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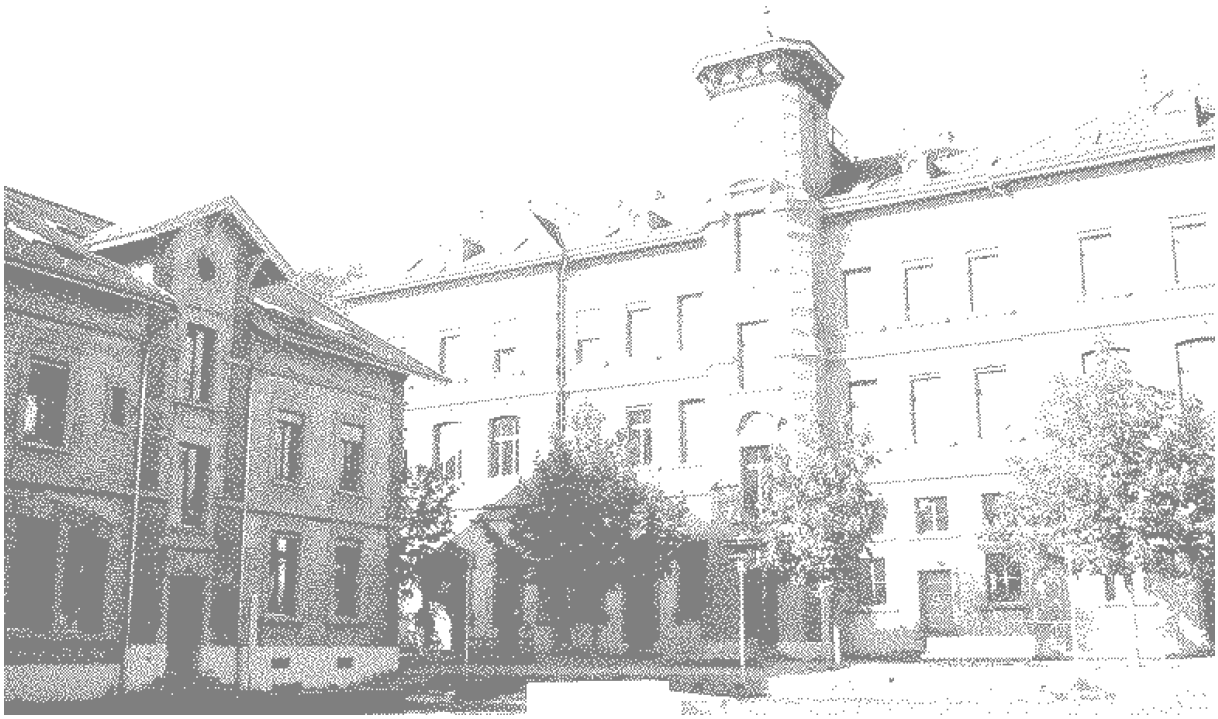
INF Annual Report 14/15



INF Annual Report

Academic Year 2014/2015

September, 2015

Contents

1 Institute of Computer Science (INF)

As of 2015, *the Institute of Computer Science has officially changed its name* to drop the suffix “and Applied Mathematics” (in German, the suffix “und angewandte Mathematik” has been dropped). As a consequence, the acronym has also been changed from IAM to INF, and consequently the web domain and email addresses are being migrated from `iam.unibe.ch` to `inf.unibe.ch`. For the time being, the old addresses will continue to work, but please update your contacts databases to use the new addresses.

1.1 Address

Neubrückstrasse 10, 3012 Bern, Switzerland
Phone: +41 31 631 86 81
E-Mail: info@inf.unibe.ch
http://www.inf.unibe.ch

1.2 Personnel

Members

I. Alyafawi; C. Anastasiades; S. Arjoumand Bigdeli; P. Bertholet; Dr. P. Brambilla; Prof. Dr. T. Braun; A. Caracciolo; Dr. P. Chandramouli; A. Chis; B. Choffat; D. Dhillon; D. Donatsch; D. Esser; Prof. Dr. P. Favaro; M. Gasparyan; A. Gomes; Q. Hu; Prof. Dr. G. Jäger; Dr. A. Jamaković-Kapić; L. Jaun; M. Jin; A. Kashev; I. Keller; I. Kokkinis; J. Kurš; Z. Li; M. Manzi; A. S. Marandi; M. Marti; L. Merino del Campo; N. Milojkovic; Prof. Dr. O. Nierstrasz; H. Osman; D. Perrone; T. Portenier; Dr. D. Probst; F. Ranzi; T. Rosebrock; J. Saltarin; Dr. E. Schiller; D. Schroth; B. Spasojević; Prof. Dr. Th. Strahm; Prof. Dr. Th. Studer; A. Szabo; J. Walker; S. Wu; Dr. Z. Zhao; 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 (August 2011 - July 2015)
Prof. Dr. Oscar Nierstrasz (August 2015 - July 2019)

Director of studies

Prof. Dr. Matthias Zwicker (August 2013 - July 2015)
Prof. Dr. Paolo Favaro (August 2015 - July 2019)

Administration

Bettina Choffat; Dragana Esser; Iris Keller; Daniela Schroth

Technical staff

Dr. Peppo Brambilla; Alexander Kashev

2 Teaching Activities

2.1 Courses for Major and Minor in Computer Science

Autumn Semester 2014

- Bachelor 1st Semester

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

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

  Programmierung 1 (T. Strahm, 5 ECTS)

- Bachelor 3rd Semester

  Computernetze (T. Braun, 5 ECTS)

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

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

- Bachelor 5th Semester

  Anleitung zu wissenschaftlichen Arbeiten (5 ECTS)

  Computergrafik (M. Zwicker, 5 ECTS)

  Machine Learning (P. Favaro, 5 ECTS)

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

- Master Courses

  Computational Photography (M. Zwicker, 5 ECTS)

  Computer Vision (P. Favaro, 5 ECTS)

  Justification Logic (T. Studer, 5 ECTS)

  Lambda Calculus (G. Jäger, 5 ECTS)

Mobile Communications (T. Braun, 5 ECTS)

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

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

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

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

Seminar: Computer Vision (P. Favaro, 5 ECTS)

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

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

- Service Courses

  Anwendungssoftware für Naturwissenschafter
  (T. Studer, 3 ECTS)

  Basic Programming for Non-Informaticians. With Practicals. (P. Brambilla, 5 ECTS)

Spring Semester 2015

- Bachelor 2nd Semester

  Datenbanken (T. Studer, 5 ECTS)

  Datenstrukturen und Algorithmen (P. Brambilla, 5 ECTS)

  Programmierung 2 (M. Lungu, O. Nierstrasz, 5 ECTS)

  Rechnerarchitektur (P. Favaro, 5 ECTS)

- Bachelor 4th Semester

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

  Berechenbarkeit und Komplexität (T. Strahm, 5 ECTS)

  Betriebssysteme (T. Braun, 5 ECTS)

  Praktikum Software Engineering (T. Studer, 5 ECTS)

- Bachelor 6th Semester

  Anleitung zu wissenschaftlichen Arbeiten (5 ECTS)

- Master Courses

  Advanced Networking and Future Internet (T. Braun, 5 ECTS)

  Compiler Construction (O. Nierstrasz, 5 ECTS)

  Complexity Theory (D. Probst, T. Strahm, 5 ECTS)

  Convex Optimization (P. Favaro, 5 ECTS)

  Explicit Mathematics and Type Theory (G. Jäger, 5 ECTS)

  Rendering Algorithms (M. Zwicker, 5 ECTS)

  Scientific Reading in Computer Networks (T. Braun, 5 ECTS)

  Scientific Writing in Computer Networks (T. Braun, 5 ECTS)

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

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

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

  Seminar: Computer Vision (P. Favaro, 5 ECTS)

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

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

- Service Courses

  Anwendungssoftware für Naturwissenschafter
  (T. Strahm, 3 ECTS)

  Applied Biological Image Processing (K. Riesen, 2 ECTS)

2.2 Colloquium in Computer Science

20/11/2014 Dr. Stefan Marr
Inria France, Lille
Programming Language Implementations

05/12/2014 Dr. Philipp Murkowsky
Puzzle ITC, Bern
Human-Computer-Interaction-Design in der Praxis

18/02/2015 Dr. Remo Ziegler
Vizrt, Zürich
Visual computing for sports broadcasting

2.3 Students

- Major Subject Students: AS 2014: 163, SS 2015: 177
- Minor Subject Students: AS 2014: 62, SS 2015: 78
- Ph.D. Candidates: AS 2014: 27, SS 2015: 33

2.4 Degrees and Examinations

- PhD: 2
- Master: 19
- Bachelor: 20
- Completion of Minor Studies: 20 (90E: 1, 60E: 2, 30E: 11, 15E: 6 (630 ECTS))
- Semester Examinations AS 2014: 636 (2389 ECTS)
- Bachelor's/Master's Theses AS 2014: 14 (310 ECTS)
- Semester Examinations SS 2015: 442 (1766 ECTS)
- Bachelor's/Master's Theses SS 2015: 18 (300 ECTS)

2.5 Activities

- Visitor Program, Gymnasium Kirchenfeld/Bern, October 23, 2014
- Contribution to the "National Future Day for Girls and Boys", Bern, November 13, 2014

- Contribution to the “Tag für Studieninteressierte”, December 2 + 3, 2014
- Taster course for female students, Bern, March 26, 2015
- Visitor Program, Gymnasium Thun-Schadau, Bern, July 2, 2015

2.6 Awards

- Annual Alumni Award 2014 for Fabrice Rousselle’s Ph.D. thesis “Image Space Adaptive Rendering”
- Annual Alumni Award 2014 for Siavash Bigdeli’s Master’s thesis “3D Light Field Photography and Applications”
- Annual Alumni Award 2014 for Michael Single’s Bachelor’s thesis “Diffraction Shaders”

3 Research Group on Communication and Distributed Systems

3.1 Personnel

Head:	Prof. Dr. T. Braun	Tel.: +41 31 511 2631 email: braun@inf.unibe.ch
Office Manager:	D. Schroth	Tel.: +41 31 511 2630 email: schroth@inf.unibe.ch
Scientific Staff:	Dr. I. Aad *	Tel.: +41 31 511 7645 email: aad@inf.unibe.ch (until 30.08.2014?)
	I. Alyafawi*	Tel.: +41 31 511 7631 email: alyafawi@inf.unibe.ch
	C. Anastasiades	Tel.: +41 31 511 2635 email: anastasi@inf.unibe.ch
	Dr. E. Bourtsoulatze*	Tel.: +41 31 511 7645 email: bourtsoulatze@inf.unibe.ch (until 30.06.2015)
	M. Gasparyan*	Tel.: +41 31 511 2639 email: gasparyan@inf.unibe.ch (since 01.06.2015)
	A. Gomes*	Tel.: +41 31 511 2636 email: gomes@inf.unibe.ch
	Dr. A. Jamakovic-Kapic*	Tel.: +41 31 511 2637 email: jamakovic@inf.unibe.ch (until 31.07.2015)
	Z. Li*	Tel.: +41 31 511 2638 email: li@inf.unibe.ch
	D. Mansour*	Tel.: +41 511 2634 email: mansour@inf.unibe.ch (until 28.02.2015)
	A. Marandi*	Tel.: +41 31 511 2639 email: marandi@inf.unibe.ch (since 01.05.2015)

	J. Saltarin*	Tel.: +41 31 511 2639 email: saltarin@inf.unibe.ch
	Dr. E. Schiller*	Tel.: +41 31 511 2633 email: schiller@inf.unibe.ch (since 15.08.2014)
	Dr. Z. Zhao*	Tel.: +41 31 511 2639 email: zhao@inf.unibe.ch
External		
Ph.D. Students:	A. Antonescu	email: antonescu@inf.unibe.ch
	M. Thoma	email: thoma@inf.unibe.ch
	L. Luceri	email: luceri@inf.unibe.ch
Guests:	B. Gill	Aalto University, Finland Trainee from 15.04 - 30.06.2015

* with financial support from a third party

3.2 Overview

The research group ”Communication and Distributed Systems” has been investigating how multimedia applications and cloud computing services with high demands on the quality, reliability and energy efficiency can be supported by mobile communication systems and networks. Moreover, we are investigating localization mechanisms for wireless devices and new Future Internet paradigms such as Information-Centric Networking.

3.3 Research Projects

SwissSenseSynergy

The SwissSenseSynergy project aims to bring together research from closely related fields, which have recently emerged due to the proliferation of wireless computing devices. In particular, the ubiquity of smart phones as well as plans to deploy large numbers of small, local-range base stations (femto cells) creates many opportunities for synergistic computation as well as numerous privacy and security concerns. At the same time, these services are much more user-centric than traditional ones. This project aims to to develop a framework for delivering secure localisation and location-based services (LBS) to users, while optimally trading off privacy requirements with user value, network performance and reliability. The following target application scenario illustrates these requirements. Application scenario: Mobility and navigation are important for a modern lifestyle. However, current navigation applications are typically limited to a few transportation modes and miss complex environmental properties or subtle user preferences. We envision an application, where information about user preferences, transportation modes, and the environment are combined into a user-oriented navigation and recommender system. Information may include real-time traffic data, public transportation, rental vehicles, air quality, weather conditions, safety ratings and user habits. The system shall suggest places to visit, transportation modes, as well as important traffic and environmental data to city officials. Users will benefit in by improved social interactions, handling mobility more sustainably and efficiently, while preserving privacy. The scenario includes several scientific challenges and research topics, which are spread across computer science and can only be met by cooperation among the consortium of SwissSenseSynergy. More precisely these include

- Localisation & prediction: Due to short range of small cell network

base stations, it is important to accurately determine the locations of mobile devices, so that handover and resource allocation can be efficiently performed in the network. Localisation can provide location-based services such as traffic prediction and is crucial to extract the semantic meaning of the location to be able to predict the mobility of the user at larger time-scales.

- Resource allocation & optimisation: Due to the trend of smaller (femto) network cells and high mobility of users, it is important to have lightweight algorithms for optimising network topology and allocating bandwidth appropriately. This heavily depends upon a good localisation model.

- User-centric location based services & crowd-sourcing: Localisation can be combined with crowd-sourcing, where mobile users supply the service with local information e.g. to create a real-time map of traffic conditions. The main challenges are to develop models for human behaviour and preferences, to ensure privacy and the accuracy of user-supplied information.

- Privacy-preservation & security: Wireless communications and crowd-sourcing raise privacy concerns, due to tracking and data collection. We aim to minimise privacy issues by developing privacy-preserving algorithms for localisation, resource allocation, prediction and crowd-sourcing. A major challenge is to combine this with mechanisms for ensuring the reliability of user-supplied information.

- Social behaviour & profile of users: The system needs to generalise the model of the user to include her environment (e.g., weather or air quality), her properties, preferences and habits, but also the other people around her. Extracting this social profile, the interconnections, and similarities between people will enable a system to adapt to the user, instead of the user adapting to the system.

Individual partners, responsible for one of the above mentioned research topics, will consider valuable knowledge from other partners to develop solutions addressing the identified problems in a collaborative way. The target application scenario will serve as a proof-of-concept and guideline for the whole project, while individual services and algorithms will be developed by each partner. The overall goal of SwissSenseSynergy is to provide a unifying framework for secure and privacy-preserving location-based services.

The CDS group is involved in the localization and tracking tasks. To design accurate indoor positioning methods based on the most popular wireless communication techniques, i.e., WiFi and LTE, we have adopted software defined radio techniques to set up a passive localization and tracking testbed for IEEE 802.11n (WiFi) signals, which use similar physical layer mechanisms (OFDM and 20MHz bandwidth) as LTE signals. Based on this testbed, we have already achieved several scientific contributions in the area of range-based indoor localization and tracking. We have investigated multipath mitigation algorithms based on channel information in OFDM system and proposed a ranging method based on non-linear regression method, which is more accurate than the commonly used log-distance path loss model. For indoor localization, we proposed an enhanced trilateration algorithm, which combines weighted centroid and constrained weighted least square algorithms (WC-CWLS). The algorithm achieves a mean positioning error of $2.4m$ for static targets and is more robust to ranging errors than linear least square algorithm. For indoor tracking, we proposed an enhanced particle filter to deal with the inaccurate likelihood estimation and moving model problems. With this enhanced particle filter, we are able to track the user with a mean error of $1.5m$.

Research staff: T. Braun, A. Hossmann, Z. Li, Z. Zhao

Financial support: Swiss National Science Foundation Sinergia project number 154458

Mobile Cloud Networking

Mobile Cloud Networking (MCN) is a EU FP7 large-scale Integrating Project (IP) funded by the European Commission, and launched in November 2012 for a period of 36 months. In total 19 partners from industry and academia perform research on MCN.

The project is primarily motivated by an ongoing transformation that drives the convergence between the mobile communication and cloud computing industry, enabled by the Internet. These observations led to a number of objectives to be investigated, implemented and evaluated over the course of the project. The top-most objectives of the MCN project are to: a) extend the concept of cloud computing beyond data centres towards the mobile end-user, b) to design an 3GPP-compliant Mobile Cloud Networking architecture that exploits and supports cloud computing, c) to enable a novel

business actor, the MCN provider, and d) to deliver and exploit the concept of an end-to-end MCN for novel applications and services. The key research and innovation issues of the MCN project are: a) how to virtualise the Radio Access Networks (RAN), b) how to design a cross-domain Infrastructure-as-a-Service (IaaS) control plane, c) how to upgrade virtualisation and cloud computing middleware to support highly demanding, real-time network applications and services, d) how to design, deploy and operate mobile communication software components to attain and fully benefit from cloud computing attributes, e) how to ensure QoE with advanced content and service migration mechanisms for mobile cloud users and f) how to support multiple cross-domain aspects that must service a multitude of business actors and stakeholders.
The CDS group is involved in the following technical work packages (WP): WP3 on Mobile Cloud Infrastructural Foundations, WP4 on Mobile Network Cloud, and WP5 on Mobile Platform. Besides, the CDS group is leading WP7 on Dissemination, Exploitation, Standardisation activities.
The scope of work within WP3 of the project is to offer a comprehensive testing framework for the LTE radio access network (RAN). In particular, the framework allows the virtualisation of base stations (running a base station in the cloud) and the development of novel algorithms for the RAN such as load balancing which can exploit the advantages of virtualisation in order to improve mobility management and service delivery. The task has delivered initial evaluations on the computational needs of LTE base stations and how running the network functions in the cloud can influence execution time. Moreover, for the management of a virtualised RAN, an architectural model was designed, consisting of entities for communication with the end users as well as orchestration of the virtual, computational and networking resources. Implementation work on the architecture was initiated and testing is currently being done.
The scope of WP4 is to develop a novel Mobile Core Cloud concept to support on-demand and dynamic deployment of mobile core networks in a cloud computing environment. In the second project year, the research activities of WP4 mainly cover the implementation and performance evaluations of Mobility and Bandwidth Prediction as a service (MOBaaS).
Mobility and Bandwidth as a service (MOBaaS) is a MCN service that generates user mobility and bandwidth prediction information to be used by any MCN defined services in order to generate triggers needed for self-adaptation procedures, e.g., optimal run-time configuration, scale-out and scale-in of service instance components, or optimal network function placement. We have successfully designed and implemented the prediction algorithms and the cloudification mechanism such that the service

can be instantiated on-demand by any other MCN services to provide prediction information. We have performed extensive performance measurements to validate the functions of MOBaaS on our in-house OpenStack cloud infrastructure. Evaluation results show that MOBaaS could provide single/group mobility and bandwidth prediction with good prediction accuracy and latency.
A key contribution of WP5 is to design and implement the follow-me cloud concept, which aims to provide cloud services and data to the mobile user as close as possible to minimize delays and improve performance. Significant contributions were made to the cloud orchestration framework, the Follow-Me Cloud concept development and the Information-Centric Networking integration into legacy and cloudified mobile networks. Such work has proven to be key in minimizing content access time and network load, while not creating relevant extra load on the cloud computing infrastructure. The work also contributed to other work packages in the project, namely to the performance evaluation carried out within Task ”Real-time Performance of Infrastructure Resource Management Frameworks” and to end-to-end evaluations performed in Task ”Experimentation and Evaluation”.
As the project entered its third year, work on WP6 Integration has also started. In particular, definition of all interfaces and the interdependence of MCN services on each other is established. To allow for smooth integration and demonstration, common functional tests are defined, based on which performance evaluation and troubleshooting can be done.

Research staff: I. Aad, I. Alyafawi, T. Braun, A. Gomes, A. Jamakovic-Kapic, Z. Li, E. Schiller, Z. Zhao

Financial support: EU FP7 Large-scale Integrating Project (IP), contract number CNECT-ICT-318109

Network Coding Based Multimedia Streaming in Content Centric Networks

Information Centric Networking architectures (ICN) have recently gained significant attention in the research community, as they promise to revolutionize the way data is exchanged in the Internet. They move from the traditional paradigm of Internet communication using IP addresses towards using names as addresses. This is motivated by the fact that when users browse the Internet, they care only about the data content and not where

the content is stored. On the contrary, the IP model of communication focuses on where the data is located. Several problems are associated with the current IP network architecture like usability, performance, security and resilience to mobility. To cope with some of these limitations, content distribution networks (CDN) and peer-to-peer architectures have been proposed. These methods mainly deal with the scalability issue and attempt to exploit better the available network resources. CDN and P2P could be seen as a first step towards ICN. Network coding has been presented a decade ago as an efficient technique for heterogeneous both wired and wireless overlay networks to increase the throughput, decrease the delay, enhance resilience, remove the need for coordination between the network nodes etc. There are two major classes of network coding algorithms namely Linear Network Coding (LNC) and Random Linear Network Coding (RLNC). Both methods operate in finite fields. LNC decides about the coding operations centrally, although there are some decentralized designs, whereas RLNC randomly performs operations in finite fields and has only a small performance penalty compared to LNC when operations are in large finite fields. Network coding is interesting for multimedia communication. The challenge with multimedia is that data is often scalable and data delivery should respect the tight decoding deadlines.
In this project, we envisage the design of novel network coding methods that will promote the use of ICN. We are building our techniques on the Content Centric Networking (CCNx) implementation, since it has many advantages like hierarchical prefixes and being open source. Some abstract ideas regarding the use of network coding in CCN have been very recently discussed. It mainly provides some examples motivating the appropriateness of network coding for the ICN framework, rather than specific solutions. In our perspective, specific problems should be resolved prior to employing such technologies. Specifically, open challenges are: what kind of prefixes should be used, security issues, where to cache information, how one can deal with multiple concurrent sessions accessing the network, could data correlation be exploited?
In the first year of the project we developed a protocol for integrating network coding in CCN. In comparison to previous works proposing to enable network coding in CCN, our proposal permit Interest aggregation and Interest pipelining, which reduce the data retrieval times. The experimental evaluation shows that the proposed protocol leads to significant improvements in terms of content retrieval delay compared to the original CCN. Our results demonstrate that the use of network coding adds robustness to losses and permits to exploit more efficiently the available network resources. The performance gains are verified for content retrieval in various

network scenarios.
Currently we are focused on multimedia streaming applications, as it is the main source of data traffic in today's Internet. We will further target on the employment of our methods in social networks deployed when users want to share multimedia data. We believe that the ICN paradigm fits well into the framework of multimedia communication over social networks as users can take advantage of multiple interfaces to acquire the multimedia data faster and exploit efficiently the cached data as typically many users seek for the same multimedia data. We are convinced that the employment of network coding in CCN will accelerate the data delivery, improve multimedia quality, enable better the available resources, and revolutionize the caching strategies in CCN framework by considering data importance.

Research staff: E. Bourtsoulatze, T. Braun, A. Marandi, J. Saltarin

Financial support: Swiss National Science Foundation project number 149225

Algorithms, Architectures and Platforms for Enhanced Living Environments (AAPELE)

Ambient Assisted Living (AAL) is an area of research based on Information and Communication Technologies (ICT), medical research, and sociological research. AAL is based on the notion that technology and science can provide improvements in the quality of life for people in their homes, and that it can reduce the financial burden on the budgets of European healthcare providers. The concept of Enhanced Living Environments (ELE) refers to the AAL area that is more related with the Information and Communication Technologies. To design, plan, deploy and operate, an AAL system often comprehends the integration of several scientific areas. The Architectures, Algorithms and Platforms for Enhanced Living Environments (AAPELE) COST Action addresses the issues of defining software, hardware and service architectures and on studying and creating more efficient algorithms and protocols for AAL. Related CDS research activities include localization of wireless devices as well as activity detection of mobile users.

Research staff: I. Alyafawi, T. Braun, Z. Li

Financial support: European Science Foundation, COST Action IC1303

Service-Centric Networking

Content-centric network (CCN) is a new and promising networking paradigm. CCN aims at moving from the host-to-host communication style to a new paradigm that focuses on content as the building block of the future Internet architecture. However, CCN does not consider the concept of services in its architecture. We believe that services, rather than content, should be the center of focus in future network architectures. This is due to the fact that content is just a subset of services and what applies to services can easily apply to content, but not the other way around.

Service-centric network (SCN) is a new networking paradigm where services are at the heart of its architecture. SCN is an object-oriented architecture where services and contents are considered as objects. Our research aims at building the SCN architecture based on CCN with extensions regarding service naming, name resolution, service routing, and service management.

We built the NextServe framework to support the publication, invocation, and orchestration of services over CCN. The naming scheme of NextServe allows services to be invoked by name. Also service results can be cached within the CCN network improving the response time significantly.

Authentication and trust in the service are another crucial topic in SCN. Legacy authentication methods can be applied to ICN without any major issues: the owner of a content signs using his private key, and publishes both content and signature, to be used by the receiver to verify that no alterations have been made on the way.

In SCN, the content is to be ”serviced” by any service point that is not necessarily trusted, thus invalidating the signature of the original content. We are investigating authentication techniques that can be used by a receiver to validate contents even after being changed by intermediate service points, without necessarily involving the owner of the original content.

Research staff: I. Aad, T. Braun, B. Gill, D. Mansour

Financial support: Swiss National Science Foundation Project No. 146376

Aproximate Decoding of Network Codes in Wireless Sensor Network

The recent advances in the field of sensing and wireless technology have fostered the deployment of wireless sensor networks (WSN) in a wide range of monitoring applications, such as industrial process monitoring, surveillance, natural phenomena monitoring etc. The common feature of all WSNs is that they typically consist of low-cost sensing devices with limited energy and processing power that are interconnected over the unreliable wireless medium. These constraints pose new challenges in terms of communication and data gathering protocol design which must comply with the low processing power requirements and the dynamic nature of the network. In an attempt to overcome the limitations of the state-of-the-art routing protocols, a new type of data gathering algorithms for WSNs have been proposed that rely on the concept of linear network coding (LNC). In LNC, the sensor nodes linearly combine the received data before forwarding it to the next hop nodes. This simple in-network processing has been proven to increase the overall throughput of the network and to improve the robustness to packet losses. In addition, the LNC operations can be performed in a distributed manner, which is of great importance for WSN applications with rapid changes in the sensor network topology.
While significant research efforts have focused on the design of well-performing network codes, less attention has been given to the problem of approximately recovering the source data when the network coded data available at the sink node is not sufficient for perfect decoding. The problem that we study in this project is twofold. Our first goal is to establish the sufficient conditions on the number of the network coded symbols that must be available at the decoder so as to approximately reconstruct the observed sensor data with respect to some fidelity criterion. The key challenge of this analysis is to properly define and quantify the amount of additional (side)information that is available at the decoder, and derive the lower bound on the number of required network coded symbols that achieves a certain reconstruction performance, as a function of the available side information and the given network coding parameters. The result of this analysis will provide insights into the theoretical performance limits of the considered approach and will guide the design of a practical decoding method for source data recovery from an incomplete set of network coded symbols. Our second objective is to propose a decoding algorithm that is able to approximately recover the observed sensor data using prior information on the inter-sensor correlation. The key challenge is to properly exploit the side information available at the decoder in or-

der to efficiently compensate for the missing network coded symbols. We propose a novel approach for exploiting the redundancy that is present in the sensed data in order to transform the rank deficient system of linear equations into an overdetermined system. We then propose to apply methods from the theory of channel coding in order to design effective low complexity decoding algorithms.

Research staff: E. Bourtsoulatze

Financial support: Hasler Foundation (from 01.01.2015 to 30.06.2015)

Enterprise Integration of WSNs and IoT-devices

The aim of the project is to investigate new methodologies to enable interoperability between wireless sensor networks (in general various heterogeneous Internet of Thing devices (IoT) devices) and enterprise IT systems. The project assumes that the lower layers of a typical IoT/WSN protocol stack is mature and concentrates on application layer protocols, service-based integration of devices and (semantic) data content abstraction. We implemented a novel semantic overlay for IoT protocols, based on a semantic service description language (Linked USDL). The project created an Internet of Things (IoT) enterprise architecture as well as investigated two approaches for integration of semantics at a service level: First, a top-down approach downscaling an enterprise protocol towards small embedded devices. Second, a bottom-up approach where the semantic information is encoded separately from the actual service. It features an implementation of the Constrained Application Protocol (CoAP) for IBM Mote Runner, a reactive VM-based operating system, and – on top of that – the OData protocol. Furthermore, a business operations-aware sleepy nodes implementation has been developed, that allows long term sleeping of IoT-devices based upon semantic information.
Evaluation results show that the performance of the platform is very promising and the overhead imposed by the semantic overlay is reasonable compared to alternatives. OData, as one example of an enterprise-level protocol has been studied and its feasibility on an IoT-device level has been demonstrated. Furthermore, an empirical study on the challenges and opportunities of semantics in IoT has been conducted.

Research staff: T. Braun, M. Thoma

Financial support: SAP (Switzerland) Inc. (until 31.03.2015)

Scaling of Distributed Applications in Cloud Computing Environments

Cloud computing enables provisioning and distribution of highly scalable services in a reliable, on-demand and sustainable manner. Our project's aim is to model and test different virtual machine (VM) scaling policies based on both Service Level Agreements (SLAs) and application-level monitoring information. We assume that the management system will control enterprise distributed applications, which are able to scale horizontally by increasing the number of VMs allocated to running the application's services. We employ SLAs for describing the performance invariants of the distributed application and then we use the SLAs as input to the management system for scaling the number of application's VMs under varying workload conditions. We consider different SLA scaling policies, both reactive and predictive. Reactive scaling simply responds to changes in the SLA compliance level (e.g. ratio of the current value of a application metric and its maximum allowed value) by changing the number of VMs allocated to a service until the SLA ratio returns to a safe value (e.g. between 0.6 and 0.9). We also developed a SLA scaling mechanism using results from queueing theory, by controlling the number of allocated VMs based on the relation between the concurrent number of requests executed by the service and the average execution time obtained at that concurrency level. We are currently extending these mechanisms to incorporate a prediction component. We are investigating the usage of both regression and non-linear mechanisms for forecasting the values of near-future workload. The project also explores modelling of distributed applications by characterising application performance under different workload patterns. We built a statistical model of the distributed application's performance by profiling the execution times of atomic operations and inter-service network round-trip times. These statistical models are then used for constructing a simulation model of the target application in CloudSim cloud simulator. We have extended CloudSim to support simulation of multiple cloud tenants (isolated applications with different SLA contracts), accurate time-shared CPU scheduling of concurrent tasks and multiple SLA-based VM scaling managers.

We have evaluated the accuracy of workload modelling in CloudSim by comparing the execution results in both a real distributed small-scale testbed and then by replicating the same workload in our extended simula-

tor. The outcomes of evaluating the reactive and predictive scaling mechanisms are encouraging and seem to validate using them as reliable means of scaling cloud systems.

Research staff: T. Braun, A. Antonescu

Financial support: SAP (Switzerland) Inc.

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, we deployed two powerful servers for offering virtual machines/networks in a fast and user-friendly way, one running Xen (http://xenserver.org/) and the other running OpenStack (http://www.openstack.org/). Virtualization alleviates the overhead of buying, setting up and managing virtual machines/networks, offering the users/researchers efficient and easy ways of running their experiments while reducing the financial costs and saving time, on a network that is not a simulation one.
Our research group also 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 infrastrucuture. 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 Master's Theses

- Marcel Stolz: An LTE Signal Analyser, July 2015
- Jürg Weber: Dynamic Adaptation of Transmission Modes for Opportunistic Content-Centric Networks, July 2015
- Tobias Schmid: Agent-Based Data Retrieval for Opportunistic Content-Centric Networks, July 2015
- Arnaud Durand: Distributed wideband software-defined radio receiver for heterogeneous systems, March 2015

3.5 Bachelor's Theses

- Oliver Stapleton: Service Distribution Mechanisms in Information-Centric Networking, July 2015
- Simon Kiener: Hybrid Indoor Localization Using Multiple Radio Interfaces, July 2015
- Adrian Kurt: Indoor Tracking with Kalman Filters Using Rss- Based Ranging, June 2015
- Arun Sittampalam: Content Discovery in Wireless Information-Centric Networks, May 2015
- René Gadow: Persistent Caching in Information-centric Networking, April 2015
- Nina Mujkanovic: Synchome - Synchronization Application For Mobile Content Retrieval, March 2015

- Urs Zysset: Improved Power-based Lateration via Wall Attenuation Factor, February 2015
- Lukas von Rotz: Adaptive Interest Lifetime for Content-Centric Requests, February 2015
- Konstantin Niedermann: Network Coding based Interactive Multiview Video Streaming in ICN Networks, February 2015
- Mansour Hamidi: Mobility Recognition Based on Android Sensors to Improve Indoor Localization, February 2015
- Alexander Striffeler: Raptor Coding in Mobile Content Centric Networks, August 2014

3.6 Further Activities

Memberships

Torsten Braun

- Erweitertes Leitungsgremium Fachgruppe "Kommunikation und Verteilte Systeme"', Gesellschaft für Informatik
- SWITCH Stiftungsrat
- SWITCH Stiftungsratsausschuss
- Vice President of SWITCH foundation
- Kuratorium Fritz-Kutter-Fonds
- Expert for Diploma Exams at Fachhochschule Bern
- Expert for Matura Exams at Gymnasium Köniz Lerbermatt
- Management committee member of COST Action IC 1303 Algorithms, Architectures and Platforms for Enhanced Living Environments (AAPELE)
- 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 Informatik Spektrum, Springer
- Editorial Board Member of MDPI Journal of Sensor and Actuator Networks

Conference Chairs

Torsten Braun

- Wired/Wireless Internet Communications 2015, Steering committee, Malaga, Spain, May 25-27, 2015
- International Symposium on Quality of Service 2014, Steering committee, Portland, OR, USA, June 15 - 16 2015

Conference Program Committees

Torsten Braun

- International Conference on Distributed Computing and Networking (ICDCN 2015), BITS Pilani, January 4-7, 2015
- Leistungs-, Zuverlässigkeits- und Verlässlichkeitsbewertung von Kommunikationsnetzen und verteilten Systemen (MMBnet 2015)
- The 8th International Workshop on Communication Technologies for Vehicles, Sousse, Tunisia, May 6-8 2015
- The 6th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT 2014), Saint-Petersburg, Russia, October 6-8 2014
- The International Conference on Network and Service Management (CNSM 2014), Rio de Janeiro, Brazil, November 17-21 2014
- 7th International Workshop on Multiple Access Communications, Halmstad, Sweden, August 27-28 2014
- 3rd IEEE International Conference on Cloud Networking (CLOUDNET 2014), Luxembourg City, Luxembourg, October 8-10 2014

- The 14th NEW2AN co-located with the 7th Conference on Smart Spaces ruSMART, Saint-Petersburg, Russia, August 27 - 29, 2014
- 80th IEEE Vehicular Technology Conference (VTC2014-Fall), Vancouver, Canada, September 14—17 2014
- 12th EAI International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services, Coimbra, Portugal, July 22-–24 2015
- The Conference on Networked Systems (NetSys), Cottbus, Germany, March 09-12 2015
- The 30th ACM/SIGAPP Symposium On Applied Computing (SAC 2015), Salamanca, Spain, April 13-17, 2015
- IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM 2015), Boston, MA, USA, June 14-17, 2015
- The IFIP Networking 2015 Conference (Networking 2015), Toulouse, France, May 20—22, 2015
- IEEE International Workshop on Software Defined 5G Networks (Soft5G 2015), London, U.K., April 17 2015
- Workshop on Micro Aerial Vehicle Networks, Systems, and Applications for Civilian Use (DroNet 2015), Florence, Italy, May 22, 2015
- International Workshop on Quality, Reliability, and Security in Information-Centric Networking, Rhodes Island, Greece, August 20, 2014

Zhongliang Zhao

- Sensor Networks Track, IEEE ISSNIP 2015
- Pervasive Computing Track, IEEE MobiSPC 2015

Project and Person Reviewing Activities

Torsten Braun

- Research Council of Norway

- Academy of Finland
- Leibniz-Gemeinschaft
- IWT - Flemish agency for Innovation by Science and Technology

Journal Article Reviewing Activities

Torsten Braun

- Elsevier Computer Networks
- IEEE Communications Magazine
- IEEE Communications Letters
- Springer Lecture Notes in Computer Science

Carlos Anastasiades

- Elsevier Journal of Network and Computer Applications (JNCA)
- Springer Wireless Networks (WINE)

Eirina Bourtsoulatze

- IEEE Transactions on Multimedia
- IEEE Communication Letters
- IEEE Transactions on Communications
- IEEE/ACM Transactions on Networking
- KSII Transactions on Internet and Information Systems
- EURASIP Journal on Image and Video Processing

André Gomes

- IEEE Wireless Communications Magazine

Eryk Schiller

- International Journal of Ad Hoc and Ubiquitous Computing (IJAHUC)

Zhongliang Zhao

- IEEE Transactions on Multimedia
- MDPI Journal Sensors
- IEEE Transactions on Vehicular Technology

Invited Talks and Tutorials

Torsten Braun

- ”Mobile Cloud Networking”, Keynote at Latin American Computing Conference (CLEI 2014), Montevideo, September 18, 2014
- ”Telematiknetze”, Bundesamt für Bevölkerungsschutz, November 25, 2014, Schwarzenburg
- ”Communication and Distributed Systems”, COST Action IC1303, 3rd WG Meeting, Malta, May 28-29, 2015
- ”Security and Privacy in the Internet of Things”, Panel at IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks, IEEE WoWMoM, June 14-17, 2015, Boston, MA, USA
- ”Content-Centric Networking in Wireless Networks”, I-CAN Workshop and Intensive Summer School on Information-Centric Access Networks, Athens University of Economics and Business, Athens, June 2-5, 2015
- ”Service-Centric Networking”, I-CAN Workshop and Intensive Summer School on Information-Centric Access Networks, Athens University of Economics and Business, Athens, June 2-5, 2015
- ”Authentication, Authorization, Accounting, and Auditing in Wireless Mesh Networks” , University of Neuchatel, February 5, 2015

Eryk Schiller

- ”Dynamic Chain Encryption Channel for Wireless Community Networks”, E. Schiller, P. Kropf, T. Braun, Workshop Autonome Systeme 2014 (AutSys2014), 26-30 October 2014 in Cala Millor, Mallorca, Spain.
- ”Virtual Networks”, E. Schiller, Islam Alyafawi, Torsten Braun, Navid Nikaein, Lúcio Ferreira, 8th IC1004 Training School: From Hetnets to Cloud Radio Access Networks, Luxembourg, 21-23 Apr. 2015.

Zhongliang Zhao

- ”Future communication architecture for mobile cloud services”, Software Defined Networking (SDN) workshop, organized by SWITCH, University of Bern, June 11 2015

3.7 Publications

Publications submitted in the academic year 2014/2015 and appearing in the following academic year are not listed.

Book Chapters

- V. Bernardo, T. Braun, M. Curado, M. Fiedler, D. Hock, T. Hossmann, K. Hummel, P. Hurni, S. Ickin, A. Jamakovic, S. Nadjm-Tehrani, T. Trinh, E. Vergara, F. Wamser, and T. Zinner. Green wireless-energy efficiency in wireless networks. In *Large-scale Distributed Systems and Energy Efficiency: A Holistic View*, pages 81–130. March 2015. ISBN:978-1-118-86463-0

Reviewed Conference Papers

- C. Anastasiades, N. Thomos, A. Striffeler, and T. Braun. RC-NDN: Raptor codes enabled named data networking. In *IEEE International Conference on Communications (ICC)*. June 2015.

- Z. Li, T. Braun, and D. Dimitrova. A time-based passive source localization system for narrow-band signal. In *The IEEE International Conference on Communications (ICC) 2015*. June 2015.

- A. Gomes and T. Braun. Load balancing in lte mobile networks with information-centric networking. In: *IEEE ICC 2015 - Third International Workshop on Cloud Computing Systems, Networks, and Applications (CCSNA)*. June 2015.

- I. Alyafawi, E. Schiller, and T. Braun, Desislava Cvetanova Dimitrova, André Sérgio Nobre Gomes, and Navid Nikaein. Critical issues of centralized and cloudified lte-fdd radio access networks. In *IEEE ICC 2015 - Next Generation Networking Symposium (ICC'15 (07) NGN)*. June 2015.

- Z. Li, T. Braun, and D. Dimitrova. A passive wifi source localization system based on fine-grained power-based trilateration. In *IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, pages 1–9. June 2015. doi:10.1109/WoWMoM.2015.7158147

- Z. Li, T. Braun, and D. Dimitrova. Methodology for gps synchronization evaluation with high accuracy. In *The IEEE 81st Vehicular Technology Conference (VTC2015-Spring)*, pages 1–6. May 2015. doi:10.1109/VTCSpring.2015.7145929

- A. Antonescu and T. Braun. Service level agreements-driven management of distributed applications in cloud computing environments. In *IFIP/IEEE International Symposium on Integrated Network Management, Dissertation Session*. May 2015. :doi:10.1109/INM.2015.7140442

- C. Anastasiades and T. Braun. Towards information-centric wireless multi-hop communication. In *Wired/Wireless Internet Communications. The 13th International Conference on Wired & Wireless Internet Communications.*, volume 9071 of *Lecture Notes in Computer Science*. May 2015. doi:10.1007/978-3-319-22572-2

- L. Pimentel, D. Rosário, M. Seruffo, Z. Zhao, and T. Braun. Adaptive Beaconless Opportunistic Routing for Multimedia Distribution. In *Wired/Wireless Internet Communications. The 13th International Conference on Wired & Wireless Internet Communications.*, volume 9071 of *Lecture Notes in Computer Science*. May 2015. doi:10.1007/978-3-319-22572-2

- A. Durand, M. Gasparian, T. Rouvinez, I. Aad, T. Braun, and T. Trinh. Bitworker, a decentralized distributed computing system based on bittorrent. In *Wired/Wireless Internet Communications. The 13th International Conference on Wired & Wireless Internet Communications*, volume 9071 of *Lecture Notes in Computer Science*. May 2015. doi:10.1007/978-3-319-22572-2

- Z. Li, A. Hossmann, and T. Braun. Range-based weighted-likelihood particle filter for rss-based indoor tracking In: *Proceedings of the 1st KuVS Expert Talk on Localization*, issue AIB-2015-8 of *Aachener Informatik-Berichte*. April 2015. ISSN:0935–3232

- A. Gomes and T. Braun. Feasibility of information-centric networking integration into lte mobile networks. In *The 30th ACM/SIGAPP Symposium On Applied Computing*, pages 627–633. April 2015. doi:10.1145/2695664.2695790

- T. Taleb, M. Corici, C. Parada, A. Jamakovic, S. Ruffino, G. Karagiannis and T. Magedanz. EASE: EPC as a service to ease mobile

core network deployment over cloud. In *IEEE Network*, vol.29, no.2, pp.78-88. March-April 2015. doi:10.1109/MNET.2015.7064907

- C. Anastasiades and T. Braun. Dynamic transmission modes to support opportunistic information-centric networks. In *International Conference on Networked Systems (NetSys 2015)*. March 2015. doi:10.1109/NetSys.2015.7089077

- Z. Li and T. Braun. A passive source localization system for ieee 802.15.4 signal. In *The International Conference on Network Systems (NetSys) 2015 (Demostration Session)*. March 2015.

- A. Antonescu and T. Braun. Simulation of sla-based vm-scaling algorithms for cloud-distributed applications. *Future Generation Computer Systems*, February 2015. doi:10.1016/j.future.2015.01.015

- A. Lapin and E. Schiller. Integrated cloud-based computational services. In *7th GI Workshop on Autonomous Systems (AutSys2014)*, number 835 in Informatik/Kommunikationstechnik. October 2014.

- F. Dudouet, P. Harsh, S. Ruiz, A. Gomes, and T. Bohnert. A case for cdn-as-a-service in the cloud: A mobile cloud networking argument. In *International Conference on Advances in Computing, Communications and Informatics (ICACCI) 2014*. September 2014. doi:10.1109/ICACCI.2014.6968495

- Z. Zhao and T. Braun. Real-world evaluation of sensor context-aware adaptive duty-cycled opportunistic routing. In *39th Annual IEEE Conference on Local Computer Networks (IEEE LCN'14)*. September 2014. doi:10.1109/LCN.2014.6925764

- A. Antonescu and T. Braun. Modeling and simulation of concurrent workload processing in cloud-distributed enterprise information systems. In *ACM SIGCOMM Workshop on Distributed Cloud Computing (DCC 2014)*. August 2014. doi:10.1145/2627566.2627575

- V. Bernardo, B. Correia, M. Curado, and T. Braun. Towards end-user driven power saving control in android devices. In *14th International Conference on Next Generation Wired/Wireless Networking (NEW2AN 2014)*, volume 8638 of *Lecture Notes in Computer Science*. August 2014. doi:10.1007/978-3-319-10353-2_20

- D. Rosario, Z. Zhao, T. Braun, E. Cerqueira, and A. Santos. A comparative analysis of beaconless opportunistic routing protocols

for video dissemination over flying ad-hoc networks. In *14th International Conference on Next Generation Wired/Wireless Networking (NEW2AN 2014)*, volume 8638 of *Lecture Notes in Computer Science*. August 2014. doi:10.1007/978-3-319-10353-2_22

- G. Wagenknecht and T. Braun. Testbed evaluation of sensor node overlay multicast. In *14th International Conference on Next Generation Wired/Wireless Networking (NEW2AN 2014)*, volume 8638 of *Lecture Notes in Computer Science*. August 2014. doi:10.1007/978-3-319-10353-2_24

- A. Lapin, E. Schiller, P. Kropf, O. Schilling, P. Brunner, A. Jamakovic, T. Braun, and S. Maffioletti. Real-time environmental monitoring for cloud-based hydrogeological modeling with hydrogeosphere. In *1st International Workshop on HPC Applications*. August 2014. doi:10.1109/HPCC.2014.154

- I. Alyafawi, D. Dimitrova, and T. Braun. SDR-based passive indoor localization system for GSM. In *ACM SIGCOMM Software Radio Implementation Forum (SRIF) 2014*. August 2014. doi:10.1145/2627788.2627790

Technical Reports

- H. Mercier, T. Braun, P. Felber, P. Kropf, P. Kuonen, and E. Riviere. 2015 Doctoral Workshop on Distributed Systems. Technical Report IAM-15-002, Le Louverain (NE), Switzerland, June 2015.

- C. Anastasiades, A. Gomes, R. Gadow, and T. Braun. Persistent Caching in Information-Centric Networking. Technical Report IAM-15-001, Bern, Switzerland, May 2015.

- I. Alyafawi, E. Schiller, T. Braun, D. Dimitrova, A. Gomes, and N. Nikaein. Critical issues of centralized and cloudified LTE FDD radio access networks. Technical Report IAM-14-002. Bern, Switzerland, October 2014.

4 Computer Vision Group

4.1 Personnel

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4.2 Overview

Prof. Dr. P. Favaro joined the Institute of Computer Science and established the Computer Vision group in June 2012. The Computer Vision group conducts research on the broad areas of image processing, machine vision, pattern recognition, and imaging and sensor design by employing models, algorithms and analysis tools from optimization theory, probability theory, and applied mathematics. Our general aim is to extract high-level information from images by using digital processing. Such high-level information can be in the form of geometric or photometric quantities about objects in the scene, or semantic attributes such as their category, their function, etc. In order to achieve this aim, we use a systematic approach based on three pillars: modeling, inference and experimental validation. The first step in digital processing requires modeling sensors and distortions of their measured signals such as optical aberrations (defocus and motion blur), noise, spatial loss of resolution and quantization. Moreov er, a careful analysis of models allows us to design novel imaging architectures that can more efficiently and accurately capture visual data. For

instance, light field cameras (recently become a commercial product) allow for single-snapshot digital refocusing (i.e., the ability to change the focus plane of an image after capture via digital processing) by incorporating a microlens array in conventional cameras. Models also allow us to infer their parameters or a distribution of their parameters by assuming some stochastic description of the data. Parameter estimation can then performed via optimization techniques, which require a careful selection of suitable algorithms and understanding of their behavior. Finally, both sensor and data models are validated experimentally by using both synthetic and real data. Currently, our efforts have been devoted to problems in: inverse imaging (deblurring, blind deconvolution, super resolution), 3D estimation (multi view stereo, photome tric stereo, coded aperture photography), motion estimation (structure from motion, tracking), and, more recently, in object categorization.

4.3 Research Projects

Image Deblurring

In photography, motion blur is an unpleasant artifact generated by camera shake and object motion during the exposure time. In some cases it is possible to avoid the problem by using the so called “lucky image” method, which amounts to taking many images and selecting the one with the best quality. If it is not possible to take many images of the same event, then the “lucky image” method can not be used. It might also happen that all the images are blurred. In this project, we consider the case where a single blurry image is available and one wants to recover a corresponding sharp image. Since no information on the motion of the camera or of the objects is given, this problem is also called *blind deconvolution*.
To estimate a sharp image one has to estimate some kind of information on the motion that generated the blurry image. This information can be represented mathematically as a function, called Point Spread Function (PSF). Each pixel of the blurry image can be represented as a convex combination of pixels of the sharp image in terms of the PSF. Since the estimation of blur function and sharp image has more unknowns than the dimension of input image, the problem is particularly challenging and a regularization prior is required.
Many successful image priors enforce sparsity of sharp image gradients. Ideally the L_0 “norm” is the best choice for promoting sparsity, but because it is computationally intractable, some methods have used a logarithmic

approximation. We also study a logarithmic image prior and empirically show how well the prior suits the blind deconvolution problem. Our analysis experimentally confirms the hypothesis that a prior should not necessarily model natural image statistics to correctly estimate the blur kernel. Furthermore, we show that a simple Maximum a Posteriori (MAP) formulation is enough to achieve state of the art results. To minimize such a formulation we devise two iterative algorithms that cope with the non-convexity of the logarithmic prior: one obtained via the primal-dual approach and one via majorization-minimization.

Research staff: Daniele Perrone, Paolo Favaro

Shape Learning

Our ultimate objective is to learn the shape of objects from unannotated images alone i.e., to create a 3D model of an object category. This is analogous to structure from motion (SFM) algorithms, where the task is to reconstruct the 3D structure of a single object instance from multiple view-points. However, while in SFM algorithms images depict the same object from different viewpoints, in our case images only share the same category. We explore steps from the SFM pipeline, focusing on how we can extend them to fit our problem.
The first step of many SFM techniques is establishing correspondences between images. In our case the appearance of the objects can change dramatically across images. In order to get good correspondences, good features are needed that are robust to appearance changes. We look at two techniques. First, we study CNN (convolutional neural network) features, that are known to be robust to appearance changes. Next, we learn part detectors with exemplar deformable parts models (DMP) using SVM learning and HOG features. We find that DPM gives good correspondences, but is computationally very costly. Correspondence matching with CNN features is fast, but the performance is not comparable with trained DPMs.
Another aspect of 3D reconstruction is view-point estimation. Because the part correspondences are not enough accurate to obtain useful 3D reconstructions, we look at estimating the relative view-points directly from image pairs. We use a number of global feature representations (CNN, HOG) to build a nearest neighbor classifiers to connect similar view-points. We find that CNN features give comparable results to exemplar DPM, but are much faster. We experiment with spectral clustering and various em-

bedding techniques to group view-points and reconstruct the pose of the objects in all images.

Research staff: Attila Szabó, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 149227

Light Field Blind Deconvolution

A light field (or plenoptic) camera is endowed with the ability of capturing spatio-angular information of a light field. Because of this ability, it is possible to obtain scene depth maps and render effects such as digital refocusing from a single image. While a conventional camera captures a projection of rays from a 3D scene onto a 2D plane, a light field camera aims to capture the intensity and direction of all incoming rays. The use of plenoptic cameras has been gaining popularity since the past few years. Different models of plenoptic cameras are becoming commercially available for consumer photography as well as for industrial inspection . However, despite their many advantages, light field (LF) cameras are not immune to blur artifacts. In many practical scenarios, either due to camera shake or motion of objects in the scene, a LF image can get motion-blurred. Unfortunately, existent texture rendering algorithms for LF cameras do not have the ability to remove motion b lur.
Thus, we address for the first time the issue of motion blur in light field images captured from plenoptic cameras. We propose a method for single image blind deconvolution with a space-varying blur due to the depth changes in the scene. Our method employs a layered model that also handles occlusions and partial transparencies due to both motion blur and the out of focus blur of the light field camera. We then reconstruct each layer and the corresponding sharp texture and motion blur via an optimization scheme. The performance of our algorithm is demonstrated on synthetic as well as real light field images with space-varying motion blur.

Research staff: Meiguang Jin, Paramanand Chandramouli and Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 153324

Development of an automated optical system for quantification of fluorescent bacterial cells

This work was a part of Aquavalens project which is funded by the European Union with an aim to protect the health of Europeans by improving methods for detection of pathogens in drinking water and water used in food preparation. We developed an imaging system that automatically detects and counts the bacterial cells present in a filter. The project was carried out with consultations from partners Vermicon and TZW (formerly DVGW).

Fluorescent In Situ Hybridization (FISH) technology allows direct detection of single E. coli and coliform bacterial cells on filter membranes. The system consists of an epifluorescence microscope with a camera, a frame grabber, a motorized mechanical table with XYZ-axis control and a PC station. The field of view of the camera is very small when compared to the dimensions of the filter. Also, the filter needs to be scanned along a set of focal planes. Consequently, a brute force approach for scanning a filter would involve capturing images at all possible XYZ locations and performing cell detection on all of these images. For a filter of diameter 20mm, this would take about 66 hours, which is not feasible for practical applications. Moreover the quantification methods for single cells are far from robust and still need skilled and well trained technicians.

Our system overcomes these issues and achieves the objectives with a processing time of eight hours per scan. In our approach, we modify the scanning procedure and significantly reduce the number of images that have to be saved and processed. The time for a full scan can be potentially reduced to less than three hours with better optics. The proposed detection algorithm is based on support vector machines (SVM), a modern pattern recognition technique to detect and count cells. This technique automatically learns to distinguish cells from the background by using a large number of examples of correct cells provided by the experts. The same system can also be adapted to detect other types of cells. Another useful feature of our system is that the user can reposition the microscope after a scan, at the same exact location where cells have been detected, and manually validate the cell counting.

Research staff: Paramanand Chandramouli, Paolo Favaro

Financial support: EU Aquavalens Project Grant Agreement No. 311846

Sketch-based Image Synthesis

Aim of this project is to enable users to design realistic images by sketching any desired scene. The user may provide an abstract layout of a scene, or more detailed sketches including textures, and the system will generate a realistic image. The user may interact with the system by altering the sketch, adding or removing details, or requesting the tool to automatically enhance the sketch from the current synthesis result, which can then be manipulated in turn.
We propose to develop novel solutions for generating realistic images from sketches. We envision an interactive system that finds and carefully matches image content to a sketch, by using a combination of geometric and photometric deformations that are low-order globally and piecewise smooth locally. Moreover, to limit the magnitude of the geometric deformations, our solution exploits a hierarchical matching of sketch parts at different scales.
Our assumption is that content in real images can be matched closely to the sketch at some scale. For example, it might not be possible to find a real image of a specific viewpoint of a smiling face, but it might be more likely to find real images of a specific viewpoint of parts of the face, e.g., the nose, the eyes, the mouth and so on. Because we strongly rely on the input sketch, we also introduce an important novel step in its analysis. To assist the author with creating an accurate sketch, our proposed system will automatically detect symmetries, repeating patterns, and perspective effects, and allow the user to amend the sketch by enforcing exact regularity of these properties. Furthermore, the system will use these properties while matching with real images to determine viewpoints, textural patterns and to deal with occlusions.

Research staff: Qiyang Hu, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 156253

4.4 Ph.D. Thesis

- Daniele Perrone, “Towards a Novel Paradigm in Blind Deconvolution: From Natural to Cartooned Image Statistics”, July 2015.

4.5 Bachelor's Thesis

- Simon Jenni, "A Study of 3D Deformable Parts Models for Detection and Pose-Estimation", March 2015.

4.6 Further Activities

Invited Talks

Paolo Favaro

- Invited Talk at University of Cambridge, Electrical Engineering Dept, UK 2015.
- Invited Talk at Computer Vision Lab, Computer Science Department, UCLA 2015.
- Invited Talk at IPAM - Computational Photography and Intelligent Cameras, UCLA 2015.
- Invited Talk at University of Saint Etienne, France.
- Invited Talk at University of Bern, IAP Laser Physics.
- Invited Talk at the Istituto Italiano di Tecnologia, Genova.

Conference Program Committees

Paolo Favaro

- Co-Organizer (with Ashok Veeraraghavan and Kari Pulli) of ICCP 2015;

Reviewing Activities

Paolo Favaro

- British Machine Vision Conference (BMVC)
- Conference on Computer Vision and Pattern Recognition (CVPR)
- Conference on Energy Minimization Methods in Computer Vision and Pattern Recognition (EMMCVPR)

- International Conference on Computer Vision (ICCV)
- European Conference on Computer Vision (ECCV)
- SIAM Journal on Imaging Sciences
- Signal Processing
- International Journal on Computer Vision
- IEEE Transactions on Image Processing
- Pattern Analysis and Machine Intelligence
- Computer Vision and Image Understanding

Paramanand Chandramouli

- IEEE Transactions on Image Processing
- Computer Vision and Image Understanding

Daniele Perrone

- Eurographics 2015
- IEEE Transactions on Image Processing
- Journal of Electronic Imaging

4.7 Publications

Journal Publications

- R. Vidal, and P. Favaro , “Low-Rank Subspace Clustering (LRSC)”, Pattern Recognition Letters, 2014.

Refereed Conference Proceedings

- T. Papadhimitri and P. Favaro, “Uncalibrated Near-Light Photometric Stereo”, British Machine Vision Conference (BMVC) 2014.
- T. Gaspar, P. Favaro and P. Oliveira, “Synchronization of Two Independently Moving Cameras Without Feature Correspondences”, European Conference on Computer Vision (ECCV) 2014.
- M. Hosseini Kamal, P. Favaro and P. Vandergheynst, “A Convex Solution to Disparity Estimation from Light Fields via the Primal-Dual Method”, International Conference on Energy Minimization Methods in Computer Vision and Pattern Recognition (EMMCVPR), 2015.
- D. Perrone, R. Diethelm and P. Favaro, “Blind Deconvolution via Lower-Bounded Logarithmic Image Priors”, International Conference on Energy Minimization Methods in Computer Vision and Pattern Recognition (EMMCVPR), 2015.

5 Logic and Theory Group

5.1 Personnel

Head:	Prof. Dr. G. Jäger	Tel: +41 (0)31 631 85 60 email: jaeger@inf.unibe.ch
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	T. Rosebrock*	Tel.: +41 (0)31 511 76 33 email: rose@inf.unibe.ch
	Dr. K. Sato*	email: sato@inf.unibe.ch (until 30.09.2014)
	Prof. Dr. T. Strahm	Tel.: +41 (0)31 631 49 98 email: strahm@inf.unibe.ch
	Prof. Dr. T. Studer	Tel.: +41 (0)31 631 39 84 email: tstuder@inf.unibe.ch
	J. Walker*	Tel.: +41 (0)31 511 76 32 email: walker@inf.unibe.ch
	Dr. J. Werner*	email: werner@inf.unibe.ch (until 30.04.2015)

Guests:	Dr. J. J. Joosten	Universitat de Barcelona,

	Dept. Lògica, Història i Filosofia de la Ciència, Spain May 2015
Prof. Dr. R. Kahle	Universidade Nova de Lisboa, Departamento de Matemática, Portugal June 2015
Prof. Dr. I. Oitavem	Universidade Nova de Lisboa, Departamento de Matemática, Portugal June 2015

* 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 general framework of this project is the proof-theoretic analysis of systems of second order arithmetic, of explicit mathematics, and of operational set theories. In particular, we examine wellordering proofs in connection with higher types and suitable inductive definitions. A further aspect of research is related to abstract computability theory in an operational setting, thus aiming towards an operational descriptive set theory.

Research staff: G. Jäger, D. Probst, F. Ranzi, T. Rosebrock, K. Sato, T. Strahm

Financial support: Swiss National Science Foundation

Structural Proof Theory and the Logic of Proofs

The Logic of Proofs has been introduced by Artemov to solve a long-standing problem of a classical provability semantics for intuitionistic logic. The main idea of his approach was to introduce proof polynomials into the object language in order to represent the structure of proofs. The idea has proved itself fruitful and resulted in the formal study of proof structure in this and other contexts, including self-referentiality of modal reasoning, epistemic paradoxes, and logical omniscience problem. In this proposal, we continue expanding the benefits of using the more expressive language of the Logic of Proofs to various areas of computer science, focusing on temporal logics, traditionally used for describing properties of reactive systems, and belief revision, which studies operations for changing agents' beliefs in accordance with new information. We also continue our investigation of the applications of proof polynomials to logics of common knowledge and dynamic epistemic logics, which describe internal epistemic attitudes of rational agents and groups of agents in static and dynamic epistemic scenarios. The new Track B of this proposal sets forth a foundational

study of fixed points in the constructive modal framework. While both intuitionistic modal logics and modal mu-calculus have received attention from the scientific community (the latter more than the former), there is virtually no study on constructive modal fixed-points, making the line of investigations proposed in Track B pioneering in this respect.

Research staff: G. Jäger, A. Kashev, I. Kokkinis, M. Marti, T. Studer

Financial support: Swiss National Science Foundation

Logics for Privacy

Consider a system of communicating agents where each agent has his own set of knowledge. An agent may share some part of this knowledge with other agents and he may consider some information as sensitive and thus keep it private. The privacy problem for an agent consists in sharing as much knowledge as possible while at the same time protecting all sensitive information. If an agent is asked about knowledge that he considers private, he has two options to keep the secret: 1. he can refuse to answer the question, or 2. he can give an incorrect answer, that is he can lie. The answering protocol determines whether a query is answered truthfully or whether (and how) the answer is distorted or refused. In this project we study the privacy problem for description logic knowledge base systems and we develop algorithms for various privacy strategies. In particular, we investigate controlled query evaluation mechanisms for ontological knowledge base systems.

This project ended in April 2015.

Research staff: T. Studer, J. Werner

Financial support: Swiss National Science Foundation

Function Algebras and Theories for Computation Complexity

The relation of recursion-theoretic characterizations in the vein of implicit computational complexity and corresponding applicative theories is well explored for classes like FPtime and FPspace. Using the original concept

of recursion with pointers, the vising fellow has developed function algebras for complexity classes based on models for non-deterministic and parallel computations, like NP and FPspace (alternating polytime). Our final goal is to extend these approaches to probabilistic classes like PP and BPP. Having that in mind we first focus on the counting class #P and in the hierarchy of the counting functions (FCH). We believe that they will work as pivot classes to reach probabilistic classes of complexity. We have a purely recursion-theoretic characterization of #P and all levels of FCH, and we are working on an applicative theory for FCH.

Research staff: I. Oitavem, T. Strahm

Financial support: SNF Short visits program

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. Thesis

- J. M. Werner: Controlled Query Evaluation in General Semantics with Incomplete Information

5.5 Bachelor's Theses

- P. Bogdanovic: Implementing Deduction Chains for the Proof Search Calculus
- D. Feller: SQL Skripte zur Vorlesung Datenbanken
- P. Frischknecht: A Proof of the Arithmetical Equivalence of EC with Full Induction and ACA
- J. Fuog: A Proof Search Implementation in Python for Justification Logic
- N. Wälle: Graph Database Fundamentals
- M. L. Wong: Tutorial of NoSQL

5.6 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 Strahm

- Member of the Consulting Board of Dialectica

Technical and Research Committees

Gerhard Jäger

- PC Member of the Fifth International Conference on Logic, Rationality, and Interaction, Taipei City, 2015
- Swiss Delegate to the IFIP Technical Committee 1 (Foundations of Computer Science)
- Board Member 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
- Member of the Kantonale Maturitätskommission
- Expert for “Maturitätsprüfungen Mathematik und Informatik”

Dieter Probst

- Expert for “Maturitätsprüfungen Mathematik und Informatik”

Thomas Strahm

- Board Member of the Swiss Society for Logic and Philosophy of Science
- Expert for “Maturitätsprüfungen Informatik”

Thomas Studer

- President of the Swiss Society for Logic and Philosophy of Science
- Swiss representative in the International Union of History and Philosophy of Science
- Expert for “Maturitätsprüfungen Mathematik und Informatik”
- Rapporteur and member of the PhD jury for Sabine Frittella, Aix-Marseille University, December 2014

Jan Walker

- Board Member of the Swiss Graduate Society of Logic and Philosophy of Science

Organized Events

Ioannis Kokkinis

- Münchenwiler Seminar, Münchenwiler, October 2014 and March 2015.

5.7 Publications

- Luca Alberucci, Jürg Krähenbühl, and Thomas Studer. Justifying induction on modal μ-formulae. *Logic Journal of IGPL*, 22(6):805–817, 2014.

- Samuel Bucheli, Roman Kuznets, and Thomas Studer. Realizing public announcements by justifications. *Journal of Computer and System Sciences*, 80(6):1046–1066, 2014.

- Ulrik Buchholtz, Gerhard Jäger, and Thomas Adrian Strahm. Theories of Proof-Theoretic Strength $\psi(\Gamma_{\Omega+1})$. In Dieter Probst and Peter Schuster, editors, *Concepts of Proof in Mathematics, Philosophy, and Computer Science*, volume 6 of *Ontos Mathematical Logic*. De Gruyter, to appear.

- Sebastian Eberhard. Applicative theories for logarithmic complexity classes. *Theoretical Computer Science*, 585:115–135, 2015.

- Sebastian Eberhard and Thomas Adrian Strahm. Unfolding Feasible Arithmetic and Weak Truth. In Theodora Achourioti, Henri Galinon, José Martínez Fernández, and Kentaro Fujimoto, editors, *Unifying the Philosophy of Truth*, volume 36 of *Logic, Epistemology, and the Unity of Science*, pages 153–167. Springer Netherlands, Dordrecht, 2015.

- Melvin Fitting and Roman Kuznets. Modal interpolation via nested sequents. *Annals of Pure and Applied Logic*, 166(3):274–305, 2015.

- Dandolo Flumini and Kentaro Sato. From hierarchies to well-foundedness. *Archive for Mathematical Logic*, 53(7-8):855–863, 2014.

- Gerhard Jäger and Rico Zumbrunnen. Explicit mathematics and operational set theory: some ontological comparisons. *The Bulletin of Symbolic Logic*, 20(03):275–292, 2014.

- Ioannis Kokkinis, Petar Maksimović, Zoran Ognjanović, and Thomas Studer. First steps towards probabilistic justification logic. *Logic Journal of IGPL*, 23(4):662–687, 2015.

- Ioannis Kokkinis and Thomas Studer. Cyclic Proofs for Linear Temporal Logic. In Dieter Probst and Peter Schuster, editors, *Concepts of*

Proof in Mathematics, Philosophy, and Computer Science, volume 6 of *Ontos Mathematical Logic*. De Gruyter, to appear.

- Roman Kuznets and Thomas Studer. Weak arithmetical interpretations for the logic of proofs. *Logic Journal of the IGPL*, to appear.
- George Metcalfe and Michel Marti. A Hennessy-Milner Property for Many-Valued Modal Logics. In Rajeev Goré, Barteld Kooi, and Agi Kurucz, editors, *Advances in Modal Logic*, volume 10 of *AiML*, pages 407–420. College Publications, London, 2014.
- Florian Ranzi and Thomas Adrian Strahm. A note on the theory $\mathrm{SID}_{<\omega}$ of stratified induction. *Mathematical Logic Quarterly*, 60(6):487–497, 2014.
- Kentaro Sato. Forcing for hat inductive definitions in arithmetic. *Mathematical Logic Quarterly*, 60(4-5):314–318, 2014.
- Kentaro Sato. Relative predicativity and dependent recursion in second-order set theory and higher-orders theories. *The Journal of Symbolic Logic*, 79(03):712–732, 2014.
- Kentaro Sato. A new model construction by making a detour via intuitionistic theories II: Interpretability lower bound of Feferman's explicit mathematics T_0. *Annals of Pure and Applied Logic*, 166(7-8):800–835, 2015.
- Kentaro Sato. Full and hat inductive definitions are equivalent in NBG. *Archive for Mathematical Logic*, 54(1-2):75–112, 2015.
- Kentaro Sato and Rico Zumbrunnen. A new model construction by making a detour via intuitionistic theories I: Operational set theory without choice is Π_1-equivalent to KP. *Annals of Pure and Applied Logic*, 166(2):121–186, 2015.
- Thomas Studer and Johannes Martin Werner. Censors for boolean description logic. *Transactions on Data Privacy*, 7(3):223–252, 2014.

6 Software Composition Group

6.1 Personnel

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*with financial support from a third party

6.2 Overview

Software systems that are used in practice must evolve over time to maintain their relevance, yet as systems evolve, they become more complex and harder to evolve. The Software Composition Group carries out research into tools, techniques and programming language mechanisms to enable the graceful evolution of complex software systems.

6.3 Research Projects

Agile Software Assessment

SNSF project #200020-144126/1
This project aims to increase the efficiency and effectiveness of software developers that are faced with software assessment tasks which include understanding legacy code, taking decisions about the system design and architecture, and making sure that these decisions are respected during the evolution of the system. To support this level of decision making, developers should be able to swiftly build dedicated tools that automate tedious software analysis tasks.
The project is organized into four orthogonal tracks. We summarize briefly our progress in each track over the past year:

- **Meta-Tooling.** Developers ask detailed and domain-specific questions about the software systems they are developing and maintaining and often they are limited to using generic development tools to answer these questions. Generic development tools, while universally applicable, make it difficult to answer domain-specific questions. We showed that tailoring debuggers to the domain of an application (e.g. parsers, message-passing infrastructures, information visualization infrastructures) significantly improves the debugging process. We are currently exploring new approaches to enable customization in other types of development tools: the *Moldable Inspector* supports the rapid composition and adaptation of object inspectors to the particularities of individual tasks and objects, while *Spotter* aims at a uniform approach for specifying and integrating searching within IDEs.

- **Agile Modeling.** A key bottleneck to effective software assessment is the construction of appropriate software models from program source code and the associated data sources. We improved a novel parsing techniques developed in the past years, that allow us to quickly construct such models: (1) we extended *bounded seas* to be compatible with layout sensitive rules thus being able to determine a scope of nested structures such as classes, methods and blocks based on indentation, (2) we improved *layout-sensitive parsing expression grammars* to support the principled specification of languages like Markdown and, (3) we investigated the possibilities of improving performance of bounded seas and parser combinator libraries in general.

- **Large-Scale Software Analysis.** With the rise of interest in open-source projects, public software repositories are filled with valuable data such as source code version history, configuration files, and bug reports. Being able to query, data mine, and monitor these repositories can reveal various facts about software systems, language features, and developer behaviour. When put in use, this knowledge helps develop tools to improve software reliability and reduce development friction. We have developed several pipelines for analyzing large software data in a scalable manner. The first pipeline analyzes the bug-fix code changes and extracts syntactic patterns. The second pipeline analyzes the use of *null* and *null checks* in Java code. The third pipeline automates the building of bug predictors based on software-derived data (software metrics) to point out the most bug-prone software entities. All three pipelines help developers find potential bugs, prioritize testing and code reviewing activities, and eventually improve software overall quality.

- **Architectural Monitoring**. The architecture of a software system consists of the design constraints that guarantee non-functional properties, such as ease of evolution, good run-time performance, and rapid build times. Unfortunately architecture is rarely explicit in code, hence it must be specified and tracked, sometimes at great cost in developer time. Research in specifying architecture using architecture description languages (ADL) has failed until now to grab a stronghold in the practice of software engineering. To increase the chance of adoption for architecture monitoring methods we took a pragmatic approach. We conducted interviews and surveys with software architects, we categorized and ranked their needs, and based on these empirical results we proposed a novel solution: an extensible and unified architecture specification language that is powerful enough to express any architectural rule and still simple enough that actual practitioners would find it practical to use. We are currently collaborating with three industrial partners to evaluate the approach.

Research staff: All members of the research group.

Duration: Jan 1, 2013 – Dec. 30, 2015

Financial support: Swiss National Science Foundation

For further details, please consult:
`http://scg.unibe.ch/asa`

6.4 Master's Theses

- Bledar Aga. Marea — a tool for breaking dependency cycles between packages. Masters thesis, University of Bern, January 2015. URL: http://scg.unibe.ch/archive/masters/Aga15a.pdf.

- Nicole Haenni. Information needs in software ecosystems development — a contribution to improve tool support across software systems. Masters thesis, University of Bern, September 2014. URL: http://scg.unibe.ch/archive/masters/Haen14b.pdf.

- Aliya Ibragimova. CiteWise — the citation search engine. Masters thesis, University of Bern, June 2015. URL: http://scg.unibe.ch/archive/masters/Ibra15a.pdf.

- Aaron Karper. Efficient regular expressions that produce parse trees. Masters thesis, University of Bern, December 2014. URL: http://scg.unibe.ch/archive/masters/Karp14a.pdf.

- Dennis Schenk. Quicksilver — a framework for hierarchical data analysis. Masters thesis, University of Bern, September 2014. URL: http://scg.unibe.ch/archive/masters/Sche14a.pdf.

6.5 Bachelor's Theses and Computer Science Projects

- Maudlin Kummer. Categorising test smells. Bachelor's thesis, University of Bern, March 2015. URL: http://scg.unibe.ch/archive/projects/Kumm15a.pdf.

- Dominique Rahm. Hikomsys: How I KnOw My SYStem — learning about Java dependencies through gamification. Bachelor's thesis, University of Bern, July 2015. URL: http://scg.unibe.ch/archive/projects/Rahm15a-Hikomsys.pdf.

- Roger Stebler. Evaluating the dynamic behavior of Smalltalk applications. Bachelor's thesis, University of Bern, April 2015. URL: http://scg.unibe.ch/archive/projects/Steb15a-VariableTracker.pdf.

6.6 Awards

- Software Language Engineering (SLE) 2014 Best Student Paper Award for The Moldable Debugger: A Framework for Developing Domain-Specific Debuggers by Andrei Chiş, Tudor Girba and Oscar Nierstrasz
- European Smalltalk User Group 2014 Technology Innovation Award (1st prize) for GT Inspector by Andrei Chiş, Tudor Girba and Aliaksei Syrel
- IWST14 Best Paper Award (3rd prize) for The Moldable Inspector: A framework for domain-specific object inspection by Andrei Chiş, Tudor Girba and Oscar Nierstrasz

6.7 Further Activities

Invited Talks

Oscar Nierstrasz

- Invited Speaker at INRIA Lille: Domain-Specific Tooling (Nov. 20, 2014)

Editorial Boards and Steering Committees

Oscar Nierstrasz

- AITO – Association Internationale pour les Technologies Objets (Member)
- CHOOSE – Swiss Group for Object-Oriented Systems and Environments (Board Member)
- JOT — Journal of Object Technology (Steering Committee Member)
- Moose Association (Board Member)
- SATToSE – Seminar Series on Advanced Techniques & Tools for Software Evolution (Steering Committee Member)
- SI – Swiss Informatics Society (Board Member)
- SIRA – Swiss Informatics Research Association (Board Member)

- SNF — Swiss National Science Foundation (Member of the Research Council)

Mircea Lungu

- Vice-President of CHOOSE – Swiss Group for Object-Oriented Systems and Environments
- Member of SI – Swiss Informatics Society

Program Committees

Oscar Nierstrasz

- PC Member of DLS 2014 (Dynamic Languages Symposium — colocated with SPLASH 2014 — Portland, US, Oct 21, 2014)
- PC Member of SLE 2014 (7th International Conference on Software Language Engineering — Västerås, Sweden, Sept 14-15, 2014)
- PC Member of Modularity 2015 Visions Track (International Conference on Modularity — Fort Collins, Colorado, March 16-19, 2015)
- PC Member of SANER 2015 ERA Track (International Conference on Software Analysis, Evolution, and Reengineering — Montreal, Canada, March 2-6, 2015)
- PC Member of ICSE 2015 (37th International Conference on Software Engineering — Florence, Italy, May 16-24, 2015)

Mircea Lungu

- Co-organizer of WEA 2015 (Third International Workshop on Ecosystem Architectures, co-located with ECSA 2015 in Dubrovnik)
- PC Member of SANER 2015 (International Conference on Software Analysis, Evolution, and Reengineering — Montreal, Canada, March 2-6, 2015)

Andrea Caracciolo

- PC Member of SATToSE 2015 (Seminar Series on Advanced Techniques and Tools for Software Evolution – Mons, Belgium, July 6-8, 2015)

Andrei Chis

- PC Member of IWST 2015 (International Workshop in Smalltalk Technologies – Brescia, Italy, July 15, 2015)
- PC Member of VISSOFT 2015 - NIER and Tools Tracks (3rd IEEE Working Conference on Software Visualization – Bremen, Germany, September 27-28, 2015)
- PC Member of VISSOFT 2015 - Artifact Evaluation Committee (3rd IEEE Working Conference on Software Visualization – Bremen, Germany, September 27-28, 2015)

Reviewing Activities

Oscar Nierstrasz

- Communications of the ACM
- ACM TOSEM
- Elsevier Science of Computer Programming
- FWO (Research Foundation Flanders)
- DFG (Deutsche Forschungsgemeinschaft)

Mircea Lungu

- Journal of Systems and Software
- SANER 2015

Haidar Osman

- TSE 2015
- ICSE 2015
- ICSME 2015
- SANER ERA 2015

Andrea Caracciolo

- ICSE 2015

- SANER 2015
- SANER ERA 2015
- ICSME 2015
- SATToSE 2015

Andrei Chis

- ICSME 2015
- ICSE 2015

Nevena Milojkovic

- ICSME 2015
- ICSE 2015
- SANER 2015

Jan Kurs

- SANER ERA 2015
- ICSE 2015

Boris Spasojevic

- ICSME 2015
- SANER ERA 2015
- ICSE 2015

6.8 Publications

Journal Papers

- Andrea Caracciolo, Mircea Lungu, and Oscar Nierstrasz. Dicto: Keeping software architecture under control. *ERCIM News*, 99, October 2014. URL: `http://ercim-news.ercim.eu/en99/special/dicto-keeping-software-architecture-under-control`.

- Camille Teruel, Erwann Wernli, Stéphane Ducasse, and Oscar Nierstrasz. Propagation of behavioral variations with delegation proxies. *Transactions on Aspect-Oriented Software Development XII*, 8989:63–95, 2015. URL: http://scg.unibe.ch/archive/papers/Teru15a-delegation-proxies.pdf, doi:10.1007/978-3-662-46734-3_2.

Conference Papers

- Andrea Caracciolo, Andrei Chiş, Boris Spasojević, and Mircea Lungu. Pangea: A workbench for statically analyzing multi-language software corpora. In *Source Code Analysis and Manipulation (SCAM), 2014 IEEE 14th International Working Conference on*, pages 71–76. IEEE, September 2014. URL: http://scg.unibe.ch/archive/papers/Cara14c.pdf, doi:10.1109/SCAM.2014.38.

- Andrea Caracciolo, Mircea Lungu, and Oscar Nierstrasz. A unified approach to architecture conformance checking. In *Proceedings of the 12th Working IEEE/IFIP Conference on Software Architecture (WICSA)*, pages 41–50. ACM Press, May 2015. URL: http://scg.unibe.ch/archive/papers/Cara15b.pdf, doi:10.1109/WICSA.2015.11.

- Andrei Chiş, Tudor Gîrba, and Oscar Nierstrasz. The Moldable Debugger: A framework for developing domain-specific debuggers. In Benoît Combemale, DavidJ. Pearce, Olivier Barais, and Jurgen J. Vinju, editors, *Software Language Engineering*, volume 8706 of *Lecture Notes in Computer Science*, pages 102–121. Springer International Publishing, 2014. URL: http://scg.unibe.ch/archive/papers/Chis14b-MoldableDebugger.pdf, doi:10.1007/978-3-319-11245-9_6.

- Jan Kurš, Mircea Lungu, and Oscar Nierstrasz. Bounded seas: Island parsing without shipwrecks. In Benoît Combemale, DavidJ. Pearce, Olivier Barais, and JurgenJ. Vinju, editors, *Software Language Engineering*, volume 8706 of *Lecture Notes in Computer Science*, pages 62–81. Springer International Publishing, 2014. URL: http://scg.unibe.ch/archive/papers/Kurs14b-BoundedSeas.pdf, doi:10.1007/978-3-319-11245-9_4.

- Nevena Milojković, Andrea Caracciolo, Mircea Lungu, Oscar Nierstrasz, David Röthlisberger, and Romain Robbes. Polymorphism

in the spotlight: Studying its prevalence in Java and Smalltalk. In *Proceedings of International Conference on Program Comprehension (ICPC 2015)*, pages 1–10, 2015. To appear. URL: http://scg.unibe.ch/archive/papers/Milo15a.pdf.

- Boris Spasojević, Mircea Lungu, and Oscar Nierstrasz. Mining the ecosystem to improve type inference for dynamically typed languages. In *Proceedings of the 2014 ACM International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software*, Onward! '14, pages 133–142, New York, NY, USA, 2014. ACM. URL: http://scg.unibe.ch/archive/papers/Spas14c.pdf, doi:10.1145/2661136.2661141.

- Boris Spasojević, Mircea Lungu, and Oscar Nierstrasz. Overthrowing the tyranny of alphabetical ordering in documentation systems. In *2014 IEEE International Conference on Software Maintenance and Evolution (ERA Track)*, pages 511–515, September 2014. URL: http://scg.unibe.ch/archive/papers/Spas14b.pdf, doi:10.1109/ICSME.2014.84.

Workshop Papers

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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) 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.

7.3 Research Projects

UNITED LIVING COLORS.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, grant nr. 132430

Efficient Sampling and Reconstruction for Image Synthesis

The goal of image synthesis using light transport simulation is to compute images of virtual, three-dimensional environments such that, if it were possible to capture photographs of equivalent physical environments, the simulated images would be visually indistinguishable from the photographs. In an actual digital camera, the brightness of a pixel is determined by measuring the number of photons and their energy incident over the area of the pixel on the sensor. Photons can be thought of as particles that scatter in the physical environment with a certain randomness, tracing out paths from light sources to the camera lens and ultimately onto the sensor, where they are absorbed. The same intuition underlies Monte Carlo methods, a broad class of techniques to simulate light transport and image formation using virtual environments and virtual cameras. They construct light paths with a certain randomness and measure their contributions over some area.

In this project, we will develop novel algorithms for two specific approaches in Monte Carlo light transport simulation, progressive photon mapping and adaptive sampling and reconstruction. Our overall goal is to further reduce the computational effort that is required to reach a desired accuracy and to avoid visual artifacts. Photon mapping is one of the main Monte Carlo methods that is widely used in image synthesis. In many scenarios photon mapping techniques are considered superior to other Monte Carlo methods, that is, they can produce more accurate results using the same computation time. A core idea of photon mapping is to estimate generalized measurements of light energy over arbitrary locations in virtual scenes. Unfortunately, using such generalized measurements leads to bias, a systematic error in simulated images. While bias can be reduced by evaluating measurements over arbitrarily small areas, this increases variance, or noise. The conventional wisdom was that this bias-variance trade-off was a fundamental property and inherent disadvantage of photon mapping. Recently it has been shown, however, that a progressive variant of photon mapping can be formulated that manages to circumvent this problem and eliminate bias in the limit. In our own work, we developed a more general theory of progressive photon mapping that frames the approach in the context of a statistical technique that we call progressive density estimation. The goal of this project is to further develop this theory and to develop advanced algorithms that increase the efficiency and extend the applicability of progressive rendering schemes.

An important observation in image synthesis is that different pixels often

require varying amounts of computation to achieve the same level of accuracy. In other words, the number of light paths that need to be sampled and evaluated in each pixel may vary. Adaptively determining an appropriate number of samples for each pixel is known as adaptive sampling. In addition, neighboring pixels often use similar light paths. Hence light paths can be shared and averaged across several pixels without causing any visible error, which is known as adaptive reconstruction. Combining adaptive sampling and reconstruction often significantly reduces the number of light paths required to obtain images that are visually indistinguishable from ground truth results. In this project we will build on our previous framework for adaptive sampling and reconstruction, which strives to minimizes the error given a certain sample budget and achieves state-of-the-art performance. In particular, we will develop advanced reconstruction filters that will further increase the accuracy of our scheme. Finally, we will combine our approach with a broader range of rendering algorithms. As an overarching research objective, we are striving to develop algorithms that reduce image errors to a minimum under a given sample budget.

Research staff: Marco Manzi, Matthias Zwicker

Financial support: Swiss National Science Foundation, grant nr. 143886

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: Siavash Bigdeli, Gregor Budweiser, Matthias Zwicker

Financial support: Commission for Technology and Innovation CTI, grant 15592.1 PFES-ES

Hand-Held 3D Light Field Photography

The convergence of sophisticated digital cameras and powerful computers in mobile devices such as smartphones and tablet computers has led to a dizzying array of new applications and tools for consumer photography, some more experimental, others firmly established in the mainstream and used by millions of consumers. In academic research, the confluence of computation and photography has led to a new research field commonly known as “computational photography”, which strives to extend the capabilities of conventional digital photography using sophisticated computational algorithms. But computational photography is not limited to operate on conventional 2D images. Instead, it can work with any representation of the distribution of light in a physical environment captured by a camera. Light fields are a natural extension of 2D images. Under the assumptions of geometric optics, they essentially represent the radiance of each light ray traveling in an environment. Light field photography has been first described more than a hundred years ago, but only recently this idea has started to show its full potential when combined with powerful computing devices. Today, various light field cameras are available for research and consumer applications. The main benefit of light field cameras is that they enable additional possibilities that are hard to achieve with conventional

cameras, such as digitally refocusing images after the data has been captured. A disadvantage of light field cameras is that they require special hardware and optical systems. Practical designs need to make trade-offs between spatial and angular resolution, leading to systems that are usually not competitive with conventional cameras in terms of pure spatial image resolution.
The main idea of this project is to develop algorithms that allow casual users to capture light fields quickly and easily using conventional cameras and a simple interaction metaphor. In addition, we are developing novel algorithms to enable a variety of applications using the captured light field data. A fundamental assumption of our approach is to work with input data consisting of image sequences captured with conventional hand-held cameras along approximately linear trajectories. Users easily acquire such data by "sweeping" the camera along a roughly horizontal path. Camera trajectories may span a few centimeters to a few meters, depending on the scene. We assume the input data consists of a few dozen images captured at several frames per second, for example acquired using a burst mode available in current digital cameras. Capturing such data is a matter of a few seconds and does not require any extra equipment or specialized hardware. Therefore, we believe the limited effort required for this approach will make it attractive to a wide range of users, and our approach will have an impact beyond research contributions to the academic community. While there exist previous techniques for hand-held light field photography, they require several minutes of user engagement and are not suitable for casual photography like our work. We are developing efficient methods to resample input image sequences from hand-held cameras into regularly sampled 3D light fields. These light fields then open up the possibility for a variety of further processing, such as refocusing, alpha matting, depth reconstruction, denoising, etc.

Research staff: Daniel Donatsch, Matthias Zwicker

Data-Driven Modeling in Computer Graphics

The objective of this project is to simplify the modeling process for computer graphics content, motivated by the observation that 3D content creation with today's tools is highly laborious and requires expert knowledge and training. We strive to make visual media production based on computer graphics available to non-specialists, fostering the development and proliferation of new types of visual media, and making visual storytelling

using 3D computer graphics widely accessible. Our approach will leverage the concept of data-driven modeling, meaning that content stored in rich databases can be browsed, retrieved, edited, and recombined in intuitive ways. Currently, we are developing methods to acquire real-world 3D data for computer graphics modeling for different types of asset categories, including dynamic, functional part-based 3D objects and complex real-world environments.

Research staff: Peter Bertholet, Matthias Zwicker

Sketch-Based Image Synthesis

The ability to express themselves or to be creative is sometimes limited by our own technical skills. One very powerful way to illustrate ideas is through images. Unfortunately, however, not all of us can do so and produce a convincing rendering of an original idea. We therefore propose the development of a computational tool that can aid authors in implementing their concepts. Our tool will take an inaccurate initial sketch of the concept and then automatically produce a realistic rendering of that sketch. The tool will also introduce adjustments to make the rendering realistic if the original sketch had distortions or flaws.

Research staff: Tiziano Portenier, Matthias Zwicker, in collaboration with Paolo Favaro

Financial support: Swiss National Science Foundation, grant nr. 156253 (co-PI with Paolo Favaro)

7.4 Master's Theses

- Mariana Barakchieva, Pre-Operative Planning of Skull Based Implants Using Surface Distance Maps (August 2014)
- Gian Calgeer, Image Space Denoising and Adaptive Sampling of Metropolis Rendered Images (September 2014)
- Tiziano Portenier, Light Transport Simulation in Endoscopic Surgery Scenes (February 2015)

7.5 Bachelor's Theses

- Samira Descombes, Reaction-Diffusion Simulation in CUDA (February 2015)
- Nicolas Scheuing, BOSS Optimisation For Interactive Stereoscopic 3D Systems (September 2014)
- Heinrich Reich, Deferred Rendering (February 2015)

7.6 Further Activities

Editorial Boards

Matthias Zwicker

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

Conference Organization

Matthias Zwicker

- Eurographics Conference, tutorials co-chair, May 4 – 8, 2015, Zürich, Switzerland

Conference Program Committees

Matthias Zwicker

- ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games (I3D), February 27 – March 1, 2015, San Francisco, California
- Eurographics Symposium on Rendering, June 23 – 26, 2015, Darmstadt, Germany
- Pacific Graphics, October 7 – 9, 2015, Beijing, China

Ph.D. and Habilitation Jury Memberships

Matthias Zwicker

- Stefanos Apostolopoulos, PhD mentor, Graduate School for Cellular and Biomedical Sciences (GCB), University of Bern
- Carlos Correa Shokiche, PhD mentor, Graduate School for Cellular and Biomedical Sciences (GCB), University of Bern
- Sandro De Zanet, PhD mentor, Graduate School for Cellular and Biomedical Sciences (GCB), University of Bern
- Joachim Dehais, PhD mentor, Graduate School for Cellular and Biomedical Sciences (GCB), University of Bern
- Pascal Dufour, PhD mentor, Graduate School for Cellular and Biomedical Sciences (GCB), University of Bern
- Raphael Meier, PhD mentor, Graduate School for Cellular and Biomedical Sciences (GCB), University of Bern

Reviewing Activities

Matthias Zwicker

- ACM Transactions on Graphics
- IEEE Computer Graphics and Applications
- IEEE Transactions on Visualization and Computer Graphics
- 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

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
- Steering Committee member of ”Prologo: Logo Programmieren in Primarschulen” funded by the Hasler Foundation
- Member of Expert Committee “Biomedical Sciences & Biomedical Engineering” for the Graduate School for Cellular and Biomedical Sciences, University of Bern
- Technology Advisor, innoBright Technologies, USA

7.7 Publications

Journal Publications

- Shihao Wu, Hui Huang, Minglun Gong, Matthias Zwicker, Daniel Cohen-Or: Deep Points Consolidation, ACM Transactions on Graphics (accepted for publication), 2015.
- Markus Kettunen, Marco Manzi, Miika Aittala, Jaakko Lehtinen, Frédo Durand, Matthias Zwicker: Gradient-Domain Path Tracing, ACM Transactions on Graphics 34(4), August 2015.
- Matthias Zwicker, Wojciech Jarosz, Jaako Lehtinen, Bochang Moon, Ravi Ramamoorthi, Fabrice Rousselle, Pradeep Sen, Cyril Soler, and Sung-Eui Yoon: Recent advances in adaptive sampling and reconstruction for Monte Carlo rendering, Computer Graphics Forum (to appear), 2015.
- Claude Knaus, Matthias Zwicker: Dual-Domain Filtering, SIAM Journal on Imaging Science 8(3), July 2015.
- Marco Manzi, Fabrice Rousselle, Markus Kettunen, Jaakko Lehtinen: Improved Sampling for Gradient-Domain Metropolis Light Transport, ACM Transanctions on Graphics 33(6), November 2014.

- Daljit Singh Dhillon, Jeremie Teyssier, Michael Single, Iarsolav Gaponenko, Michel Milinkovitch, Matthias Zwicker: Interactive Diffraction from Biological Nanostructures, Computer Graphics Forum 33(8), August 2014.

Refereed Conference Proceedings

- Samira Descombes, Daljit Dhillon, Matthias Zwicker, Optimized CUDA-based PDE Solver for Reaction Diffusion Systems on Arbitrary Surfaces, GPUComp Workshop, Conference on Parallel Processing and Applied Mathematics (PPAM), accepted for presentation, 2015.

- Nima Kalantari, Fabrice Rousselle, Pradeep Sen, Sung-Eui Yoon, Matthias Zwicker: Denoising Your Monte Carlo Renders: Recent Advances in Image Space-Adaptive Sampling and Reconstruction, ACM SIGGRAPH Course, 2015.

- Marco Manzi, Markus Kettunen, Miika Aittala, Jaakko Lehtinen, Frédo Durand, Matthias Zwicker: Gradient-Domain Bidirectional Path Tracing, Proc. Eurographics Symposium on Rendering, 2015.

- Matthias Zwicker, Wojciech Jarosz, Jaako Lehtinen, Bochang Moon, Ravi Ramamoorthi, Fabrice Rousselle, Pradeep Sen, Cyril Soler, and Sung-Eui Yoon: Recent advances in adaptive sampling and reconstruction for Monte Carlo rendering, Eurographics Tutorial, 2015.

8 Administration

University:

T. Braun:	Member of the Committee for Computing Services (Kommission für Informatikdienste)
	Representative of University of Bern in SWITCH Stiftungsrat
Th. Strahm:	Board member of Mittelbauvereinigung of University of Bern
	Member of Senate
	Member of Central Library Commission
M. Zwicker:	Graduate School for Cellular and Biomedical Sciences: member of the Expert Committee on Biomedical Engineering

Faculty:

G. Jäger:	Member of the Strategy Board
	Joint Master in Computer Science of the Universities of Bern, Fribourg and Neuchatel: member of the Branch Committee
O. Nierstrasz:	Chair, Teaching Evaluation Committee, Faculty of Natural Sciences
Th. Strahm:	Member of the Finance Board
	President of library commission Exakte Wissenschaften Plus
Th. Studer:	Member of the Strategy Board
M. Zwicker:	Member of the Board of Studies

	Joint Master in Computer Science of the Universities of Bern, Fribourg and Neuchatel: member of the Branch Committee

Institute:

T. Braun :	Member of Hauskommission Engehalde
G. Jäger:	Managing Director of INF
O. Nierstrasz:	Deputy Director of INF
Th. Strahm:	Member of Library Committee Exakte Wissenschaften
	Member of Hauskommission Exakte Wissenschaften
M. Zwicker:	Director of Studies