs Telematik, Bundesamt für Bevölkerungsschutz, Schwarzenburg, Switzerland, November 22, 2011

Nikolaos Thomos

- Network Coding for Multimedia Communications, University of Edinburgh, U.K., Dec. 2011

- Low-Cost Network Coding for Collaborative Video Streaming, University Carlos III & IMDEA networks, Spain, May 2012
- Network Coding for Multimedia Communications, University of Surrey, U.K., May 2012
- Low-Cost Network Coding for Collaborative Video Streaming, University of Edinburgh, U.K., May 2012

Organized Events

- The CDS group took part at "Fit in IT - Roadshow" organized at several high schools in Switzerland: Alte Kantonsschule Aarau, September 14, 2011, Kantonsschule Olten, November 8, 2011, Kantonsschule Rychenberg Winterthur, November 22, 2011 and Kantonsschule Zug, December 1, 2011.
- Europe day 2012 at the University of Bern, May 9, 2012: The CDS group took part at the Europe day 2012, where researchers from EU-funding projects could present their achievements. CDS presented, together with its partner DFRC AG, Zug, Switzerland, its two Eurostars projects - LBA and In3DGuide. A small demo was installed on the premises of the event that showed in real time statistics on the guests' presence and mobility.
- The seminar on Wireless Integration of Sensor networks in Hybrid (WISH) architectures at the University of Bern, March 15, 2012: The one-day seminar on Wireless Integration of Sensor networks in Hybrid architectures (WISH) took place at the University of Bern on March 15, 2012. The seminar was co-sponsored by the Nachwuchsförderungs-Projekt pool of the University of Bern, the CDS group and the company 89grad.
- The EuroSys 2012 conference, jointly organized by the University of Bern and the University of Neuchâtel at University of Bern, Switzerland, April 10-13, 2012.
- Computer Science Summer School seminar, organized together with the Dependable Systems and Networks group and Distributed Systems group of University Neuchâtel, at La Vue-des-Alpes, Switzerland, July 4-6, 2012.

3.9 Publications

Publications submitted in the academic year 2011/2012 and appearing in 2012/2013 or later are not listed.

Books

- Thomas Staub: Development, Testing, Deployment & Operation of Wireless Mesh Networks: Addressing various challenges encountered in the life cycle of Wireless Mesh Networks, Südwestdeutscher Verlag für Hochschulschriften, July 18, 2012, ISBN 978-3-8381-3358-4

Reviewed Journal and Conference Papers

- Fausto Guzzo da Costa, Torsten Braun, J Ueyama, Gustavo Pessin, Fernando Santos: Arquitetura baseada em veculos areos no tripulados e redes de sensores sem fio para aplicaes agrcolas, VIII Congresso Brasileiro de Agroinformatica, SBIAGRO 2011, Bento Goncalves, Brazil, October 17-21, 2011, pp.1-5
- Philipp Hurni, Markus Anwander, Gerald Wagenknecht, Thomas Staub, Torsten Braun: TARWIS - A Testbed Management Architecture for Wireless Sensor Network Testbeds, International Conference on Network and Service Management (CNSM), Paris, France, October 24-28, 2011, pp.1-4, ISBN 978-1-4577-1588-4
- Vitor Bernardo, Marilia Curado, Thomas Staub, Torsten Braun: Towards Energy Consumption Measurement in a Cloud Computing Wireless Testbed, IEEE First Symposium on Network Cloud Computing and Applications (NCCA 2011), Toulouse, France, November 21-23, 2011, pp.91-98, ISBN 978-1-4577-1667-6
- Philipp Hurni, Ulrich Bürgi, Markus Anwander, Torsten Braun: TCP Performance Optimizations for Wireless Sensor Networks, 9th European Conference on Wireless Sensor Networks, Trento, Italy, February 15-17, 2012, pp.17-32, ISBN 978-3-642-28168-6
- Geoff Coulson, Barry Porter, Ioannis Chatzigiannakis, Christos Koninis, Stefan Fischer, Dennis Pfisterer, Daniel Bimschas, Torsten

Braun, Philipp Hurni, Markus Anwander, Gerald Wagenknecht, Sandor Fekete, Alexander Kröller, Tobias Baumgartner: Flexible Experimentation in Wireless Sensor Networks, *Communications of the ACM*, Vol.55, Nr.1, January 1, 2012, pp.82-90, ISSN 0001-0782

- Philipp Hurni, Markus Anwander, Gerald Wagenknecht, Thomas Staub, Torsten Braun: TARWIS A testbed management architecture for wireless sensor network testbeds, *IEEE/IFIP Network Operations and Management Symposium (NOMS)*, Maui, Hawaii, USA, April 16-20, 2012, pp.611-614, ISBN 978-1-4673-0267-8
- Denis do Rosario, Rodrigo Costa, Helder Paraense, Kassio Machado, Eduardo Cerqueira, Torsten Braun: A smart multi-hop hierarchical routing protocol for efficient video communication over wireless multimedia sensor networks, *2nd IEEE International Workshop on Smart Communication Protocols and Algorithms*, Ottawa, Canada, June 10-15, 2012, pp.8113-8117
- Almerima Jamakovic, Markus Anwander, Torsten Braun, Peter Kropf, Eryk Schiller, Jan Schwanbeck, Thomas Staub: A4-Mesh: Connecting Remote Sites, *Switch Journal*, March 1, 2012, pp.15-17
- Matthias Thoma, Klaus Sperner, Torsten Braun: Service Descriptions and Linked Data for Integrating WSNs into Enterprise IT, *34th International Conference on Software Engineering*, Zürich, Switzerland, June 2-9, 2012, pp.43-48, ISBN 978-1-4673-1789-4
- Fausto Costa, Jo Ueyama, Torsten Braun, Gustavo Pessin, Fernando Osorio, Patricia Vargas: The use of Unmanned Aerial Vehicles and Wireless Sensor Networks in Agricultural Applications, *IEEE International and Remote Sensing Symposium*, Munich, Germany, July 22-27, 2012, pp.5045-5048, ISBN 978-1-4673-1158-8
- Zhongliang Zhao, Torsten Braun: Topology Control and Mobility Strategy for UAV Ad-hoc Networks: A Survey, *Joint ERCIM eMobility and MobiSense Workshop*, Santorini, Greece, June 8, 2012, pp.27-32, ISBN 978-3-9522719-3-3
- Gerald Wagenknecht, Markus Anwander, Torsten Braun: Performance Evaluation of Reliable Overlay Multicast in Wireless Sensor Networks, *10th International Conference on Wired/Wireless Internet Communications (WWIC)*, Santorini, Greece, June 6-8, 2012, pp.114-125, ISBN 978-3-642-30629-7

- Gerald Wagenknecht, Markus Anwander, Torsten Braun: SNOMC: An Overlay Multicast Protocol for Wireless Sensor Networks, 9th Annual Conference on Wireless On-demand Network Systems and Services (WONS), Courmayeur, Italy, January 9-11, 2012, pp.75-78, ISBN 978-1-4577-1721-5
- Desislava Dimitrova, Islam Alyafawi, Torsten Braun: Experimental Comparison of Bluetooth and WiFi Signal Propagation for Indoor Localisation, 10th International Conference on Wired/Wireless Internet Communications (WWIC), Santorini, Greece, June 6-8, 2012, pp.126-137, ISBN 978-3-642-30629-7
- Rossitza Goleva, Seferin Mirtchev, Dimitar Atamian, Desislava Dimitrova, Oleg Asenov: Experimental Analysis of QoS Provisioning for Video Traffic in Heterogeneous Networks, Joint ERCIM eMobility and MobiSense Workshop, Santorini, Greece, June 8, 2012, pp.62-69, ISBN 978-3-9522719-3
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- Markus Anwander, Torsten Braun, Almerima Jamakovic, Thomas Staub: Authentication and Authorisation Mechanisms in support of Secure Access to WMN Resources, The Fourth IEEE International Workshop on Hot Topics in Mesh Networking (HOTMESH), San Francisco, USA, June 25th, 2012, ISBN 978-1-4673-1239-4
- Desislava Dimitrova, Hans van den Berg, Geert Heijenk, Remco Litjens: LTE uplink scheduling - flow level analysis, 4th international conference on Multiple access communications (MACOM), Trento, Italy, September 11-13, 2011, pp.181-192, ISBN 978-3-642-23795-9
- Islam Alyafawi: Towards Self-Learning Radio-Based Localization Systems, IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM PhD Forum), Lugano, Switzerland, March 19-23, 2012, pp.556-557, ISBN 978-1-4673-0905-9

Technical Reports

- Philipp Hurni, Torsten Braun: Link-Quality Aware Run-Time Adaptive Forward Error Correction Strategies in Wireless Sensor Networks, Universität Bern, Institut für Informatik und angewandte Mathematik, Bern, Switzerland, November 22, 2011, IAM-11-003
- Vasilios Siris, Chiara Boldrini, Raffaele Bruno, Marco Conti, Carlos Anastasiades, Torsten Braun, Marilia Curado, David Palma, Paulo Mendes, Bruno Batista, Ivana Zarko, Kresimir Pripuzic: Content-Centric Architectures for Moving Objects, COST Action IC0906 WiNeMO white paper, June 06, 2012

4 Computer Vision Group

4.1 Personnel

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* with financial support from a third party

4.2 Overview

Prof. Dr. P. Favaro joined the IAM in June 2012. Details about his activities will be presented in the annual report 12/13.

5 Logic and Theory Group

5.1 Personnel

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City University of New York,
Graduate Center,
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June 2012

Prof. Dr. L. Beklemishev

M.V. Lomonossov Moscow
State University,
Department of
Mathematical Logic and
Theory of Algorithms,
Russia
May and June 2012

* with financial support from a third party

5.2 Overview

The LTG research group (logic and theory group) focuses on theoretical computer science and mathematical logic, especially proof theory, computational logics and theory of computation. We have been dealing for many years with formal methods, analysis of deductions, general computations and, in particular, applications of mathematical logic to computer science. During the previous year the main subject areas have been the following:

Computational Logic: Logical formalisms are perfectly suited to the specification of complex systems, the representation of knowledge and information, the description of processes (e.g. in distributed multi-agent systems) and for providing formal proofs of important system properties such as, for example, correctness and fairness. The research group has long been interested in the deductive, procedural and dynamic aspects of the corresponding formalisms and in the design of modern deductive systems. New approaches are being developed for information update purposes. In addition, the way in which simple, logical formalisms can be extended to become genuine multi-user systems taking into account the dynamic aspects of ontologies in the data mining context and in connection with the semantic web is being investigated.

Proof Theory: This research topic focuses on the development and analysis of formal systems of first and second order arithmetic, set theory and

of what are known as logical frameworks (type and set theoretical, explicit, constructive, extensional, intentional). Our interests range from feasible subsystems of arithmetic to highly impredicative set and type theories and deals with the interplay between constructive, recursive and operational approaches. In addition, abstract computations and computable knowledge are being investigated.

5.3 Research Projects

Algebraic and Logical Aspects of Knowledge Processing

The main focus of this research project is on three foundational pillars of classical, constructive and feasible axiomatic systems. We will study these frameworks by using a variety of proof-theoretic techniques and by emphasizing their computational properties. The main formal frameworks considered are: - first- and second-order arithmetic - (admissible) set theory - explicit mathematics - operational set theories - class theory - theories of partial truth Although this project builds upon the research work done within the scope of the previous project SNF Nr. 200020-119759, it also addresses two new research streams: - a proof theory of class theories in relationship to systems of second order arithmetic - a new unified truth-theoretic view of weak explicit formalisms The project is organized in three parts as follows:

1. Reflections and inductive definitions
2. Operational set theory and explicit mathematics
3. Feasible and (sub-)recursive proof and type systems

Research staff: S. Eberhard, D. Flumini, G. Jäger, T. Nemoto, K. Sato, Th. Strahm, R. Zumbrunnen

Financial support: Swiss National Science Foundation

Structural Proof Theory and the Logic of Proofs

The original idea that prompted Artemov to develop the Logic of Proofs LP was to solve a long-standing problem posed by Gdel more than half a century before. This goal has been achieved by introducing into the formal

logical language new objects called proof polynomials or, in epistemic setting, evidence terms. They enable us to reason about individual proofs or about evidence within the logical language. The goal of this project is to extend the benefits of this more expressive language to the logics used to describe common knowledge, a phenomenon important for distributed systems, temporal logics, which are used in specification and verification of correctness of computation, and a more general formalism of the so-called modal μ -calculus. A new promising area of application for evidence terms is belief revision, i.e., the change in opinions, for instance, as a result of announcements. The standard approaches to modeling such changes lead to paradoxical situations: an announcement of a true fact may make this announced fact false. The more expressive language with evidence terms, which represent reasons for beliefs, is also capable of modeling beliefs, including higher-order beliefs about beliefs of other agents. At the same time, it provides natural syntactic means of distinguishing between the beliefs held before the announcement and those resulting from the announcement, means lacking in the standard setting. A public announcement is undeniably direct material evidence for the announced fact, albeit this evidence may not be conclusive. Thus, the use of a language capable of operating with such evidence is highly desirable.

We also study the relationship between the structure of proof polynomials and structural properties of formal proofs. Among other things, formal proofs allow for computer verification. This study includes automating the process of evidence extraction from a given formal proof of validity of a statement about provability or about agents' beliefs. Further, we plan to study a certain well-developed type of such formal proofs, called sequent proofs, and the process of the so-called cut-elimination, i.e., elimination of intermediate lemmas, which is central to this type of proofs. The goal of this study is to develop proof polynomials based on this particular type of formalism, whereas proof polynomials developed by Artemov are based on a different formalism, that of Hilbert proofs, and hence do not preserve the structure of sequent derivations.

Research staff: S. Bucheli, R. Goetschi, G. Jäger, A. Kashev, R. Kuznets, Y. Savateev

Financial support: Swiss National Science Foundation

A Proof Theory for Modal Fixed Point Logics

Temporal logics are widely used to specify and verify the correctness of information systems when system reliability is crucial. Epistemic logics with common knowledge are important for reasoning about knowledge. Both types of logics are examples of modal fixed point logics. While these logics are well-understood semantically, our syntactic understanding of them is lacking. The state of proof theory for modal logics in general is widely recognised as unsatisfactory. For modal fixed point logics in particular there are no satisfactory cut-free sequent systems. Such systems generally are suitable for automated proof search and, together with their cut elimination procedures, can serve as a basis for declarative programming languages. We intend to address the problem of designing cut-free sequent systems for modal fixed point logics on two levels:

1. Whenever possible we plan to develop such systems together with syntactic cut elimination procedures. If possible, we aim for traditional sequent systems in Gentzen style, but if needed we will also employ ideas from richer proof theoretic formalisms such as the display calculus or deep inference.
2. On the other hand, if no cut-free systems exist for modal fixed point logics, we hope to gain a better understanding of why they do not exist. In this case we are interested in good syntactic approximations.

The development of a proof theory for modal fixed point logics is an important theoretical contribution to the understanding of inference and deduction in these logics, and thus in particular a relevant underpinning of specification and verification of information systems. It is central ground work concerning the procedural aspects of frameworks dealing with information.

Research staff: G. Jäger, K. Sato, Y. Savateev

Financial support: Hasler Foundation

Computational Proof Theory

This is a joint research project of the LTG group and the Department of Mathematical Logic and Theory of Algorithms in Moscow. Both groups have a strong background in mathematical logic - in particular proof theory, provability logic and general modal logics - and expertise in applying

concepts and techniques of mathematical logic in connection with recent developments in (theoretical) computer science. Among the interests of both groups are the attempts to analyze existing formal systems in order to classify their expressive as well as proof-theoretic powers and to design new and more flexible formal frameworks. In doing this, interesting results about computational and logical complexities (lower and upper bounds) of algorithms developed within these frameworks can be obtained frequently. Although working towards similar aims, the research traditions of Moscow and Bern are quite distinct.

Berns approach is rooted in traditional Gentzen- and Schütte-style (infinitary) proof theory and the proof-theoretic analysis of subsystems of second order arithmetic, set theory, explicit mathematics and type systems and still pursuing this line. Moscow school of logic has its roots in the works of Kolmogorov, Novikov and Markov. It is traditionally strong in constructive logic and mathematics, algorithmic problems in algebra, various non-classical logics and their semantical and computational aspects, and in descriptive complexity and complexity of algorithms.

The following three research streams address topics of mutual interests:

1. Provability algebras, metapredicativity and impredicativity
2. Functionality and common knowledge in justification logic
3. Structurally enhanced proof-theory for modal and substructural logics

It is expected that the combination and integration of the conceptual approaches and methods of both groups will allow to clarify the general landscape and to solve some long-standing open problems.

Research staff: G. Jäger, R. Kuznets, F. Ranzi, Th. Strahm, Th. Studer

Financial support: SBF (Staatssekretariat für Bildung und Forschung)

Logics for Privacy

The problem of data privacy is to verify that confidential information stored in an information system is not provided to unauthorized users and, therefore, personal and other sensitive data remain private. The main challenge in such a context is to share some data while protecting other personally identifiable information. The aim of our project is to develop formal

methods and the corresponding algorithms to enable automated reasoning about data privacy. Data stored in a relational database or knowledge base system usually is protected from unauthorized access. Users of such a system are then only allowed to access a limited portion of the stored information. In this situation the following important questions arise:

1. What can a user infer from the information to which he has access?
2. Can we guarantee that a user cannot obtain knowledge about certain sensitive information?
3. Is it possible to grant a user information access in such a way that she is able to fulfill her duties without letting her know secret information?

We will address these questions not in their full generality, but we intend to study the following concrete issue. Controlled query evaluation is an approach to privacy preserving query answering where the answer to a query is distorted if it would leak sensitive information to the user. We plan to develop a formal framework to enable controlled query evaluation for ontological knowledge base systems. To achieve this aim we will mainly use tools and techniques from modal logic in general and description logic in particular.

Research staff: Th. Studer, J. Werner

Financial support: Swiss National Science Foundation

Computational Structure of Classical Duality (Ambizione)

The Curry-Howard correspondence, also known as the proofs-as-programs correspondence, is the observation that logical proofs and computer programs are two ways of presenting the same mathematical objects. This project aims to extend the scope of the correspondence in two important directions: on the logical side, towards capturing classical logic, the logic used in natural and mathematical reasoning, and on the computational side to the idea of a “process”; a program which interacts with many other programs by passing messages.

Background: In the 1930s, Alonzo Church developed a calculus (the lambda calculus) a language for writing down what we now call computable functions. At the same time Gerhard Gentzen was developing natural deduction; a language for writing down formal proofs. Both these languages

were conceived as tools for exploring the foundations of mathematics, with the advent of computer science, representations of computable functions became a more practical concern. Lambda calculus was the inspiration for Lisp, the first functional programming language. Meanwhile, William Alvin Howard discovered a link between logic and functional programming: natural deduction proofs could be seen themselves as terms of the lambda calculus. In other words, a proof is a kind of computation, and a very well-behaved kind at that. This observation, known as the Curry-Howard correspondence, has led and continues to lead to an enormous body of theoretical and practical work in computer science and logic.

Goals of the project: Computer science has developed much since its inception, and we no longer think of computer problems as simply calculating a function, but more as interacting with a complex, varying environment comprised of users and other programs. The lambda calculus is unsuited for representing such programs, and other calculi (called process calculi) are used instead to reason about them. These calculi lack the elegant theoretic underpinning enjoyed by the lambda calculus. On the other hand, natural deduction fails to faithfully represent a fundamental reasoning mode: the ability to recognise that a statement is the same as its double negation. This property of logic is called "Duality". A much better calculus for reasoning under duality, called the sequent calculus, was also developed by Gentzen, but its computational meaning has been difficult to discern.

This project aims to extend the proofs as programs correspondence by representing proofs using duality within a new, theoretically inspired language of processes.

Research staff: R. McKinley

Financial support: Swiss National Science Foundation

Refining Reasoning via Justification Extraction: A Proof-Theoretic Approach (Ambizione)

This project aims to extend the scope of Justification Logic to areas where traditionally Modal Logic has been applied—such as artificial intelligence, multi-agent systems, belief revision, dynamic epistemic logic, knowledge representation, program specification and verification, etc. Despite the popularity of the modal language, it has well-known drawbacks such as the

Logical Omniscience Problem and lacks expressivity to deal with the "Justified" part of the famous "Knowledge as Justified True Belief" paradigm. Justification Logic provides a solution by refining the language with syntactic objects that are interpreted as justifications (or proofs, or witnesses) and by introducing a formal machinery for handling them.

The success of Modal Logic is due in part to its versatility: the modal language can be used to describe different phenomena by varying the axioms within the same language. Thus, it is necessary to provide a translation not only for the modal language in general, but also for individual theories in the modal language that are used in various applications. This process of translating modal reasoning into reasoning with justifications is called realization. Unfortunately, the applicability scope of the currently known realization algorithms is greatly narrowed by the fact that they require that the modal logic being translated have a purely syntactic and cut-free proof system. In particular, the most commonly used axiomatic, Hilbert-style representation of modal reasoning is not suitable for these realization algorithms.

Since developing cut-free proof systems has proven to be difficult, this project proposes to develop new cut-tolerant realization techniques. A natural way of achieving this goal is by using the tools of structural proof theory: manipulating symbolic representations of proofs and devising algorithms for obtaining representations with required structural properties. The success of this project will allow automating justification extraction for a wide range of modal logics, especially those that resist cut elimination, including temporal modal logics and public announcement logics.

Research staff: R. Kuznets

Financial support: Swiss National Science Foundation

Logic and Computation

This very general project deals with the close connections between mathematical logic and certain parts of computer science, and emphasis is put on a proof-theoretic approach to some of the central questions in this area of research. These include the development of perspicuous and feasible logical frameworks for studying typical questions in computer science like termination and correctness of functional programs, properties of distributed systems and the like.

We study applicative theories as well as strongly typed formalisms and are interested in the connections to constructive and explicit mathematics. Furthermore, we are interested in analyzing the close connections between the complexities of computations and proofs in suitable formalizations, ranging from propositional calculi up to abstract frameworks for computations (in higher types).

Research staff: All members of the research group

5.4 Ph.D. Theses

- S. Bucheli: Justification Logics with Common Knowledge
- J. Krähenbühl: On the Relationship between Choice Schemes and Iterated Class Comprehension in Set Theory

5.5 Master's Thesis

- D. Fabian: Applicative theories on tree ordinal numbers.

5.6 Bachelor's Theses

- S. Bünzli: The Problem of Logical Omniscience
- C. Hess: Der Satz von Barr: Beweis mit natuerlichem Schliessen
- RP. Kohler: Java-Programm zur interaktiven Bearbeitung von JALC-Herleitungen
- O. Truffer: Der Satz von Barr: Beweis mit partieller Schnittelimination

5.7 Further Activities

Editorial Boards

Gerhard Jäger

- Member of the editorial board of Archive of Mathematical Logic
- Member of the editorial board of Logica Universalis

Thomas Stahm

- Member of the consulting board of Dialectica

Technical and Research Committees

Gerhard Jäger

- Research Council Member of the Swiss National Science Foundation
- Vice President of the Fachausschuss Karrieren of the Swiss National Science Foundation
- Member of the Steering Committee of the Platform Mathematics, Astronomy and Physics (MAP) of the Swiss Academy of Sciences
- Member of the Scientific Council of the European Association for Computer Science Logic
- PC Member (Chair) of the Workshop Explicit Paradigms in Logic and Computer Science
- Member of the Kantonale Maturitätskommission
- Expert for Maturitätsprüfungen Mathematik und Informatik

Roman Kuznets

- PC Member of Symposium on Logical Foundations of Computer Science 2013
- PC Member of the Workshop Explicit Paradigms in Logic and Computer Science

Dieter Probst

- Expert for Maturitätsprüfungen Mathematik und Informatik

Thomas Strahm

- President of the Swiss Society for Logic and Philosophy of Science
- PC Member of the Workshop Explicit Paradigms in Logic and Computer Science
- Expert for Maturitätsprüfungen Mathematik und Informatik

Thomas Studer

- Secretary of the Swiss Society for Logic and Philosophy of Science
- Swiss representative in the International Union of History and Philosophy of Science
- PC Member of the Workshop Explicit Paradigms in Logic and Computer Science
- Expert for Maturitätsprüfungen Mathematik und Informatik

Organized Events

- Explicit Paradigms in Logic and Computer Science, June 2012

5.8 Publications

- K. Brännler and Th. Studer. Syntactic cut-elimination for a fragment of the modal μ -calculus. *Annals of Pure and Applied Logic*. To appear.
- S. Bucheli, R. Kuznets, and Th. Studer. Decidability for justification logics revisited. In *Selected papers of Ninth International Tbilisi Symposium on Language, Logic and Computation*, Springer's Lecture Notes in Artificial Intelligence. To appear.
- S. Bucheli, R. Kuznets, and Th. Studer. Realizing public announcements by justifications. *Journal of Computer and System Sciences*. To appear.
- SR. Buss and R. Kuznets. Lower complexity bounds in justification logic. *Annals of Pure and Applied Logic*, 163, 2012.
- S. Eberhard and Th. Strahm. Unfolding feasible arithmetic and weak truth. Submitted.
- S. Eberhard and Th. Strahm. Weak theories of truth and explicit mathematics. In P. Schuster U. Berger, H. Diener and M. Seisenberger, editors, *Logic, Construction, Computation*. Ontos Verlag, 2012.

- R. Goetschi and R. Kuznets. Realization for justification logics via nested sequents: Modularity through embedding. *Annals of Pure and Applied Logic*, 163, 2012.
- G. Jäger. Operational closure and stability. Submitted.
- G. Jäger and R. Zumbrunnen. About the strength of operational regularity. In P. Schuster U. Berger, H. Diener and M. Seisenberger, editors, *Logic, Construction, Computation*. Ontos Verlag, 2012.
- R. Kuznets and Th. Studer. Justifications, ontology, and conservativity. In Thomas Bolander, Torben Braüner, Silvio Ghilardi, and Lawrence Moss, editors, *Advances in Modal Logic, volume 9*. College Publications, 2012.
- R. McKinley. Canonical proof nets for classical logic. *Annals of Pure and Applied Logic*. To appear.
- R. McKinley. Proof nets for herbrand's theorem. *ACM Transactions on Computational Logic*. To appear.
- G. Mints and Th. Studer. Cut-elimination for the mu-calculus with one variable. In D. Miller and Z. Ésik, editors, *Proceedings 8th Workshop on Fixed Points in Computer Science*, 2012.
- D Probst and Th. Strahm. Admissible closures of polynomial time computable arithmetic. *Archive for Mathematical Logic*, 50, 2011.
- K. Sato. Relative predicativity and dependent recursion in second-order set theory and higher order theories. Submitted.
- Y. Savateev. Product-free lambek calculus is np-complete. *Annals of Pure and Applied Logic*, 163, 2012.
- D Spescha and Th. Strahm. Realisability in weak systems of explicit mathematics. *Mathematical Logic Quarterly*, 57(6), 2011.
- Th. Studer. Justified terminological reasoning. In I. Virbitskaite E. Clarke and A. Voronkov, editors, *Proceedings of Perspectives of System Informatics PSI'11*.
- Th. Studer. A universal approach to guarantee data privacy. *Logica Universalis*. To appear.

- Th. Studer. An application of justification logic to protocol verification. In B. Werner, editor, *Proceedings of Computational Intelligence and Security CIS 2011*, 2011.
- Th. Studer. Justification logic, inference tracking, and data privacy. *Logic and Logical Philosophy*, 20, 2011.

6 Software Composition Group

6.1 Personnel

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6.2 Overview

Programming languages and software analysis tools are the instruments that programmers and software engineers use to develop and evolve software systems. The Software Composition Group carries out research that aims to increase the power and expressiveness of programming languages and the flexibility and leverage of software analysis tools. Particularly, we are investigating mechanisms and techniques that enable the graceful evolution of software systems by taking a view that considers change to be the only constant at the center of the software process.

6.3 Research Projects

Synchronizing Models and Code

Successful software systems are under constant pressure to adapt to changing circumstances and requirements. These adaptations are of varying granularity levels, and may need to take effect over extreme variations in time scale and granularity: from fine-grained, short-term adaptations to resources and run-time contexts to long-term evolution of software that requires adaptation at the architectural level. In each of these cases we are faced with the challenge of keeping the source code and the running software synchronized with changes in the higher-level domain and requirement models. This synchronization, is often difficult because current languages and runtime systems assume global consistency.

In this project we are studying novel techniques to keep software systems synchronized with models in the face of varying granularities of change over different time scales. During the last year we have made progress in the following research tracks:

- *Dynamic meta-objects*: We have developed Bifröst, an object-centric approach to reflection. Bifröst models meta-objects explicitly, exclusively targeting objects as the sole reflective unit of change. This model provides a unification of different reflection approaches.
- *Modeling the meta-level as explicit meta-events* observable by development tools. Chameleon is a tool that provides an operational decomposition of the meta-level. Instrumentation is dedicated to generating meta-events, and is fully separated from analysis tools that selectively subscribe to these events by applying the observer pattern at the meta-level.
- *Domain-specific profiling*. We developed MetaSpy, a framework for defining domain-specific profilers. We also presented three real-world case-studies showing how MetaSpy fulfills the domain-specific profiler requirements. The use of Bifröst makes it possible to instrument specific objects to provide runtime abstractions related to profiling information.
- *Object-Centric Debugging* closes the gap between developers' questions and the debugging tool by shifting the focus in the debugger from the execution stack to individual objects. The essence of object-centric debugging is to let the user perform operations directly on the

objects involved in a computation, instead of performing operations on the execution stack. Bifröst's meta-objects were used to apply object-specific breakpoints dynamically to drive the debugger from within the runtime environment.

- *First-class, active contexts*: Software updates must be installed dynamically to avoid costly maintenance windows. We have developed an approach to dynamic updates called Theseus that associates different versions of classes and objects to first-class contexts. The update of the software is incremental and first-class contexts control the progressive transition from one version of the software to the next. We have implemented prototypes of our approach for Smalltalk and Java.
- *Linked, active source code*: Current software development tools fail to address synchronization of code shared between independent systems (medium-grained and medium-term as well as long-term adaptations). As software evolves, libraries, components and even fragments are frequently duplicated, adapted and specialized across software projects. We have established a connection between software projects by building a database of all projects in the Squeak-source code repository. The database makes it easy to find similar items across projects. As a first case study, we have established how much code is cloned across repositories: over 14% of all methods in the repository are present in at least 2 different projects.
- *Polyglot systems modeling and analyses*: Modern software systems are developed using multiple frameworks and technologies that in turn rely on different languages. Novel analyses that take into account this variety of technologies and languages are needed to support the evolution of modern “polyglot” software systems. To enable new kind of analyses we have developed a meta-model that describes the elements composing polyglot systems and the connections between them. By leveraging this meta-model we tackled the problem of change impact propagation and, we are developing novel metrics-based visualizations to support architectural validation.
- *Evolutionary and Collaborative Architecture Recovery*: Software Architecture Recovery is an activity applied to a system whose initial architecture has eroded. When the system is large, the user must use dedicated tools to support the recovery process. We are furthering our research and development of SoftwareNaut — our pro-

prototype tool that supports architecture recovery through interactive exploration and visualization. Classical architecture recovery features, such as filtering and details on demand, are enhanced with evolutionary capabilities when multi-version information about a subject system is available. The tool allows sharing and discovering the results of previous analysis sessions through a global repository of architectural views indexed by systems.

Research staff: All members of the research group.

Duration: Oct. 2010 – Sept. 2012

Financial support: Swiss National Science Foundation,
Project #200020-131827

For further details, please consult:
<http://scg.unibe.ch/research/snf10>

6.4 Ph.D. Theses

- Toon Verwaest. *Bridging the Gap between Machine and Language using First-Class Building Blocks*. Phd thesis, University of Bern, March 2012. Available from: <http://scg.unibe.ch/archive/phd/verwaest-phd.pdf>.

6.5 Master's Theses

- Raffael Krebs. Vera — an extensible Eclipse plug-in for Java enterprise application analysis. Master's thesis, University of Bern, April 2012. Available from: <http://scg.unibe.ch/archive/masters/Kreb12a.pdf>.
- Andrea Quadri. Chameleon: Decoupling instrumentation from development tools with explicit meta-events. Master's thesis, University of Bern, January 2012. Available from: <http://scg.unibe.ch/archive/masters/Quad12a.pdf>.

6.6 Bachelor's Theses and Computer Science Projects

- Olivier Flückiger. Implementing Pinocchio a VM-less metacircular runtime library for dynamic languages. Bachelor's thesis, University of Bern, December 2011. Available from: <http://scg.unibe.ch/archive/projects/Flue11a.pdf>.
- Ramon Wenger. Modeling infiltration. Bachelor's thesis, University of Bern, July 2012. Available from: <http://scg.unibe.ch/archive/projects/Weng12a.pdf>.
- Ramon Wenger. Programming in Javascript — a guide. Bachelor's thesis, supplementary documentation, University of Bern, July 2012. Available from: <http://scg.unibe.ch/archive/projects/Weng12b.pdf>.

6.7 Awards

- 2011 Faculty Prize for Camillo Bruni's MSc thesis, *Optimizing Pinocchio*
- 2011 IAM Alumni prize for Max Leske's Bachelor thesis, *The Genesis of Pharo: The Complete History of Pharo with Git*
- EAPLS best paper award at TOOLS 2012 for *Incremental Dynamic Updates with First-class Contexts* by Erwann Wernli, Mircea Lungu and Oscar Nierstrasz

6.8 Further Activities

Invited Talks

Oscar Nierstrasz

- Keynote speaker at IWRE 2012 (3rd India Workshop on Reverse Engineering, co-located with ISEC '12 — Kanpur, India, Feb 22, 2012)
- Keynote speaker at ICPC 2012 (20th IEEE International Conference on Program Comprehension — Passau, Germany, June 11-13, 2012)

Mircea Lungu

- Invited Talk at University of California, Irvine: Reverse Engineering Software Ecosystems. July 2011.

Editorial Boards and Steering Committees**Oscar Nierstrasz**

- JOT — Journal of Object Technology (Editor-in-Chief)
- SNF — Swiss National Science Foundation (Member of the Research Council)
- Springer LNCS – SL2 – Programming Techniques and Software Engineering (Series Editor)
- SIRA – Swiss Informatics Research Association (Board Member)
- SI – Swiss Informatics Society (Board Member)
- AITO – Association Internationale pour les Technologies Objets (Member)
- CHOOSE – Swiss Group for Object-Oriented Systems and Environments (Board Member)
- ESEC – European Software Engineering Conference (Steering Committee Member)
- MoDELS – International Conference on Model Driven Engineering Languages and Systems (Steering Committee Member)
- SC – Software Composition Symposium (Steering Committee Member)
- SATToSE – Seminar Series on Advanced Techniques & Tools for Software Evolution (Steering Committee Member)
- Moose Association (Board Member)

Mircea Lungu

- CHOOSE – Swiss Group for Object-Oriented Systems and Environments (Board Member, Publicity Chair)

- SI – Swiss Informatics Society (Board Member)

Jorge Ressia

- SI – Swiss Informatics Society (Member)
- CHOOSE – Swiss Group for Object-Oriented Systems and Environments (Board Member)

Program Committees

Oscar Nierstrasz

- External Review Committee Member of OOPSLA 2011 (SPLASH/OOPSLA — Portland Oregon, USA, Oct 22-27, 2011)
- PC Member of Onward! 2011 (ACM Conference on New Ideas in Programming and Reflections on Software, colocated with SPLASH/OOPSLA — Portland, Oregon, USA, Oct 22-27 2011)
- PC Member of ICSM 2011 (27th IEEE International Conference on Software Maintenance — Williamsburg, VA, USA, Sept 25 - Oct 1, 2011)
- PC Member GTTSE Summer School (Generative & Transformational Techniques in Software Engineering — Braga, PT, July 3-9, 2011)
- PC Member of C5 (The Tenth International Conference on Creating, Connecting and Collaborating through Computing — U Southern California, USA, Jan 18-20, 2012)
- PC Member of SE 2012 (Software Engineering 2012 — Berlin, Germany, Feb 27 - March 2, 2012)
- PC Member of Smalltalk Directions (Colocated with Smalltalk Industry Conference 12 — Biloxi, Mississippi, USA, March 19-21, 2012)
- PC Member of XP2012 (XP2012 Theme: Agile By Design — Malm, Sweden, May 21-25 2012)
- Tutorials Co-Chair for ICSE 2012 (34th International Conference on Software Engineering — Zurich, Switzerland, June 2-9, 2012)
- PC Member of ICPC 2012 (20th IEEE International Conference on Program Comprehension — Passau, Germany, June 11-13, 2012)

Mircea Lungu

- PC Member of the Posters and Tool Demos Track of ICSE 2012 (34th International Conference on Software Engineering — Zurich, Switzerland, June 2-9, 2012)
- PC Member of WCRE 2012 (19th Working Conference on Reverse Engineering — Kingston, Ontario, Canada, October 15-18)
- PC Member of the Tool Demo Track of ICSM 2012 (The 28th IEEE International Conference on Software Maintenance — Riva del Garda, Italy, Sept 23-30, 2012)
- PC Member of the Tool Demo Track of ICSM 2011 (The 27th IEEE International Conference on Software Maintenance — Williamsburg, VA, USA, Sept 25-Oct 1, 2011)
- PC Member of the Tool Demo Track of the ESEC/FSE 2011 (The 8th Joint Meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering — Szeged Hungary, September 5-9, 2011)
- PC Member of CSMR 2012, (The 16th European Conference on Software Maintenance and Reengineering — Szeged Hungary, March 27-30, 2012)
- PC Member of CSMR 2011 (The 15th European Conference on Software Maintenance and Reengineering — Oldenburg, Germany, March 14, 2011)
- PC Member of IWPSE/EVOL 2011 (The 12th International Workshop on Principles on Software Evolution 7th ERCIM Workshop on Software Evolution — Szeged Hungary, September 5-6, 2011)

Jorge Ressia

- Co-organizer of DYLA 2012 (Workshop on Dynamic Languages and Applications – co-located with PLDI/ECOOP 2012, June 9 2012, Beijing, China).
- PC Member of DYLA 2012 (Workshop on Dynamic Languages and Applications – co-located with PLDI/ECOOP 2012, June 9 2012, Beijing, China).

- PC Member of IWST 2012 (International Workshop on Smalltalk Technologies – co-located with ESUG 2012, Gent, Belgium, August 28, 2012).
- PC Member of MDSM 2011 (First International Workshop on Model-Driven Software Migration – co-located with CSMR2011, March 14, 2011, Oldenburg, Germany)

Reviewing Activities

Oscar Nierstrasz

- FWO (Research Foundation Flanders)
- Elsevier Science of Computer Programming
- Swiss National Science Foundation
- Netherlands Organisation for Scientific Research

Mircea Lungu

- European Commission
- Netherlands Organisation for Scientific Research
- Journal of Systems and Software (JSS), Elsevier
- Science of Computer Programming (SCP), Elsevier
- Empirical Software Engineering (EMSE), Springer
- Journal of Software Maintenance and Evolution: Research and Practice (JSME), Willey & Sons
- Journal of Software and Systems Modeling (JSoSyM), Springer

Fabrizio Perin

- CSMR 2012 - Tool Demonstration (European Conference on Software Maintenance and Reengineering)
- Onward 2011 (ACM Conference on New Ideas in Programming and Reflections on Software, co-located with SPLASH/OOPSLA)
- ICPC 2012 (International Conference on Program Comprehension).

- ICSM 2012 (International Conference on Software Maintenance).
- GPCE 2012 (Generative Programming and Component Engineering).
- XP 2012 (International Conference on Agile Software Development)

Jorge Ressia

- Onward! 2011 (ACM Conference on New Ideas in Programming and Reflections on Software – Co-located with SPLASH/OOPSLA, Portland, Oregon USA, October 22-27, 2011)
- ICSM 2011 (IEEE 27th International Conference on Software Maintenance – Williamsburg, VA, USA, September 25-30, 2011)
- SE 2012 (Software Engineering – Berlin, Germany, Feb 27 - March 2, 2012).
- DSAL 2012 (Workshop on Domain-Specific Aspect Languages – Potsdam, Germany, March 26-30).
- ICPC 2012 (20th IEEE International Conference on Program Comprehension – Passau, Germany, June 11-13, 2012)
- ICSM 2012 (International Conference on Software Maintenance – Riva del Garda, Italy, Sept 23-30, 2012).
- GPCE 2012 (Generative Programming and Component Engineering – Dresden, Germany, September 26-27, 2012).
- SLE 2012 (International Conference on Software Language Engineering – Dresden, Germany, September 26-27, 2012).

Niko Schwarz

- ICSM 2012 (International Conference on Software Maintenance).
- Journal of Object Technology, Volume 11, no. 1. (April 2012). Special section on TOOLS Europe 2011.
- ICPC 2012 (20th IEEE International Conference on Program Comprehension — Passau, Germany, June 11-13, 2012)
- SE 2012 (Software Engineering – Berlin, Germany, Feb 27 - March 2, 2012).

- WCRE 2012 (19th Working Conference on Reverse Engineering — Kingston, Ontario, Canada, October 15-18)

Toon Verwaest

- Onward! 2011 (ACM Conference on New Ideas in Programming and Reflections on Software, Co-located with SPLASH/OOPSLA)
- ICMT 2012 (International Conference on Model Transformation)
- ICPC 2012 (20th IEEE International Conference on Program Comprehension — Passau, Germany, June 11-13, 2012)

Erwann Wernli

- XP 2012 (International Conference on Agile Software Development – Malm, Sweden, May 21-25, 2012)
- IST (Information and Software Technology)
- ICSM 2012 (International Conference on Software Maintenance – Riva del Garda, Italy, Sept 23-30, 2012)
- ICMT 2012 (International Conference on Model Transformation – Prague, Czech Republic, May 28-29, 2012)
- GPCE 2012 (Generative Programming and Component Engineering – Dresden, Germany, September 26-27, 2012)
- CSMR 2012 (European Conference on Software Maintenance and Reengineering – Szeged, Hungary, March 27-30, 2012)

6.9 Publications

Journal Papers

- Mircea Lungu, Michele Lanza, and Oscar Nierstrasz. Evolutionary and collaborative software architecture recovery with Software-naut. *Science of Computer Programming (SCP)*, pages available online, to appear in print, 2012. Available from: <http://scg.unibe.ch/archive/papers/Lung12b.pdf>, doi:10.1016/j.scico.2012.04.007.

- Mircea Lungu and Oscar Nierstrasz. Recovering software architecture with SoftwareNaut. *ERCIM News*, 88, January 2012. Available from: <http://ercim-news.ercim.eu/en88/special/recovering-software-architecture-with-softwareNaut>.
- Mircea Lungu, Oscar Nierstrasz, and Niko Schwarz. Big software data analysis. *ERCIM News*, 89, April 2012. Available from: <http://ercim-news.ercim.eu/en89/special/big-software-data-analysis>.
- Oscar Nierstrasz. Agile software assessment with Moose. *SIGSOFT Softw. Eng. Notes*, 37(3):1–5, May 2012. Available from: <http://scg.unibe.ch/archive/papers/Nier12aASA.pdf>, doi:10.1145/180921.2180925.
- Fabrizio Perin, Lukas Renggli, and Jorge Ressa. Linguistic style checking with program checking tools. *Journal of Computer Languages, Systems and Structures*, 2011. Available from: <http://scg.unibe.ch/archive/papers/Peri11aNaturalLanguageCheckingWithProgramCheckingTools.pdf>, doi:10.1016/j.cl.2011.11.002.
- Jorge Ressa, Alexandre Bergel, Oscar Nierstrasz, and Lukas Renggli. Modeling domain-specific profilers. *Journal of Object Technology*, 11(1):1–21, April 2012. Available from: http://www.jot.fm/contents/issue_2012_04/article5.html, doi:10.5381/jot.2012.11.1.a5.
- Niko Schwarz, Mircea Lungu, and Oscar Nierstrasz. Seuss: Decoupling responsibilities from static methods for fine-grained configurability. *Journal of Object Technology*, 11(1), 2012. Available from: http://www.jot.fm/issues/issue_2012_04/article3.pdf, doi:10.5381/jot.2012.11.1.a3.

Conference Papers

- Amir Aryani, Fabrizio Perin, Mircea Lungu, Abdun Naser Mahmood, and Oscar Nierstrasz. Can we predict dependencies using domain information? In *Proceedings of the 18th Working Conference on Reverse Engineering (WCRE 2011)*, October 2011. Available from: <http://scg.unibe.ch/archive/papers/Aria11aWCRE11.pdf>, doi:10.1109/WCRE.2011.17.

- Lile Hattori, Marco D'Ambros, Michele Lanza, and Mircea Lungu. Software evolution comprehension: Replay to the rescue. In *Proceedings of the 19th International Conference on Program Comprehension*, pages 161–170. IEEE Computer Society Press, 2011. Available from: <http://inf.unisi.ch/faculty/lanza/Downloads/Hatt2011a.pdf>, doi:10.1109/ICPC.2011.39.
- Raffael Krebs and Fabrizio Perin. Reverse engineering Java enterprise applications in Eclipse. In *Proc. of the Sixth Workshop of the Italian Eclipse Community (Eclipse-IT)*, pages 28–39, September 2011. Available from: <http://scg.unibe.ch/archive/papers/Kreb11aVera.pdf>.
- Mircea Lungu, Romain Robbes, and Michele Lanza. Recovering inter-project dependencies in software ecosystems. In *ASE'10: Proceedings of the 25th IEEE/ACM International Conference on Automated Software Engineering*. ACM Press, 2010. Available from: <http://scg.unibe.ch/archive/papers/Lung10a.pdf>, doi:10.1145/1858996.1859058.
- Oscar Nierstrasz and Mircea Lungu. Agile software assessment. In *Proceedings of International Conference on Program Comprehension (ICPC 2012)*, pages 3–10, 2012. Available from: <http://scg.unibe.ch/archive/papers/Nier12bASA.pdf>, doi:10.1109/ICPC.2012.6240507.
- Jorge Ressa, Alexandre Bergel, and Oscar Nierstrasz. Object-centric debugging. In *Proceeding of the 34rd international conference on Software engineering, ICSE '12*, 2012. Available from: <http://scg.unibe.ch/archive/papers/Ress12a-ObjectCentricDebugging.pdf>, doi:10.1109/ICSE.2012.6227167.
- Niko Schwarz. Hot clones: A shotgun marriage of Search-Driven development and clone management. In *2012 16th European Conference on Software Maintenance and Reengineering*, volume 0, pages 513–515, Los Alamitos, CA, USA, March 2012. IEEE. Available from: <http://scg.unibe.ch/archive/papers/Schw12d-clones-shotgun-marriage.pdf>, doi:10.1109/CSMR.2012.67.
- Niko Schwarz. Hot clones: Combining search-driven development, clone management, and code provenance. In *2012 34th*

International Conference on Software Engineering (ICSE), pages 1628–1629. IEEE, June 2012. Available from: <http://scg.unibe.ch/archive/papers/Schw12c-clones-provenance.pdf>, doi: 10.1109/ICSE.2012.6227221.

- Niko Schwarz, Mircea Lungu, and Romain Robbes. On how often code is cloned across repositories. In *Proceedings of the 2012 International Conference on Software Engineering, ICSE 2012*, pages 1289–1292, Piscataway, NJ, USA, 2012. IEEE Press. Available from: <http://scg.unibe.ch/archive/papers/Schw12a-scalable-clones.pdf>.
- Erwann Wernli, Mircea Lungu, and Oscar Nierstrasz. Incremental dynamic updates with first-class contexts. In *Objects, Components, Models and Patterns, Proceedings of TOOLS Europe 2012*, pages 304–319, 2012. Available from: <http://scg.unibe.ch/archive/papers/Wern12a.pdf>, doi:10.1007/978-3-642-30561-0_21.

Book Chapters

- Sandro Schulze and Niko Schwarz. How to make the hidden visible — code clone presentation revisited. In Rainer Koschke, Ira D. Baxter, Michael Conradt, and James R. Cordy, editors, *Software Clone Management Towards Industrial Application (Dagstuhl Seminar 12071)*, volume 2, pages 35–38. Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, June 2012. Available from: <http://scg.unibe.ch/archive/papers/Schu12a-clone-representation.pdf>.

Workshop Papers

- Alexandre Bergel, Felipe Bañados, Romain Robbes, and David Röthlisberger. Spy: A flexible code profiling framework. In *Smalltalks 2010*, 2010.
- Jorge Ressa, Fabrizio Perin, and Lukas Renggli. Suicide objects. In *Proceedings of the 6th Workshop on Dynamic Languages and Applications, DYLA '12*, pages 1:1–1:2, New York, NY, USA, 2012. ACM. Available from: <http://scg.unibe.ch/archive/papers/Ress12cSuicide0bjects.pdf>, doi:10.1145/2307196.2307197.
- Erwann Wernli. Theseus: Whole updates of Java server applications. In *Proceedings of HotSWUp 2012 (Fourth Workshop on Hot*

Topics in Software Upgrades), pages 41–45, June 2012. Available from: <http://scg.unibe.ch/archive/papers/Wern12b.pdf>, doi: 10.1109/HotSWUp.2012.6226616.

7 Computer Graphics Group

7.1 Personnel

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* with financial support from a third party

7.2 Overview

The Computer Graphics Group (CGG) was established in September 2008, when Prof. Zwicker joined the University of Bern as the successor of Prof. Bieri. The research of the Computer Graphics Group focuses on fundamental methods to generate and manipulate images using computers. We develop algorithms and systems for realistic and real-time rendering, and animation and modeling of three-dimensional shapes. We are also interested in novel representations for 3D geometry, such as point-based representations. Finally, we investigate signal processing techniques, in particular for multi-view 3D displays. Our research has applications in digital entertainment, multimedia, and data visualization.

Rendering

Rendering, or image synthesis, is a core problem in computer graphics. We develop algorithms for efficient, physically-based rendering. We are also interested in rendering for interactive applications, and we investigate techniques to simulate light transport in real-time.

Animation and Modeling

Computer graphics scenes are composed of three-dimensional shapes that are stored in computer memory using mathematical representations. Our research is concerned with modeling and animating these three-dimensional shapes. We focus on developing sophisticated mathematical methods that allow for realistic shapes and motions, and intuitive user interfaces that make modeling and animation simple and efficient.

Point-Based Graphics

We are interested in novel mathematical representations of three-dimensional shapes. In our research, we show that point-based techniques are viable alternatives to conventional approaches, such as triangle meshes or parametric surfaces, for a variety of applications from rendering to modeling.

Multi-View 3D Displays

Automultiscopic displays show stereoscopic images that can be viewed from any viewpoint without special glasses. They hold great promise for the future of television and digital entertainment. We develop signal processing techniques to optimize image quality by reducing sampling artifacts and adapting the signal to the display properties. We are also interested in multi-view content creation and manipulation techniques.

7.3 Research Projects

Multi-Dimensional Sampling for Image Synthesis

In this project we address research challenges that are still limiting the capabilities of image synthesis technology. In particular, we are developing

more efficient algorithms for image synthesis by studying this problem from the perspective of multidimensional sampling.

Images represent distributions of light. While light in the physical world can be interpreted as a continuous quantity, it needs to be represented discretely for computer processing. This leads to the problem of sampling, which is at the core of this project. Computer graphics deals with various forms of sampled light to achieve realistic and efficient image synthesis. This includes, for example, the notion of light paths that store the amount of light transmitted along paths including several reflections at surfaces; the concept of transport operators that describe how light is passed between pairs of surface points; or radiance distributions that represent the light that is reflected in each direction at each surface point. All three concepts represent multidimensional functions, which means that we need multiple parameters to identify each sample. Light paths are identified by their sequence of intersection points with surfaces. The dimensionality of a light path depends on the number of intersections, but is potentially unbounded. A sample of a transport operator can be identified by a pair of surface points. A surface point is given by two parameters, hence a pair of points is four-dimensional. Radiance distributions are functions of surface locations and directions, therefore they are also four-dimensional. This is to explain why multidimensional sampling plays a central role in image synthesis.

Our research in this project focuses on two areas, realistic image synthesis and light transport for interactive rendering, which at their core involve multidimensional sampling issues. We analyse both topics from the perspective of multidimensional sampling, identify specific research challenges, and develop more efficient and flexible algorithms. Improvements of these core algorithms for image synthesis will find broad applications in computer graphics. They will reduce the resources required for realistic image synthesis, and enable more natural and effective interactive applications.

Research staff: Claude Knaus, Marco Manzi, Fabrice Rousselle, Matthias Zwicker

Financial support: Swiss National Science Foundation

UNITED LIVING COLORS dot CH: Integrating Evolutionary Developmental Genetics, 3D Computer Graphics, and Natural Photonics for Deciphering Variation & Complexity in Reptilian Color Traits

This project integrates the expertise of three research groups in Switzerland (evolutionary and developmental geneticists, University of Geneva; 3D computer graphics scientists, University of Bern; and condensed-matter physicists, University of Geneva) to gain an improved understanding of the mechanisms generating variation, complexity, and convergence of color traits in animals, in particular reptiles.

A key issue in evolution is to understand how morphology and physiology are altered to produce new forms serving novel functions. Basically no study to date integrated genomics/transcriptomics, developmental genetics, quantitative genetics, and extensive phenotyping of corresponding traits in natural populations for a better understanding of the link between genotype and phenotype in an ecological and phylogenetic framework. The pigmentation system in vertebrates is promising for exploring that connection: closely-related species as well as natural populations exhibit astonishing variations in color and color patterns, and this variation is of great ecological importance as it plays critical roles in thermoregulation, photoprotection, camouflage, display, and reproductive isolation (hence, speciation). Other advantages of focusing on color traits are that they can be quantified and modeled objectively, some of the involved signalling pathways have been partly uncovered in model organisms, and they provide among the best examples of convergence within and among species.

In the context of this project, the Computer Graphics Group develops tools for the acquisition of both 3D geometry and color texture at very high resolution on living animals. Further, we perform the mathematical analysis of the acquired texture phenotypes, mathematical modeling of the mechanisms generating color patterns, as well as computer simulations of reaction-diffusion on 3D geometries acquired from real animals.

Research staff: Daljit Dhillon, Matthias Zwicker

Financial support: Swiss National Science Foundation, Sinergia program

Interactive Motion Synthesis for Character Animation

The goal of this project is to develop algorithms for interactive character animation. Synthesizing realistic motion of human characters is a core topic in computer animation and has broad applications in virtual reality for tele-collaboration and training, computer games, and movie production. Many of the most successful character animation techniques are based on recombining fragments of motion capture data. Motion capture data records the motion of real people captured using special cameras. To reuse captured motion data to generate new animations, fragments of the captured data are organized in so-called motion graphs. In motion graphs each graph node corresponds to a pose, and potential transitions between poses correspond to arcs in the graph. They produce natural motions because they directly reuse captured motion data, and they can generate complex motions by concatenating a large number of motion fragments. In most systems, a user needs to provide a number of constraints to specify a motion. Based on the user constraints, motion synthesis is cast as a search problem. A search algorithm finds a path through the motion graph that satisfies the user constraints while minimizing some additional cost function. There are many variations of this scheme available in the literature, describing various ways to construct motion graphs, specify constraints, concatenate and interpolate motion fragments, etc. Because the complexity of searching for an optimal path through a motion graph is exponential to the connectivity of the graph and in the length of the desired motion sequence, it is challenging to apply these techniques for interactive applications.

In this project we develop efficient algorithms to synthesize character animations for interactive applications. Our approach is based on a bidirectional search strategy for motion synthesis using motion graphs. Our goal is to improve the search efficiency while preserving the search quality. In addition, we develop intuitive user interfaces to allow animators to easily specify desired motions. Our approach builds on a sketching metaphor, where the user controls and edits the character animation by indicating desired motions using pen strokes.

Research staff: Wan-Yen Lo, Matthias Zwicker

Video Stabilization for Hand-Held Cameras

Video footage produced using hand-held cameras often suffers from shaky camera motion. This is most common in material captured casually with

small devices such as cell phones or compact cameras. Often, watching such videos can be a rather uncomfortable experience because of excessive camera shake. While it is possible to avoid such problems during video capture using professional equipment such as steadycam stabilizing systems or sophisticated rigs, these are usually too expensive and too complex to use for casual videographers.

The goal of this project is to develop post-processing algorithms that automatically achieve a smooth camera motion after the fact. This is a challenging problem because it involves recovering the actual camera motion in three-dimensional space, obtaining a desired virtual camera motion that is smooth but still similar to the actual motion, and rendering an output video sequence from the perspective of the virtual camera.

Conventional approaches often try to extract information from static objects visible in the video data. The information gathered from static objects makes it possible to recover camera motion using standard techniques. In practice it is quite common, however, that input videos do not contain enough static objects for this to work. The goal of our approach, therefore, is to generalize such techniques to be able to process data that does not allow the extraction of information from static objects.

Research staff: Daniel Donatsch, Matthias Zwicker

Signal Processing for Multi-View 3D Displays

In this project we develop a multi-dimensional signal processing framework and signal processing algorithms for multi-view 3D displays. Multi-View 3D displays offer viewing of high-resolution stereoscopic images from arbitrary positions without glasses. These displays consist of view-dependent pixels that reveal a different color to the observer based on the viewing angle. Although the basic optical principles of multi-view auto-stereoscopy have been known for over a century, it is only recently that displays with increased resolution, or systems based on multiple projectors, have made them practical.

Multi-view displays feature a number of advantages over competing autostereoscopic display technologies, such as stereo-projection systems using shuttered or polarized glasses. Most importantly, multi-view displays do not require users to wear any special glasses, which leads to a more natural and unrestricted viewing experience. They also do not require head tracking to provide motion parallax; instead, they provide accurate perspective views from any point inside a viewing frustum simultaneously.

They are truly multi-user capable, since none of the display parameters needs to be adjusted to a specific individual user.

As a disadvantage, the amount of data that needs to be processed, rendered, and transmitted to such displays is an order of magnitude larger than for stereo-pair projection systems. In this project we develop techniques that aim at performing these operations as efficiently as possible based on a multi-dimensional signal processing framework for multi-view displays. This approach provides a concise tool to study various aspects of data acquisition, processing, rendering, and compression, and it promises to eliminate several drawbacks of multi-view displays that have been unresolved in the past.

Research staff: Gregor Budweiser, Matthias Zwicker

Financial support: Commission for Technology and Innovation CTI

7.4 Master's Theses

- Gregor Budweiser, Semi automatic 2D-3D conversion (April 2012)
- Matthias Griessen, Multiview autostereoscopic displays and rendering (August 2011)
- Simon Fankhauser, Processing of multi-view video data for 3D displays (May 2012)
- Daniel Frey, A global texture pipeline and data-driven matting (August 2012)
- Michael Heimann, Influence of stereoscopic displays on visual saliency (May 2012)
- Marco Manzi, Adaptive sampling and reconstruction for interactive ray tracing (May 2012)

7.5 Bachelor's Theses

- Manuel Rüfenacht, Autostereoscopic image generation (July 2012)
- Remo Diethelm, Microsoft Kinect - technology and applications (July 2012)

- Selina Indermühle, Interactive editing with subdivision surfaces (July 2012)

7.6 Further Activities

Editorial Boards

Matthias Zwicker

- Computer Graphics Forum: The International Journal of the Eurographics Association, Associate Editor

Conference Program Committees

Matthias Zwicker

- ACM SIGGRAPH 2012, August 5 – 9, 2012, Los Angeles, USA
- Eurographics Symposium on Rendering 2012, June 27 – 29, Paris, France
- Eurographics 2012, May 13 – 18, Cagliari, Italy

Reviewing Activities

Claude Knaus

- The Visual Computer
- ACM SIGGRAPH conference

Fabrice Rousselle

- ACM SIGGRAPH conference
- Pacific Graphics conference

Matthias Zwicker

- Swiss National Science Foundation
- European Research Council

- Hasler Stiftung
- ACM Transactions on Graphics
- IEEE Transactions on Visualization and Computer Graphics
- IEEE Transactions on Circuits and Systems for Video Technology
- Computer Graphics Forum, The International Journal of the Eurographics Association
- Computers & Graphics, An International Journal of Systems & Applications in Computer Graphics, Elsevier
- ACM SIGGRAPH conference
- ACM SIGGRAPH Asia conference
- Eurographics conference

Technical and Research Committees

Matthias Zwicker

- Board member of SI-GRAVIS, Special Interest Group on Computer Graphics, Vision, and Visualization of the Swiss Informatics Society (SI)
- Expert for Matura Exams at Gymnasium Burgdorf

7.7 Publications

Journal Publications

- Fabrice Rousselle, Claude Knaus, and Matthias Zwicker: Adaptive Sampling and Reconstruction using Greedy Error Minimization, ACM Transactions on Graphics, 30(6):159:1–159:12, 2011.
- Wojciech Jarosz, Derek Nowrouzezahrai, Robert Thomas, Peter-Pike Sloan, and Matthias Zwicker: Progressive Photon Beams, ACM Transactions on Graphics, 3(6):181:1–181:12, 2011.

Refereed Conference Proceedings

- Wan-Yen Lo, Claude Knaus, and Matthias Zwicker: Learning Motion Controllers with Adaptive Depth Perception, Proceedings of the 2012 ACM/Eurographics Symposium on Computer Animation, 2012.

8 Ph.D. Theses under the Supervision of Professors Emeriti

Hanspeter Bieri

- Marc Hugi, Automatische 3D-Rekonstruktion von physischen Stadtmodellen am Beispiel des klassischen Stadtmodells von Bern
- Lorenz Ammon, Kollaboratives Erstellen grafischer 3D-Modelle in der 3D Digital Content Creation

Horst Bunke

- A. Fischer: Handwriting Recognition in Historical Documents
- E. Indermühle: Analysis of Digital Ink in Electronic Documents

9 Administration

University:

T. Braun: Member of the Committee for Computing Services (Kommission für Informatikdienste)

Faculty:

G. Jäger: Member of the Planning Board
Th. Studer: Member of the Planning Board
M. Zwicker: Member of the Board of Studies

Institute:

T. Braun : Member of Hauskommission Engehalde
G. Jäger: Managing Director of IAM
O. Nierstrasz: Deputy Director of IAM
Th. Strahm: Member of Library Committee Exakte Wissenschaften
Member of Hauskommission Exakte Wissenschaften
Th. Studer: Director of Studies (February 2012 - July 2012)
M. Zwicker: Director of Studies (August 2011 - January 2012)