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Universität Bern

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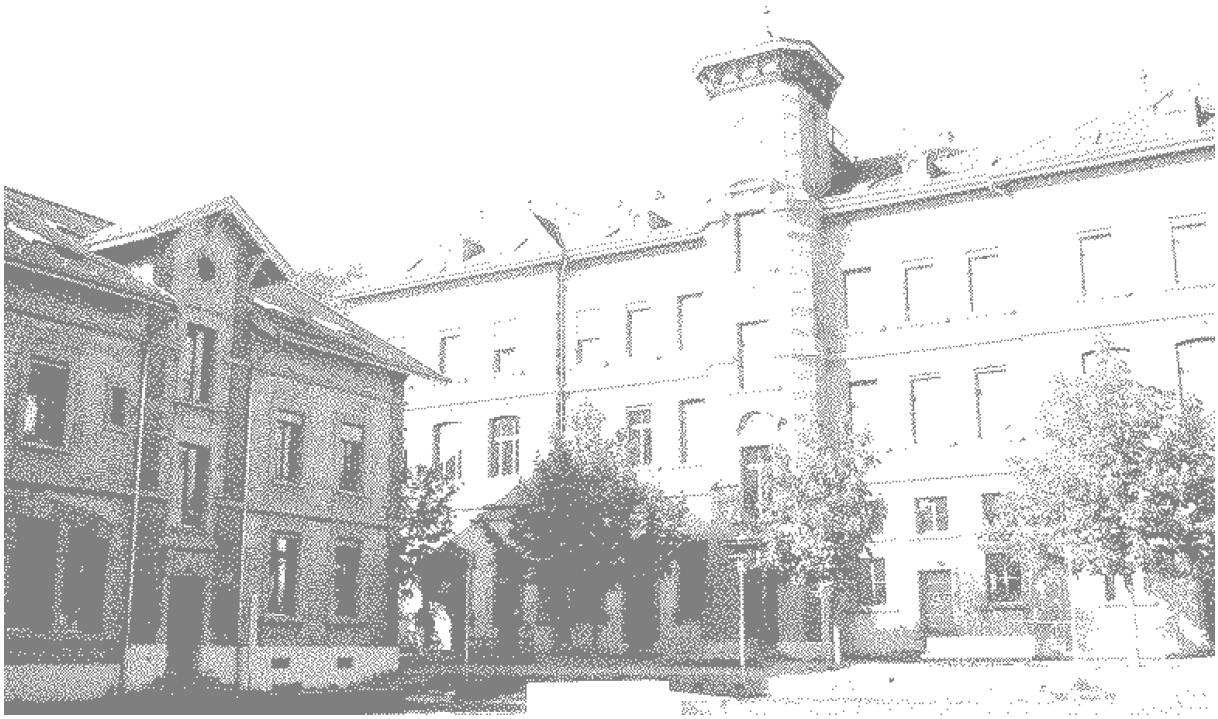
INF Annual Report 15/16



INF Annual Report

Academic Year 2015/2016

September, 2016

Contents

1 Institute of Computer Science (INF)

1.1 Address

Neubrückstrasse 10, 3012 Bern, Switzerland
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1.2 Personnel

Members

I. Alyafawi; C. Anastasiades; S. Arjoumand Bigdeli; M. Bärtschi; P. Bertholet; Dr. P. Brambilla; Prof. Dr. T. Braun; A. Caracciolo; J.L. Carrera; Dr. P. Chandramouli; A. Chis; B. Choffat; C. Corrodi; J. Duarte; D. Esser; Prof. Dr. P. Favaro; M. Gasparyan; Dr. M. Ghafari; A. Gomes; Q. Hu; Prof. Dr. G. Jäger; L. Jaun; M. Jin; E. Kalogeiton; M. Karimzadeh; A. Kashev; I. Keller; I. Kokkinis; J. Kurš; Z. Li; M. Manzi; A. Marandi; M. Marti; L. Merino del Campo; N. Milojkovic; Prof. Dr. O. Nierstrasz; M. Noroozi; H. Osman; T. Portenier; Dr. D. Probst; F. Ranzi; T. Rosebrock; J. Saltarin; Dr. K. Sato; Dr. E. Schiller; D. S. Schroth; B. Spasojević; Dr. S. Steila; M. Stolz; Prof. Dr. Th. Strahm; Prof. Dr. Th. Studer; A. Szabo; Y. Tymchuk; J. Walker; X. Wang; 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. Oscar Nierstrasz

Director of studies

Prof. Dr. Paolo Favaro

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 2015

- 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 (D. Probst, 5 ECTS)

  Einführung in Software Engineering (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

  Concurrency: State Models and Design Patterns (O. Nierstrasz, 5 ECTS)

  Sensor Networks and the Internet of Things (T. Braun, 5 ECTS)

  3D Geometry Processing (M. Zwicker, 5 ECTS)

  Computer Vision (P. Favaro, 5 ECTS)

Modal Logic (T. Studer, 5 ECTS)

Proof Theory (G. Jäger, 5 ECTS)

Seminar: Software Composition (O. Nierstrasz, 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: Logic and Algebra, (G. Jäger, G. Metcalfe, 5 ECTS)

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

- Service Courses

  Anwendungssoftware für Naturwissenschafter
  (T. Studer, 3 ECTS)

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

Spring Semester 2016

- Bachelor 2nd Semester

  Datenbanken (T. Studer, 5 ECTS)

  Datenstrukturen und Algorithmen (M. Zwicker, 5 ECTS)

  Computer Architecture (A. Szabo, 5 ECTS)

  Programmierung 2 (O. Nierstrasz, 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

  Programming Languages (O. Nierstrasz, 5 ECTS)

  Mobile Communications (T. Braun, 5 ECTS)

  Rendering Algorithms (M. Zwicker, 5 ECTS)

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

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

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

  Seminar: Logic and Theoretical Computer Science (T. Studer, T. Strahm, 5 ECTS)

- Service Courses

  Anwendungssoftware für Naturwissenschafter
  (T. Strahm, 3 ECTS)

2.2 Students

- Major Subject Students: AS 2015: 177, SS 2016: 199
- Minor Subject Students: AS 2015: 71, SS 2016: 95
- Ph.D. Candidates: AS 2015: 30, SS 2016: 38

2.3 Degrees and Examinations

- PhD: 9
- Master: 15
- Bachelor: 22
- Completion of Minor Studies: 14 (90E:0, 60E: 4, 30E: 7, 15E: 3, 495 ECTS)

- Semester Examinations AS2015: 632 (2445 ECTS)
- Bachelor's/Master's Theses AS 2015: 10 (220 ECTS)
- Semester Examinations SS2016: 466 (1826 ECTS)
- Bachelor's/Master's Theses SS 2016: 10 (160 ECTS)

2.4 Activities

- Participation in "Projektwoche Faszination Informatik" organized by "Schweizer Jugend forscht", Bern, September, 2015
- Contribution to the "National Future Day for Girls and Boys", Bern, November 12, 2015
- Contribution to the "Bachelor Infotage", December 1+2, 2015
- Taster course for female students, Bern, March 17, 2016
- Visitor Program, Gymnasium Thun, Bern, June 28, 2016

2.5 Awards

- Eurographics Annual Award for Best PhD Thesis 2016 for Fabrice Rousselle's Ph.D. thesis "Image Space Adaptive Rendering"
- Faculty Prize 2015 for Daniele Perrone's Ph.D. thesis "Towards a Novel Paradigm in Blind Deconvolution: From Natural to Cartooned Image Statistics"
- Annual Alumni Award 2015 for Daljit Singh's Ph.D. thesis "On Modeling and Simulating Reptile Skin Coloration"
- Faculty prize 2015 for Jürg Weber's Master's thesis "Dynamic Adaptation of Transmission Modes for Opportunistic Content-Centric Networks"
- Annual Alumni Award 2015 for Tobias Schmid Master's thesis "Agent-Based Data Retrieval for Opportunistic Content-Centric Networks"
- Annual Alumni Award 2015 for Paul Frischknecht's Bachelor's thesis "A Proof of the Arithmetical Equivalence of EC with Full Induction and ACA"

3 Communication and Distributed Systems Group

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:		
	I. Alyafawi*	Tel.: +41 31 511 7631 email: alyafawi@inf.unibe.ch (until 31.08.2015)
	C. Anastasiades	Tel.: +41 31 511 2635 email: anastasi@inf.unibe.ch (until 01.06.2016)
	J. Carrera*	Tel.: +41 31 511 7645 email: karimzadeh@inf.unibe.ch (since 01.11.2015)
	J. Duarte	Tel.: +41 31 511 2639 email: duarte@inf.unibe.ch (since 01.02.2016)
	M. Gasparyan*	Tel.: +41 31 511 7645 email: gasparyan@inf.unibe.ch
	A. Gomes*	Tel.: +41 31 511 2636 email: gomes@inf.unibe.ch
	E. Kalogeiton*	Tel.: +41 31 511 2638 email: kalogeiton@inf.unibe.ch (since 01.05.2016)
	M. Karimzadeh	Tel.: +41 31 511 7645 email: karimzadeh@inf.unibe.ch (since 01.02.2016)
	Z. Li*	Tel.: +41 31 511 2638 email: li@inf.unibe.ch (until 30.04.2016)
	A. Marandi*	Tel.: +41 31 511 2634 email: marandi@inf.unibe.ch
	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
	M. Stolz	Tel.: +41 31 511 2637 email: stolz@inf.unibe.ch
	Dr. Z. Zhao*	Tel.: +41 31 511 2639 email: zhao@inf.unibe.ch

External Ph.D. Students:	
A. Antonescu	email: antonescu@inf.unibe.ch (until 31.10.2015)
L. Luceri	email: luceri@inf.unibe.ch
G. Manzo	email: gaetanomanzo@gmail.com (since 01.05.2016)
M. Thoma	email: thoma@inf.unibe.ch
Teaching:	
Dr. Ph. Hurni	email: hurni@inf.unibe.ch (01.08.15-31.01.16)
Guests:	
Dr. A. Neto	Department of Informatics and Applied Mathematics, Federal University of Rio Grande do Norte/BR (29.05.16-08.06.16)

* 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 develop a framework for delivering secure localization and location-based services (LBS) to users, who optimally trade off privacy requirements with user value, network performance and reliability. To achieve this goal, the project targets at building a synergistic platform, which consists of a testbed based on mobile crowdsensing and Internet of Things, a data model for representing the different sources of collected data, and a prediction engine for analyzing the data and producing insights. We have published two scientific papers in peer-reviewed conferences/journals, in which one paper [Li et al., 2016] is about our latest research activity of indoor localization, and another paper

[Hossmann et al., 2015] is a joint effort of all the partners, which described the overall approach and concept of the project and its challenges in a comprehensive way.
The CDS group is involved in and leading the sub-project of “mobility, localization and tracking”, in which our tasks are indoor localization/tracking and mobility prediction. For indoor localization and tracking, we have developed novel passive positioning system for WiFi target and systems, which can extract channel state information from overheard packets to design enhanced methods for ranging and positioning. The novel ranging method can mitigate multi-path propagation based on channel information and is robust to ranging errors caused by non-line-of-sight propagation based on a new propagation model. An enhanced particle filter has been designed to extend the aforementioned passive positioning system to support passive tracking of mobile targets. It could deal with the inaccurate likelihood estimation and moving model problems. The enhanced particle filter solution fuses received WiFi radio signals, smart-phone embedded inertial sensors and physical information of the environment (floor plans), to achieve high tracking accuracy. Our system has been evaluated in extensive experiments, and it is able to achieve a mean accuracy of 1 m and a 90% accuracy of 2.3 m in real-time.
In the task of mobility prediction, our goal is to predict the future locations of mobile users based on the their historical and current context, such as GPS locations, frequency and duration of visiting a place, and the smart-phone system information, such as WLAN connections, movement acceleration, running applications, etc. We propose to apply machine learning algorithms to generate decision trees to make predictions. In order to construct a decision tree that is able to classify users’ future location, we have to extract different types of features from their daily behavior traces, such that different places could be represented by different characteristics. To do this, we consider information like user movements’ temporal features, smart-phone system information, such as running application, charging status, etc. We have conducted experiments using different machine learning algorithms such as Bayes Networks, J48 decision tree, ensemble learning methods, etc. With our extracted features, we could achieve the best prediction accuracy of around 85%, which is much better than most of the existing works that only consider temporal features of users’ movements.
In addition to our own individual research progress, the CDS group has collaborated with other project partners. For instance, we have tested our indoor localization algorithm in other partners’ office areas to validate our approach, and we are also working on integrating our real-time application

with the smart office management application from other project partners.

Research staff: Z. Zhao, Z. Li, J. Carrera, M. Karimzadeh, T. Braun.

Financial support: Swiss National Science Foundation Sinergia project number 154458

Mobile Cloud Networking

Mobile Cloud Networking (MCN) was a EU-FP7 large-scale Integrating Project (IP) funded by the European Commission. In total, 19 partners from industry and academia performed research on MCN. MCN was launched in November 2012 and was successfully finished on 30 April 2016.

The project was primarily motivated by an ongoing transformation that still drives convergence between the mobile communication and cloud computing industry enabled through the Internet. It led to a number of objectives that had to be investigated, implemented and evaluated over the project life-time. The top-most objectives of the MCN project were to: a) extend cloud computing towards the mobile end-user, b) design a 3GPP-compliant Mobile Cloud Networking architecture that exploited and supported cloud computing, c) enable a novel business actor, i.e., the MCN provider, and d) 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 were: a) virtualization of Radio Access Networks (RAN), b) design of a cross-domain Infrastructure-as-a-Service (IaaS) control plane, c) virtualization and cloud computing middleware to support highly demanding, real-time network applications and services, d) design, deployment, and operation of mobile communication software components to attain and fully benefit from cloud computing attributes, e) ensure QoE with advanced content and service migration mechanisms for mobile cloud users, and f) support of multiple cross-domain aspects of services interacting with a multitude of business actors and stake-holders. The CDS group was involved in the following work packages (WP): WP3 on Mobile Cloud Infrastructural Foundations, WP4 on Mobile Network Cloud, WP5 on Mobile Platform, WP6 on Experimentation and Evaluation, and WP7 on Dissemination, Exploitation, Standardization activities.

Our work-scope within WP3 was to offer a comprehensive framework for the LTE radio access network (RAN). In particular, the framework allowed for virtualization of base stations (running a base station in the cloud). We

delivered an execution platform for RAN and a management framework for virtualized RAN. Finally, a distributed cloudified solution having a separate RRH (remote radio head) and BBU (base-band unit) connected through an Ethernet fronthaul was provided.
Our scope of WP4 was put on implementation and performance evaluations of Mobility and Bandwidth Prediction as a Service (MOBaaS). Mobility and Bandwidth as a Service (MOBaaS) was an MCN service that generated user mobility and bandwidth prediction. This information could be used by other services to trigger self-adaptation procedures, e.g., optimal run-time configuration, scale-out and scale-in of service instance components, or optimal network function placement. Evaluation results showed that MOBaaS was able to provide single user/group mobility and bandwidth prediction with good prediction accuracy and latency.
Our key contribution of WP5 was the implementation of the follow-me cloud concept, which aimed to provide cloud services and data as close as possible to an end user; this minimized delays and improved performance.
The performance of our modules was successfully evaluated. They were integrated with other services of MCN in WP6. Finally, we have performed an end-to-end evaluation of a cloudified mobile operator composed of all the MCN services developed.
In WP7, we successfully disseminated project results by various mechanisms including, publications, social media channels, events, standards, software releases, etc.

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

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

Testbeds

The CDS group possesses a **cloud infrastructure** based on Dell Power Edge Servers. We have three machines R320, R520, and R530 supporting 100 parallel threads (50 cores) and 448 GB RAM. Moreover, an external storage Dell PowerVault md3800i provides disk space of 10.3 TB in Raid 5 and Raid 6. The network backbone is based on Dell N4032 switches with 48 10 GbE-T ports and 80 Gb/s backbone connection. The infrastructure supports the following services perfectly integrated with the Lightweight Directory Access Protocol (LDAP) of the institute.

- Mirantis OpenStack 8.0 (IaaS research cloud)

- OwnCloud (shared storage)
- Wiki (information dissemination)
- Etherpad (collaborative real-time editor)
- SVN (collaborative version management system)

For collaborative administration and monitoring, we use:

- Teampass (password management system)
- Nagios (monitoring)

CDS owns an **IoT testbed** of 40 MEMSIC Telsob nodes deployed in the building of the Institute of Computer Science of the University of Bern. The testbed consists of the following sensor nodes:

- 40 TelosB by Crossbow (now Willow)
  - Texas Instruments 16 bit microprocessor (TI MSP 430)
  - 802.15.4 radio interface
  - Fixed Power Supply via the USB Interface
  - Temperature, humidity and light sensor
  - 1 MB external flash
- 7 MSB-430 Sensor Nodes
  - Texas Instruments 16 bit microprocessor (TI MSP 430)
  - CC1020 radio interface
  - Temperature, humidity and acceleration sensor
  - SD memory interface

The CDS testbed hence consists of 47 sensor nodes. The network spans across 4 floors of one building of the Institute of Computer Science of the University of Bern. The 7 MSB430 nodes are placed indoors. Out of the 40 TelosB nodes, 39 nodes are placed indoors, in rooms or corridors of the building, and one node is an outdoor node placed on the top window sill of the small tower.

FIRE LTE testbeds for open EXperimentation

FIRE LTE testbeds for open EXperimentation (FLEX) is an EU-FP7 large-scale Integrating Project (IP) funded by the European Commission. Currently, the consortium holds 16 active partners, but is going to be officially extended with new members that joined through the Second Open Call. CDS also joined FLEX through the Second Open Call for 10 month work between 1.4.2016 and 31.1.2017.
FLEX aims to provide fully open and operational LTE experimental facilities. Based on a combination of truly configurable commercial equipment, truly configurable core network software, fully open source components, and on top of those, sophisticated emulation and mobility functionalities, the FLEX facility allows researchers from academia and industry to test services and applications over real LTE infrastructures, or experiment with alternative algorithms and architectures of the core and access network.
In the scope of the FLEX project, CDS aims to implement and extensively evaluate the Mobile Edge Computing (MEC) caching framework. We will provide a MEC server collocated with an OpenAirInterface-based macro eNB LTE station. The MEC caching application will be executed as a Virtual Network Function (VNFs) on top of the virtualized environment. Finally, we will evaluate the performance of the newly develop solution.

Research staff: E. Schiller, T. Braun.

Financial support: EU FP7 Large-scale Integrating Project (IP), contract number 612050

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 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 scalability issues and attempt to better exploit 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 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.

Content Centric Networking (CCN) and Named Data Networking (NDN) are the most prominent versions of ICN. CCN refers to the architecture project started at PARC, which included leading the development of a software codebase that represents a baseline implementation of this architecture. NDN refers to the NSF-funded Future Internet Architecture project, which originally used CCNx as its codebase, but as of 2013 has forked a version to support the needs specifically related to the NSF-funded architecture research and development (and not necessarily of interest to PARC).

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 second year of the project we continued to develop a protocol, namely NetCodCCN, for integrating network coding in CCN. We published a first version of our protocol, based on the work of the first year and part of the second year. Now we are close to submit a new publication with the updated protocol, which improves resiliency in different topologies. More-

over, we have changed our code base from CCNx to the NDN project implementation. Moreover, we have developed applications that enable DASH multimedia communications on top of our architecture. This will allow us to show not only how our protocol can improve download times, but also how it can increase the average Quality of Experience seen by DASH clients.
Content discovery, i.e., locating the demanded content is one of the major challenges in ICN. This task is performed by routing schemes or resolution-based solutions in ICN. In this project, we focused on NDN and proposed BFR, a Bloom filter-based, fully distributed, content oriented, and topology agnostic routing approach at the intra-domain level for NDN. In BFR, origin servers advertise their contents using Bloom filters in order to reduce bandwidth and storage overhead significantly. The proposed BFR outperforms flooding and shortest path approaches in NDN in terms of mean hit distance, normalized communication cost, average round-trip delay, and robustness to topology changes without requiring extensive signalling between nodes. BFR requires quite a small storage overhead for maintaining content advertisements. Nevertheless, we proposed also storage management strategies in order to keep the storage overhead for content advertisements reasonably low.

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

Financial support: Swiss National Science Foundation project number 149225

Service-Centric Networking

Content-Centric Networking (CCN) does not well support 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 because 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 Networking (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 routing, name resolution, service naming, and service management.
We built the L-SCN (Layered-SCN) architecture to support services over CCN. L-SCN uses a two-layer forwarding scheme combined of nodes and

Bloom filters. L-SCN aims to minimize protocol overhead and maximize the shared information about services and resources available in the network. We have extended the existing NDN implementation in ndnSIM with new data structures and forwarding techniques. The default CCN routing mechanism was not changed. Therefore, traditional CCN traffic can be forwarded as usual. We have implemented and evaluated our design in ndnSIM by comparing its processing time performance against available forwarding strategies in ndnSIM. The results show that our architecture outperforms the three existing strategies in ndnSIM, which are the Best Route, Multicast, and Random forwarding strategies. We intend to extend L-SCN with important SCN requirements such as session support. We are investigating service session support techniques that can be used in the network to handle service session requests.

Research staff: M. Gasparyan, T. Braun.

Financial support: Swiss National Science Foundation Project No. 146376

CONtext and conTent Aware CommunicaTions for QoS support in VANETs (CONTACT)

Communication in Vehicular Ad Hoc Networks (VANETs) have been investigated during the last years due to the development of applications that may enable safer and more autonomous driving. The main characteristic of VANETs is that the topology constantly changes, because the vehicles move with high speeds and most likely with an unpredictable way. In recent years, applications for VANETs include mostly safety but also infotainment applications. The CONTACT project aims to ensure the Quality of Service (QoS) in VANET networks, by exploiting Content Centric Networking (CCN), Software Defined Networking (SDN) and Floating Content (FC). CCN provides a novel communication approach that differs from traditional communication paradigms, since the messages are exchanged based on their content and not on the location of the hosts. SDN separates the network's control plane, which performs the routing decision, from the data plane, which is responsible for data forwarding. FC refers to self-organizing information responsible for finding its own storage on top of a highly dynamic set of mobile nodes. The goal is to keep content at some specified location known as anchor zone, despite the unreliability of the devices on which it may be stored. The main dependability requirements

of FC are survivability, availability, and accessibility. We aim to combine these three methods in order to develop communication techniques and apply them to VANETs to guarantee high QoS. In particular, we would like to increase the reliability and the scalability of applications in VANETs by exploiting the CCN and SDN paradigms. Moreover, we aim to keep drivers informed about safety on road. Furthermore, the combination of CCN and FC can be advantageous in particular cases. For instance, when content objects are bound to a specific geographic region, and stored on a subset of nodes within the region itself, the replication characteristic of FC introduces redundancy, which can be useful when nodes cannot be continuously active and hence do not make content permanently available due to high node failure rates, intermittent connectivity, load balancing, etc. On the other hand, content searching and finding can become more efficient if the geographic area of the floating content is derived from the content name, and, therefore, CCN Interest messages can be forwarded to that geographic area to meet the requested content. Finally, we combine FC with SDN. The main purpose is a centralized approach that exploits an SDN controller. The latter could establish and resize the size and shape of the anchor zone for the FC. The main advantage is that each node in the anchor zone could receive and replicate the floating content, even in areas with high density of messages and/or vehicles.

Research staff: E. Kalogeiton, J. Duarte, T. Braun.

Financial support: Swiss National Science Foundation (SNSF), project number: 164205

3.4 Ph.D. Theses

- Islam Alyafawi “Real-Time Localization using Software defined Radio”, August, 2015
- Florian Antonescu “Service Level Agreements-Driven Management of Distributed Applications in Cloud Computing Environments”, October, 2015
- Zan Li “Fine-grained Indoor Positioning and Tracking Systems”, April, 25, 2016
- Carlos Anastasiades “Information-Centric Networking in Mobile and Opportunistic Networks”, June, 2016

3.5 Master's Theses

- Tobias Schmid "Agent-Based Data Retrieval for Opportunistic Content-Centric Networks", August, 2015
- Jürg Weber "Dynamic Adaptation of Transmission Modes for Opportunistic Content-Centric Networks", August, 2015
- Danilo Burbano "Indoor Tracking by Particle Filter Combining CIR-based Ranging and Inertial Sensors", October, 2015
- Jose Luis Carrera "Improve Trilateration Accuracy By LOS/NLOS Identification and MIMO", October, 2015

3.6 Bachelor's Theses

- Oliver Stapleton "Service Distribution Mechanisms in Information-Centric Networking", August, 2015
- Jakob Schaerer "Universal Large Scale Sensor Network", July, 2016
- Severin Zumbrunn "Universal Large Scale Sensor Network", July, 2016

3.7 Further Activities

Memberships

Torsten Braun

- Erweitertes Leitungsgremium Fachgruppe "Kommunikation und Verteilte Systeme", Gesellschaft für Informatik
- SWITCH Stiftungsrat
- SWITCH Stiftungsratsausschuss
- Interim President of SWITCH foundation (November 2015 to March 2016) and vice president before and after that period
- Kuratorium Fritz-Kutter-Fonds

- Expert for Diploma Exams at Fachhochschule Bern
- Expert for Matura Exams at Gymnasium Neufeld, Bern
- Management committee member of COST Action IC1303 Algorithms, Architectures and Platforms for Enhanced Living Environments (AAPELE)
- Management committee member of COST Action CA15127 Resilient communication services protecting end-user applications from disaster-based failures (RECODIS)
- Management committee substitute member of the COST Action CA15104 Inclusive Radio Communication Networks for 5G and beyond (IRACON)
- 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 (Multidisciplinary Digital Publishing Institute) Journal of Sensor and Actuator Networks

Conference and workshop organization

Torsten Braun

- 1st International INFOCOM Workshop on Software-Driven Flexible and Agile Networking, Steering committee, San Francisco, CA, USA, April 11, 2016
- Wired/Wireless Internet Communications 2015, Steering committee, Thessaloniki, Greece, May 25-27, 2016
- International Symposium on Quality of Service 2016, Steering committee, Beijing, China, June 20-21, 2016

Conference Program Committees

Torsten Braun

- 15th International Conference on Next Generation Wired/Wireless Advanced Networks and Systems (NEW2AN 2015), St. Petersburg, RUSSIA, August 26-28, 2015
- 8th International Workshop on Multiple Access Communications (MACOM 2015), Helsinki, Finland, September 3-4, 2015
- 8th ICT Innovations Conference 2015, Ohrid, FYR. Macedonia, September 5-7, 2015
- Leistungs-, Zuverlässigkeits- und Verlässlichkeitsbewertung von Kommunikationsnetzen und verteilten Systemen (MMBnet 2015),Universität Hamburg, Germany, September 10-11, 2015
- 3rd IEEE International Conference on Cloud Networking (CLOUDNET), Niagara Falls, Canada, October 5-7, 2015
- 9th International Workshop on Communication Technologies for Vehicles (Nets4Cars 2015), Munich, Germany, October 5-7, 2015
- 7th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT), Brno, Czech Republic, October 6-8, 2015
- IEEE 12th International Conference on Mobile Ad hoc and Sensor Systems (MASS), Dallas, USA, Russia, October 19-22, 2015
- 40th IEEE Local Computer Networks Conference (LCN 2015), Florida, USA, October 26-29, 2015
- 18th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM) 2015, Cancun, Mexico, November 2-6, 2015
- 11th International Conference on Network and Service Management (CNSM 2015), Barcelona, Spain, November 9-13, 2015
- IEEE Global Communications Conference (GLOBECOM), San Diego, CA, USA, December 6-10, 2015
- IFIP/IEEE Wireless Days 2016 Conference, Toulouse, France, March 23-25, 2016

- IEEE Wireless Communications and Networking Conference (WCNC 2016), Doha, Qatar, April 3-6, 2016
- 31st ACM Symposium on Applied Computing (SAC 2016), Pisa, Italy, April 4-8, 2016
- IFIP Networking 2016 Conference, Vienna, Austria, May 17-19, 2016
- 2nd International Conference on Smart Computing (SMARTCOMP 2016), St. Louis Missouri, USA, May 18-20, 2016
- IEEE International Conference on Communications (ICC 2016), Kuala Lumpur, Malaysia, 23-27 May 2016
- International Conference on Wired and Wireless Internet Communications, Thessaloniki, Greece, May 25-27, 2016
- IEEE/ACM International Symposium on Quality of Service (IWQoS), Beijing, China, June 20-21
- 15th IFIP Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net), Vilanova i la Geltrú, Spain, June 20-22, 2016
- IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM 2016), Coimbra, Portugal, June 21-24, 2016

Project and Person Reviewing Activities

Torsten Braun

- Research Council of Norway
- European Framework Programme for Research Horizon 2020
- Danish Council for Independent Research
- Flanders Innovation & Entrepreneurship
- German-Israeli Foundation for Scientific Research and Development
- Chalmers University
- Universität zu Lübeck

Journal Article Reviewing Activities

Torsten Braun

- Elsevier Computer Networks
- IEEE Communications Magazine
- Hindawi Mobile Information Systems
- Elsevier Computers and Electronics in Agriculture
- Multidisciplinary Digital Publishing Institute (MDPI) Sensors Open Access Journal
- Springer Lecture Notes in Computer Science

Eryk Schiller

- IEEE Transactions on Network and Service Management
- Elsevier Ad-hoc Networks

Carlos Anastasiades

- IEEE Network Magazine
- Elsevier Computer Communications
- Springer Wireless Information Networks

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

Talks and Tutorials

Torsten Braun

- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, Beihang University, August 26, 2015
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, University of Science and Technology of China, Hefei, August 28, 2015
- Invited talk: “Issues with State-based Energy Consumption Modelling”, OMNeT++ Community Summit, Zürich, September 3, 2015
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, Gottfried Wilhelm Leibniz Universität Hannover, February 10,2016
- Keynote talk: “Mobile Follow-Me Cloud-Integrating NFV, MEC, ICN and Mobility Prediction”, WWIC 2016, Thessaloniki, Greece, May 26, 2016
- Invited talk: “Communication and Distributed Systems”, Universidade Estadual de Campinas, July 22, 2016
- Invited talk: “Future Internet Architecture for Mobile / Wireless Networks”, Universidade de São Paulo, São Carlos, July 25, 2016
- Invited talk: “Future Internet Architecture for Mobile / Wireless Networks”, Universidade Federal do Pará, Belem, Brazil, July 29, 2016

PhD Committee Memberships

Torsten Braun

- Mehdi Asadpour, ETH Zürich
- Ahmed Abujoda, Gottfried Wilhelm Leibniz Universität Hannover

3.8 Publications

Journal Papers

- Anastasiades, C., Schmid, T., Weber, J., and Braun, T. (2016a). Information-Centric content retrieval for Delay Tolerant Networks. *Computer Networks*.
- Anastasiades, C., Weber, J., and Braun, T. (2016b). Dynamic unicast: Information-centric multi-hop routing for mobile ad-hoc networks. *Computer Networks*.
- Bernardo, V., Fonseca, V., Curado, M. P., and Braun, T. (2015). Evaluation of video transmission energy consumption and quality. *Wireless Personal Communications*, 87(2):565–592.
- Gomes, A. S. N., Sousa, B., Palma, D., Fonseca, V., Zhao, Z., Monteiro, E., Braun, T., Simoes, P., and Cordeiro, L. (2016b). Edge caching with mobility prediction in virtualized LTE mobile networks. *Future Generation Computer Systems*.

Conference Papers

- Alyafawi, I., Braun, T., and Dimitrova, D. C. (2015). Robust indoor localization of narrowband signals. In *Personal, Indoor, and Mobile Radio Communications (PIMRC), 2015 IEEE 26th Annual International Symposium on*, pages 2193–2198.
- Alyafawi, I., Durand, A., and Braun, T. (2016a). High-performance wideband SDR channelizers. In *14th International Conference on Wired & Wireless Internet Communications (WWIC)*.
- Alyafawi, I., Kiener, S., and Braun, T. (2016b). Hybrid indoor localization using multiple radio interfaces. In *17th IEEE International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM)*.
- Anastasiades, C., Gomes, A. S. N., Gadow, R., and Braun, T. (2015a). Persistent caching in information-centric networks. In *40th Annual IEEE Conference on Local Computer Networks (LCN 2015)*, pages 64–72. IEEE.

- Anastasiades, C., Sittampalam, A., and Braun, T. (2015b). Content discovery in wireless information-centric networks. In *40th IEEE Conference on Local Computer Networks (LCN)*, pages 28–36. IEEE.
- Anastasiades, C., von Rotz, L., and Braun, T. (2015c). Adaptive Interest lifetimes for information-centric wireless multi-hop communication. In *8th IFIP Wireless and Mobile Networking Conference (WMNC)*, pages 40–47. IFIP.
- de Arco, J. E. S., Bourtsoulatze, E., Thomos, N., and Braun, T. (2016). NetCodCCN: a network coding approach for Content-Centric Networks. In *IEEE International Conference on Computer Communications (INFOCOM 2016)*. IEEE.
- Gomes, A. S. N., Braun, T., and Monteiro, E. (2016a). Enhanced caching strategies at the edge of LTE mobile networks. In *IFIP Networking 2016 Conference (Networking 2016)*, pages 350–358.
- Hossmann, A. M., Li, Z., Zhao, Z., Braun, T., Angelopoulos, C. M., Evangelatos, O., Rolim, J., Papandrea, M., Garg, K., Giordano, S., Tossou, A. C. Y., Dimitrakakis, C., and Mitrokotsa, A. (2015). Synergistic user <-> context analytics. In *7th International Conference covering topics in ICT Innovations*, volume 399, pages 163–172. Springer International Publishing.
- Karimzadeh, M., Zhao, Z., Hendriks, L., de O. Schmidt, R., la Fleur, S., van den Berg, H., Pras, A., Braun, T., and Corici, M. (2015). Mobility and bandwidth prediction as a service in virtualized LTE systems. In *IEEE International Conference on Cloud Networking (IEEE CloudNet 2015)*, pages 132–138.
- Katsalis, K., Nikaein, N., Schiller, E. J., Favraud, R., and Braun, T. (2016). 5G architectural design patterns. In *IEEE International Conference on Communications (ICC) 2016*.
- Król, M., Schiller, E. J., Rousseau, F., and Duda, A. (2016). WEAVE: Efficient geographical routing in large-scale networks. In *International Conference on Embedded Wireless Systems and Networks (EWSN 2016)*, Proceeding EWSN '16 Proceedings of the 2016 International Conference on Embedded Wireless Systems and Networks, pages 89–100, Canada. Junction Publishing.
- Li, Z., Acuna, D. B., Zhao, Z., Carrera, J. L., and Braun, T. (2016). Fine-grained indoor tracking by fusing inertial sensor and physical

layer information in WLANs. In *IEEE International Conference on Communications (ICC)*.

- Nikaein, N., Knopp, R., Gauthier, L., Schiller, E. J., Braun, T., Pichon, D., Bonnet, C., Kaltenberger, F., and Nussbaum, D. (2015a). Demo – Closer to Cloud-RAN: RAN as a Service. In *Proceedings of the 21st ACM Annual International Conference on Mobile Computing and Networking (ACM MOBICOM) Demonstrations*, pages 193–195. ACM.

- Nikaein, N., Schiller, E. J., Favraud, R., Katsalis, K., Stavropoulos, D., Alyafawi, I., Zhao, Z., Braun, T., and Korakis, T. (2015b). Network store: Exploring slicing in future 5G networks. In *Proceedings of the 10th ACM Workshop on Mobility in the Evolving Internet Architecture (ACM MobiArch) co-located with the 21st ACM Annual International Conference on Mobile Computing and Networking (ACM MOBICOM)*, pages 8–13. ACM.

- Rizzo, G., Palattella, M. R., Braun, T., and Engel, T. (2016). Content and context aware strategies for QoS support in VANETs. In *30th International Conference on Advanced Information Networking and Applications (AINA-2016)*.

- Rosário, D. L., Seruffo, M., Cerqueira, E., Both, C. B., Braun, T., and Gerla, M. (2016). Trends in human-centric multimedia networking scenarios. In *The 15th IFIP Annual Mediterranean Ad Hoc Networking Workshop*.

- Thoma, M., Triantafyllos, A., and Braun, T. (2015). An application-layer RESTful sleepy nodes implementation for Internet of Things systems. In *8th IFIP Wireless and Mobile Networking Conference*, pages 16–23.

- Zhao, Z. and Braun, T. (2015). SCAD: Sensor context-aware adaptive duty-cycled beaconless opportunistic routing for WSNs. In *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, pages 2038–2043. IEEE.

- Zhao, Z., do Rosario, D. L., Braun, T., and Cerqueira, E. (2015a). A tutorial of the Mobile Multimedia Wireless Sensor Network (M3WSN) OMNeT++ framework. In *OMNeT++ summit'15*.

- Zhao, Z., Karimzadeh, M., Braun, T., and Pras, A. (2015b). A demonstration of mobility prediction as a service in cloudified LTE networks.

In *IEEE International Conference on Cloud Networking (IEEE CloudNet 2015)*, pages 78–80.

Technical Reports

- Bourtsoulatze, E., Thomos, N., Saltarin, J., and Braun, T. (2015). Content-aware delivery of scalable video in network coding enabled Named Data Networks. Technischer Bericht IAM-15-003. INF - Institut fur Informatik, Universitat Bern
- Li, Z., Acuña, D. B., Zhao, Z., Villacrés, J. L. C., and Braun, T. (2015). Fine-grained indoor tracking by fusing inertial sensor and physical layer information in WLANs. Technischer Bericht IAM-15-004. INF - Institut fur Informatik, Universitat Bern
- Li, Z. and Braun, T. (2015). Passively track WiFi users with an enhanced particle filter using power-based ranging. Technischer Bericht IAM-15-005. INF - Institut fur Informatik, Universitat Bern

4 Computer Graphics Group

4.1 Personnel

Heads:	Prof. Dr. M. Zwicker	Tel.: +41 31 631 3301 email: zwicker@inf.unibe.ch
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* with financial support from a third party

4.2 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.

4.3 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. This project concluded with Daljit Dhillon's successful Ph.D. defense in November 2015.

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 es-

timation. 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

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. This project concluded with Daniel Donatsch's successful Ph.D. defense in October 2015.

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, Shihao Wu, 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)

4.4 Ph.D. Theses

- Daniel Donatsch, Computational Tools for Stereo and Light Field Photography (October 2015)

- Daljit Singh Dhillon, On Modeling and Simulating Reptile Skin Coloration (November 2015)

4.5 Bachelor's Theses

- Urs Gerber, Real-Time Face Rendering (September 2015)
- Gian-Luca Mateo, KADA: Kinect Assisted Duplo Tracking (September 2015)
- Delio Vicini, Improved Gradient-Domain Reconstruction (September 2015)
- Oscar Meier, Evaluation of AR Toolkits (December 2015)
- Adrian Wälchli, Layered 3D from Perspective Images (May 2016)

4.6 Further Activities

Editorial Boards

Matthias Zwicker

- The Visual Computer, International Journal of Computer Graphics, Associate Editor

Conference Program Committees

Matthias Zwicker

- ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games (I3D), February 27 – 28, 2016, Redmond, Washington, USA
- Eurographics 2016, Annual Conference of the Eurographics Association for Computer Graphics, May 09 – 13, 2016, Lisbon, Portugal
- Eurographics Symposium on Rendering, June 22 – 24, 2016, Dublin, Ireland
- SIBGRAPI, October 04 – 07, 2016, Sao Jose Dos Campos, Brasil

Ph.D. and Habilitation Jury Memberships

Matthias Zwicker

- Liana Manukyan, external co-referee, Faculty of Science, University of Geneva
- 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

- Expert for Matura Exams at Gymnasium Oberaargau, Langenthal
- 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

4.7 Publications

Journal Publications

- Marco Manzi, Markus Kettunen, Fredo Durand, Matthias Zwicker, Jaakko Lehtinen: Temporal Gradient-domain Path Tracing, ACM Transactions on Graphics, to appear.
- Marco Manzi, Delio Vicini, Matthias Zwicker: Regularizing Image Reconstruction for Gradient-Domain Rendering with Feature Patches, Computer Graphics Forum 35(2), May 2016.
- Shihao Wu, Hui Huang, Minglun Gong, Matthias Zwicker, Daniel Cohen-Or: Deep Points Consolidation, ACM Transactions on Graphics 34(6), November 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.

Refereed Conference Proceedings

- Qiyang Hu, Paolo Favaro, Matthias Zwicker: 3D Face Reconstruction with Silhouette Constraints, Vision, Modeling, and Visualization (2016), conditionally accepted.

- Samira Descombes, Daljit Dhillon, Matthias Zwicker: Optimized CUDA-based PDE Solver for Reaction Diffusion Systems on Arbitrary Surfaces, Chapter Parallel Processing and Applied Mathematics, Lecture Notes in Computer Science (Volume 9573), April 2016.
- Siavash Bigdeli, Gregor Budweiser, Matthias Zwicker: Temporally Coherent Disparity Maps using CRFs with Fast 4D Filtering, 3rd IAPR Asian Conference on Pattern Recognition (ACPR), November 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, August 2015.

Technical Reports

- Daljit Dhillon, Michel Milinkovitch, Matthias Zwicker: Bifurcation Analysis of Reaction Diffusion Systems on Arbitrary Surfaces, technical report, arXiv:1605.01583.
- Peter Bertholet, Alexandru-Eugen Ichim, Matthias Zwicker: Temporally Consistent Motion Segmentation from RGB-D Video, technical report, arXiv:1608.04642.

5 Computer Vision Group

5.1 Personnel

Heads:	Prof. Dr. P. Favaro	Tel.: +41 31 631 3301 email: paolo.favaro@inf.unibe.ch
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5.2 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 machine learning, computer vision, image processing, 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. Moreover, 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 be 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, photometric stereo, coded aperture photography), motion estimation (structure from motion, tracking), and unsupervised learning.

5.3 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.
Although there are many successful methods, most of them incorporate heuristics. We aim to propose a principled formulation which also achieves performance comparable to state of the art algorithms. In this work, we

study the use of an L2 norm constraint for the PSF and show how it helps favor sharp images. Due to this constraint, even with the use of a simple Gaussian prior for the sharp image, we can estimate the PSF and the latent image accurately. 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 exactly, we use a splitting method that deals with the non-convexity of the L2 norm prior.

Research staff: Meiguang Jin, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 153324

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 blur.

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

Layer Separation

When imaging scenes consisting of transparent surfaces, the radiance components present behind and in front of the transparent surface get superimposed. Separating the two layers from a composite image is inherently ill-posed since it involves determining two unknowns from a single observation. Existing approaches address this problem by using additional information obtained by capturing a sequence of images from a moving camera, or by modifying the data acquisition modality, or by imposing specific models on images. We propose to use a light field camera from which layer separation can be achieved using a single observation.
In a light field image of a scene with superimposing reflections, the captured colors are related to the radiances of the reflected and transmitted layers through a point spread function (PSF). The PSF depends on the depth values of the layers and the optical settings of the LF camera. The contributions from both the layers get merged in the observation. Due to the merging of intensities, the standard multi-view correspondence approach cannot be used for depth estimation. We develop a neural network-based classifier for estimating depth maps. Our classifier can also separate the scene into reflective and non-reflective regions. The depth estimation process has a runtime of only a few seconds when implemented on a GPU. With the knowledge of the scene depth, we arrive at the PSFs of the two layers and subsequently reconstruct the radiances within a regularization framework.

Research staff: Paramanand Chandramouli, Mehdi Noroozi and Paolo Favaro

3D Face Reconstruction

The aim of this project is to reconstruct 3D face models of individuals from collections of images that are captured in uncontrolled environments wherein variations in illumination, pose, and expression are present. Such

3D reconstructions can be useful for face and expression recognition, or to produce facial animations.
The quality of the 3D reconstructions is limited since the only constraints on the reconstruction are photometric consistency and correspondence with sparse facial landmarks. Based on previous work on 3D face reconstruction, we introduce silhouette constraints to improve the quality of unconstrained 3D face reconstruction. The main idea is to extract silhouette points on the 3D reconstruction, and match them with automatically detected silhouette points in the input images. We include these constraints in the 3D reconstruction objective, which we solve in an iterative process. In each iteration step, we recompute the silhouette points using the current 3D reconstruction and update the corresponding contraints in the objective. As a consequence, the silhouettes of the 3D reconstruction converge towards the silhouettes in the input images. The results demonstrate that the new silhouette constraints lead to higher reconstruction quality.

Research staff: Qiyang Hu, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 156253

Unsupervised Learning of Visual Representations

Information processing tasks can be either very easy or very difficult depending on how the information is represented. This general principle is applicable to daily life as well as to machine learning and computer science. A good representation is the one that makes subsequent learning easier. The choice of representation will usually depend on the choice of the subsequent learning task. Convolutional Neural Networks (CNN) have demonstrated an impressive performance in many computer vision tasks when trained on large labeled datasets. We can think of feedforward networks trained by supervised learning as performing a kind of representation learning. While the last layer of a network is typically a linear classifier (softmax), the rest of the network learns to provide a representation to this classifier. We often have a very large amount of unlabeled training data and relatively little labeled data. Training with supervised learning techniques on the labeled subset often results in severe overfitting. Our goal is to learn efficient representations from large scale unlabeled training data.
We build a CNN that can be trained to solve Jigsaw puzzles as a pretext task. The network is then repurposed to solve object classification and

detection. Jigsaw puzzles have been associated with learning since their inception. They were introduced in 1760 by John Spilsbury as a pretext to help children learn geography. Studies in psychonomics show that Jigsaw puzzles can be used to assess visuospatial processing in humans. Indeed, the Hooper Visual Organization Test is routinely used to measure an individual's ability to organize visual stimuli. We propose to use Jigsaw puzzles to develop a visuospatial representation of objects in the context of CNNs. To maintain the compatibility across tasks, we introduce the context-free network (CFN), a siamese-ennead CNN. The CFN takes image tiles as input and explicitly limits the receptive field (or context) of its early processing units to one tile at a time. Our experimental evaluations show that the learned representations capture semantically relevant content. We pretrain the CFN on the training set of the ILSVRC2012 dataset and transfer the features to the combined training and validation set of PascalVOC2007 for object detection (via fast RCNN) and classification. These features outperform all current unsupervised features with 51.8% for detection and 68.6% for classification, and reduce the gap with supervised learning (56.5% and 78.2% respectively).

Research staff: Mehdi Noroozi, Paolo Favaro

Unsupervised Viewpoint Estimation

Viewpoint estimation is traditionally solved by supervised techniques using classification. A classifier is trained to predict the viewpoint from annotated samples. In our project we estimate viewpoints without using viewpoint annotation.

Recent works have shown that convolutional neural networks produce features that are sensitive to 3D viewpoint changes. This is surprising because they were trained to ignore viewpoint changes. We show in our work that we can exploit this property to establish a link between similar viewpoints of objects in the same category and build a view graph. This is achieved by simulating virtual viewpoints generated by the images and a shape hypothesis.

We further develop a probabilistic model to recover the absolute viewpoint assignment using relative viewpoint estimates between image pairs. We train a convnet to classify the relative viewpoints between image pairs.

Subsequently, we estimate the absolute viewpoint directly with the convnet, so the reconstruction step is no longer needed. We train the network with image pairs of the same object instance, where the relative changes

are known. The objective function measures the consistency of the viewpoint assignment between the image pairs.

Research staff: Attila Szabó, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 149227

Exploiting Videos to Learn Object Detection and Categorization in Images

We assume that a category is defined by its characteristic textures/colors (if any) and its characteristic 3D shape (up to local or articulated deformations). Images and videos are space-time instances of an object category with additional transformations (e.g., pose, viewpoint, intraclass variation, illumination, occlusions, clutter and so on) that do not characterize the category. Given a model of the object category (textures and 3D shape), the removal of these transformations is relatively well defined. However, when the model is unknown, the problem becomes extremely challenging. The biggest problem is how to relate the content of one image instance with another image instance. In other words one needs to find correspondences between parts of different instances of an object. Because of the high variability of the appearance of instances of an object, this task is extremely difficult. To simplify this step we propose to use short videos instead of images. Our objective is first to learn high-performance visual representations (feature vectors) from videos and then such visual representations can be transferred to other tasks such as object detection/categorization, action recognition, pose estimation and so on.

Research staff: Xiaochen Wang, Paolo Favaro

Financial support: China Scholarship Council

5.4 Master's Thesis

- Michele Wyss, "Segmentation in 3D using eye-tracking technology", July 2016 (ARTORG).

5.5 Further Activities

Tutorial Organizer

Paolo Favaro

- “Removing Camera Blur” at ICCV 2015

Ph.D. Thesis Examiner

Paolo Favaro

- “Structure Modeling of High Dimensional Data: New Algorithms and Applications”, M. H. Kamal, EPFL, 2015

Master’s Thesis Examiner

Paolo Favaro

- “Towards Automatic Segmentation of Longitudinal Brain Tumor”, R. Meier, ISTB, UniBe, 2016

Doctorate Course

Paolo Favaro

- “Inverse Problems in Imaging” at Universita’ di Padova, Italy 2016

Invited Talks

Paolo Favaro

- Invited Talk at Max Planck Institute, Tuebingen, Germany 2016
- Invited Talk at Siemens Healthcare, Princeton, NJ - USA 2016
- Invited Talk at University of California, Berkeley, USA 2016
- Invited Talk at SIAM Conference on Imaging Science, Albuquerque, NM - USA 2016
- Invited Talk at Stanford University, USA 2016
- Invited Talk at Adobe Systems Inc., San Jose, CA - USA 2016
- Invited Talk at Apple Inc., Cupertino, USA 2016

Conference Program Committees

Paolo Favaro

- Area chair of ICCV 2015 and CVPR 2016

Journal Committees

Paolo Favaro

- Associate Editor for IEEE Transactions on Pattern Analysis and Machine Intelligence 2016
- Associate Editor for IEEE Signal Processing Magazine, Special Issue on Signal Processing for Computational Photography and Displays, 2016

Reviewing Activities

Paolo Favaro

- GCPR 2016
- ICCP 2016
- SIGGRAPH 2016
- Journal of Digital Signal Processing 2016
- ERC grant 2015
- IEEE Transactions on Pattern Analysis and Machine Intelligence 2015
- Springer Book Proposal 2015

Paramanand Chandramouli

- IEEE Transactions on Pattern Analysis and Machine Intelligence 2016
- IEEE Transactions on Industrial Electronics 2016
- Journal of Visual Communication and Image Representation 2016
- IEEE Transactions on Image Processing 2015

5.6 Publications

Journal Publications

- D. Perrone and P. Favaro, “A Clearer Picture of Total Variation Blind Deconvolution”, IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), 2015.
- D. Perrone and P. Favaro, “A Logarithmic Image Prior for Blind Deconvolution”, International Journal of Computer Vision (IJCV), 2015.
- T. Gaspar, P. Oliveira and P. Favaro, “Synchronization of Independently Moving Cameras via Motion Recovery”, SIAM Journal on Imaging Sciences, 2016.

Refereed Conference Proceedings

- M. Jin, P. Chandramouli and P. Favaro, “Bilayer Blind Deconvolution with the Light Field Camera”, IEEE International Conference on Computer Vision Workshop (ICCV Inverse Rendering Workshop), 2015.
- A. Szabó, A.Vedaldi and P. Favaro, “Building the View Graph of a Category by Exploiting Image Realism”, IEEE International Conference on Computer Vision Workshop (ICCV Workshop on 3D Representation and Recognition), 2015.
- M. Noroozi and P. Favaro, “Unsupervised Learning of Visual Representations by Solving Jigsaw Puzzles”, European Conference on Computer Vision (ECCV), 2016.
- Q. Hu, M. Zwicker and P. Favaro, “3D Face Reconstruction with Silhouette Constraints”, International Symposium on Vision, Modeling and Visualization (VMV), 2016.
- P. Chandramouli, M. Noroozi and P. Favaro, “ConvNet-based Depth Estimation, Reflection Separation and Deblurring of Plenoptic Images”, Asian Conference on Computer Vision (ACCV), 2016.

6 Logic and Theory Group

6.1 Personnel

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	Dr. F. Ranzi*	email: ranzi@inf.unibe.ch (until 31.10.2015)
	T. Rosebrock*	Tel.: +41 (0)31 511 76 33 email: rose@inf.unibe.ch
	Dr. K. Sato*	Tel.: +41 (0)31 511 76 21 email: sato@inf.unibe.ch

	Dr. S. Steila	Tel.: +41 (0)31 511 76 17 email: steila@inf.unibe.ch
	J. Walker*	Tel.: +41 (0)31 511 76 32 email: walker@inf.unibe.ch

Guests:	Dr. R. Kuznets	TU Wien, Fakultät für Informatik, Austria October 2015
	S. Steila	Università degli Studi di Torino, Scuola di Dottorato in Scienze della Natura e Tecnologie Innovative, Italy October 2015
	Dr. B. Afshari	TU Wien, Institut für Diskrete Mathematik und Geometrie, Austria November 2015
	Dr. R. Bruni	Università degli Studi di Firenze, Dipartimento di Lettere e Filosofia, Italy November 2015
	Dr. G. Leigh	TU Wien, Institut für Diskrete Mathematik und Geometrie, Austria November 2015

* with financial support from a third party

6.2 Overview

The Logic and Theory research group (LTG) 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.

6.3 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, S. Steila, 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

The operational paradigm: its mathematical and philosophical frontiers

This project assesses the limits of mathematical knowledge inherent in and provided by an operational approach – an approach which plays a central role in Feferman's explicit mathematics and operational set theory – from various mathematical and philosophical perspectives. The notion of predicativity goes back to Russell and Poincare and was formally made precise by Feferman and Schütte, who were also able to exactly characterize predicative mathematics.
The first part of this proposal is about an extension of predicativity, which we call metapredicativity, in taking a more liberal approach to "building up

set-theoretic universes from below". We aim at a conceptually and technically convincing classification of those formal systems that are no longer predicative in the sense of Feferman-Schütte but whose proof-theoretic analysis can be carried through by purely predicative methods. Our solution should unravel this dichotomy by providing a foundationally convincing explanation. In addition, we aspire to determine the limit of metapredicativity.
The second part is concerned with the design and analysis of strong operational systems and independence results making use of those. For this purpose, new extensions or generalizations of forcing and realizability techniques will be developed. The main products will be scientific results, documented in research articles. In addition, presentations of our results at international conferences, exchange visits, and the training of graduate students are envisaged. The long term impact of this project will provide convincing answers concerning the foundational relevance of an alternative approach to formalizing mathematics which, however, is closer to mathematical practice.

Research staff: M. Bärtschi, G. Jäger, D. Probst, K. Sato, S. Steila, T. Strahm

Financial support: John Templeton Foundation

Logic and Computation

This very general project deals with the close connections between mathematical logic and certain parts of computer science, and emphasis is put on a proof-theoretic approach to some of the central questions in this area of research. These include the development of perspicuous and feasible logical frameworks for studying typical questions in computer science like termination and correctness of functional programs, properties of distributed systems and the like.
We study applicative theories as well as strongly typed formalisms and are interested in the connections to constructive and explicit mathematics. Furthermore, we are interested in analyzing the close connections between the complexities of computations and proofs in suitable formalizations, ranging from propositional calculi up to abstract frameworks for computations (in higher types).

Research staff: All members of the research group

6.4 Ph.D. Theses

- I. Kokkinis: Uncertain Reasoning in Justification Logic
- F. Ranzi: From a Flexible Type System to Metapredicative Wellordering Proofs

6.5 Bachelor's Theses

- M. Eisele: A Discussion of the Rice, Rice-Shapiro, and Myhill Shepherdson Theorems
- R. Imhof: Vollständigkeitsbeweis für Distributed Knowledge
- S. Matter: Soundness and completeness of a first order probabilistic logic with approximate conditional probabilities
- B. Sugden: An Explanation of Blum's Speed-Up Theorem

6.6 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
- Member of the Editorial Board of Journal of Symbolic Logic

Technical and Research Committees

Gerhard Jäger

- 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 (until 2015)

- Member of the Ambizione Panel of the Swiss National Science Foundation
- Member of the Scientific Council of the European Association for Computer Science Logic
- PC Member of the Fifth International Conference on Logic, Rationality, and Interaction, Taipei City, 2015
- 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 Delegate to the International Union of History and Philosophy of Science
- Board Member of the Platform Mathematics, Astronomy and Physics (MAP) of the Swiss Academy of Sciences
- PC Member of Advances in Modal Logic 2016
- Rapporteur and Member of the PhD Jury for Fabrizio Alberetti, University of Neuchâtel, 2015
- Expert for “Maturitätsprüfungen Mathematik und Informatik”
- Local Organizer of the Swiss Olympiad in Informatics Finals, 2016

Jan Walker

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

Organized Events

Michael Bärtschi

- Together with G. Jäger and K. Sato. Operations, Sets, and Types (international workshop supported by the John Templeton Foundation), Münchenwiler, April 2016.

Gerhard Jäger

- Together with M. Bärtschi and K. Sato. Operations, Sets, and Types (international workshop supported by the John Templeton Foundation), Münchenwiler, April 2016.

Ioannis Kokkinis

- Arbeitstagung Bern-München, München, December 2015.
- Arbeitstagung Bern-München, Bern, May 2016.

Kentaro Sato

- Together with M. Bärtschi and G. Jäger. Operations, Sets, and Types (international workshop supported by the John Templeton Foundation), Münchenwiler, April 2016.

6.7 Publications

- Stefano Berardi and Silvia Steila. Ramsey's theorem for pairs and k colors as a sub-classical principle of arithmetic. *Journal of Symbolic Logic*, In Press.
- Ulrik Torben 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*, pages 115–140. De Gruyter, 2016.
- Gerhard Jäger. Relativizing operational set theory. *The Bulletin of Symbolic Logic*, In Press.
- Gerhard Jäger and Michel Marti. A canonical model construction for intuitionistic distributed knowledge. In *Advances in Modal Logic 2016*, In Press.

- Gerhard Jäger and Michel Marti. Intuitionistic common knowledge or belief. *Journal of Applied Logic*, In Press.

- Gerhard Jäger and Dieter Probst. A Proof-Theoretic Analysis of Theories for Stratified Inductive Definitions. In Reinhard Kahle and Michael Rathjen, editors, *Gentzen's Centenary - The Quest for Consistency*, pages 425–454. Springer, 2015.

- Reinhard Kahle, Thomas Adrian Strahm, and Thomas Studer, editors. *Advances in Proof Theory*, volume 28 of *Progress in Computer Science and Applied Logic*. Springer International Publishing, Cham, 2016.

- Ioannis Kokkinis. The Complexity of Non-Iterated Probabilistic Justification Logic. In Marc Gyssens and Guillermo Simari, editors, *Foundations of Information and Knowledge Systems - 9th International Symposium, FoIKS 2016, Linz, Austria, March 7-11, 2016. Proceedings*, volume 9616 of *Lecture Notes in Computer Science*, pages 292–310. Springer, Cham, 2016.

- Ioannis Kokkinis, Zoran Ognjanović, and Thomas Studer. Probabilistic Justification Logic. In Sergei Artemov and Anil Nerode, editors, *Logical Foundations of Computer Science - International Symposium, LFCS 2016, Deerfield Beach, FL, USA, January 4-7, 2016. Proceedings*, volume 9537 of *Lecture Notes in Computer Science*, pages 174–186. Springer, Cham, 2016.

- 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*, pages 171–192. De Gruyter, 2016.

- Roman Kuznets and Thomas Studer. Weak arithmetical interpretations for the logic of proofs. *Logic Journal of IGPL*, 24(3):424–440, 2016.

- Michel Marti and Thomas Studer. Intuitionistic modal logic made explicit. Submitted.

- Dieter Probst and Peter Schuster, editors. *Concepts of Proof in Mathematics, Philosophy, and Computer Science*, volume 6 of *Ontos Mathematical Logic*. De Gruyter, 2016.

- Florian Ranzi and Thomas Adrian Strahm. A flexible type system for the small Veblen ordinal. Submitted.
- Giovanni Sommaruga and Thomas Adrian Strahm, editors. *Turing's Revolution: The Impact of His Ideas about Computability*. Birkhäuser Basel, 2015.
- Silvia Steila and Keita Yokoyama. Reverse mathematical bounds for the termination theorem. *Annals of Pure and Applied Logic*, In Press.
- Thomas Adrian Strahm. Unfolding Schematic Systems. In Gerhard Jäger and Wilfried Sieg, editors, *Feferman on Foundations - Logic, Mathematics, Philosophy*. Springer, In Press.
- Thomas Studer. *Relationale Datenbanken: von den theoretischen Grundlagen zu Anwendungen mit PostgreSQL*. eXamen.press. Springer Berlin Heidelberg, Berlin, Heidelberg, 2016.

7 Software Composition Group

7.1 Personnel

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*with financial support from a third party

7.2 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.

7.3 Research Projects

Agile Software Analysis

SNSF project #200020-162352

Software developers actually spend much of their time not just producing new code, but analysing the existing code base. Integrated Development Environments (IDEs) however are mostly glorified text editors, and offer only limited support for developers to query and analyse software systems. In this continuation of our SNF project *Agile Software Assessment*, we proceed to explore new ways to enable developers to efficiently answer detailed questions about the software system under development.
The project is organized into four orthogonal tracks. We summarize briefly our progress in each track over the past year:

- **Agile Model Extraction.** Before we can analyze software, we must parse it and model it. Given the large range of different programming languages and technologies used in modern projects, this poses a technical challenge.

  Highly expressive and composable parsing frameworks required by agile modeling cannot compete with high-performance top-down parsers. Furthermore, the improved expressiveness of parsers developed in the recent years causes even higher parsing overhead. We have focused on the performance of parsers for parsing expression grammars (PEGs) and have developed several parsing strategies for different subsets of parsing expressions. As a validation of these techniques we have implemented a parser compiler — source-to-source transformation tool that analyzes and transforms a PEG definition to a high-performance top-down parser that switches between these parsing strategies during a single parsing phase.

- **Context-Aware Tooling.** To make informed decisions developers commonly formulate detailed and domain-specific questions about their software systems and use tools to explore available information and answer those questions. Generic development tools, while universally applicable, make it difficult to answer domain-specific questions. Through our work on *moldable tools* we propose that developers build software using development tools tailored to their specific application domains. To support moldable tools we have introduced *moldable development* as an approach for developing software in

which developers evolve development tools together with their applications. We further investigated how to apply the moldable tools idea to enable contextual-aware searching within an IDE and developed *Moldable Spotter*, a framework enabling developers to easily create custom searches for domain objects. We also looked at how to apply the *Moldable Debugger* to improve the debugging of concurrent threads.

Debuggers are a central part in the development and testing workflow. Most debuggers are used by setting static breakpoints on the source code and halting the execution when reaching a specific point in the source code. We are exploring ways to improve the way debuggers operate and are used. In particular, we aim to design and implement a debugger — based on object-centric debugging and the moldable tools approach — that allows developers to specify complex and domain-specific breakpoint conditions based on the states of run-time objects and object relations rather than source code locations. We are currently developing a prototype in the Pharo programming system.

A large number of visualization tools and techniques have been developed over the years, but it is a non-trivial task to identify a suitable visualization for a given problem at hand and to deploy the visualization for that task. To address this problem we have carried out a systematic literature review of visualization techniques in the literature, and the questions they address. We have also designed a tool that contains a tag-cloud based visualization built from frequent questions that arise during development. In it, tags connect to icons representing suitable visualization examples that were collected from the examples shipped with the Roassal visualization engine. The visualization builds on the tools included in the Pharo programming language and environment allowing developers to (i) spot tags related to their questions, (ii) find linked suitable visualizations, and (iii) adapt the visualization examples to answer their particular question.

- **Ecosystem Mining.** Fixing bugs is a key activity in software maintenance. Analyzing a large corpus of Java open source programs, we found out that “missing null check” is the most recurrent bug. We have investigated more deeply null checks in this corpus and empirically shown that the improper use of “null” is a main source of defects in Java systems. We are currently developing an Eclipse plugin that warns developers about potential missing null checks.

A bug predictor is a machine learning model trained on software metrics to predict defective software entities. Bug prediction is a well researched field in software engineering. However, previous studies did not take into account the cost effectiveness of using a bug predictor. We did an extensive empirical study, experimenting with different bug prediction configurations such as metrics AI models, and response variables. Two main findings stand out. First, there is no universal solution in bug prediction as every software project is unique and has its own best bug prediction configuration set. Second, bug prediction works fine for some projects but it is not applicable for all projects as the cost effectiveness varies significantly from one project to another.

The lack of static type information in dynamically typed languages hampers program comprehension. Type inference algorithms tend to gain in complexity in order to avoid the problem of producing false positives or false negatives. We have explored cheap heuristics that aim to provide a developer with fast and accurate information about the types of variables. These types are then sorted based on different static and dynamic heuristics. The proposed heuristics are reasonably precise. We have found that this approach tends to work well both for library and project-related types.

- **Evolutionary Monitoring.** Tool developers often rely on data from other related projects to improve their tools. Unfortunately, there is little to no support for them in terms of software evolution. As software evolves, the gathered data become stale and less useful. We have developed a framework to produce tools that use data from related projects. The framework monitors changes in these projects and updates the required data on regular intervals. We are exploring the applicability of this framework by building experimental tools that leverage different aspects of the framework, such as the distinction between gathering and presenting the data, static versus dynamic analysis, and report-guided heuristics versus direct use of data.

  One can introduce faulty code into a software system while implementing a new feature or performing a refactoring. This code can have run-time side effects, or make it harder to maintain the software system in general. In many cases faulty code sections can be automatically detected by static analyzers. We offer live feedback allowing developers to immediately see potential problems. The drawback of this approach are false positives that are presented to developers

in the same live manner. To maintain the satisfaction of developers we had to listen carefully to their feedback and quickly react by tweaking the rules used by static analyzer. The challenge that we are facing now, is what features do developers need to shape the static analyzer rules themselves? As the static analyzer rules are changing over the time, another problem arises when one wants to analyze the quality evolution of a project. The quality value may change not only because of changes made to the project's source code, but also because of the changes in the quality rules. We were able to decompose the quality fluctuations by using visualization techniques.

Research staff: All members of the research group.

Duration: Jan 1, 2016 – Dec. 30, 2018

Financial support: Swiss National Science Foundation

For further details, please consult:
`http://scg.unibe.ch/asa2`

7.4 Ph.D. Theses

- Andrea Caracciolo. *A Unified Approach to Architecture Conformance Checking*. PhD thesis, University of Bern, March 2016. URL: `http://scg.unibe.ch/archive/phd/caracciolo-phd.pdf`.

7.5 Master's Theses

- Max Leske. Improving live debugging of concurrent threads. Masters thesis, University of Bern, August 2016. URL: `http://scg.unibe.ch/archive/masters/Lesk16a.pdf`.

- Cedric Reichenbach. DoodleDebug, clustered — morphing DoodleDebug into a clustered setup using fat clients. Masters thesis, University of Bern, August 2015. URL: `http://scg.unibe.ch/archive/masters/Reic15a.pdf`.

- Michael Rüfenacht. Error handling in PEG parsers — local error recovery for PetitParser. Masters thesis, University of Bern, August 2016. URL: `http://scg.unibe.ch/archive/masters/Ruef16a.pdf`.

- Oskar Truffer. Continuous integration with architectural invariants — a case study about architectural monitoring in practice. Masters thesis, University of Bern, December 2015. URL: http://scg.unibe.ch/archive/masters/Truf15a.pdf.

7.6 Bachelor's Theses and Computer Science Projects

- Pascal Giehl. Zeeguu translate application — extending the Zeeguu platform to the Android device. Bachelor's thesis, University of Bern, August 2015. URL: http://scg.unibe.ch/archive/projects/Gieh15a.pdf.
- Joël Guggisberg. Automatic token classification — an attempt to mine useful information for parsing. Bachelor's thesis, University of Bern, December 2015. URL: http://scg.unibe.ch/archive/projects/Gugg15a.pdf.
- Andreas Hohler. Teamizer — developing a suitable schedule and poll platform for the sports club unihockey lohn. Bachelor's thesis, University of Bern, December 2015. URL: http://scg.unibe.ch/archive/projects/Hohl15a.pdf.
- Rathesan Iyadurai. Parsing Ruby with an island parser. Bachelor's thesis, University of Bern, April 2016. URL: http://scg.unibe.ch/archive/projects/Iyad16a-ParsingRuby.pdf.
- Milan Kubicek. F# parsing expression grammar. Bachelor's thesis, University of Bern, August 2016. URL: http://scg.unibe.ch/archive/projects/Kubi16a.pdf.
- Kenneth Radunz. Dicto auto-complete engine — a back end for autocompletion. Bachelor's thesis, University of Bern, June 2016. URL: http://scg.unibe.ch/archive/projects/Radu16a.pdf.
- Linus Schwab. Using rss feeds to support second language acquisition. Bachelor's thesis, University of Bern, June 2016. URL: http://scg.unibe.ch/archive/projects/Schw16a.pdf.
- Dominik Seliner. EggShell — a workbench for modeling scientific communities. Bachelor's thesis, University of Bern, August 2016. URL: http://scg.unibe.ch/archive/projects/Seli16a.pdf.

- Karan Sethi. Modelling the acquisition of natural language. Bachelor's thesis, University of Bern, August 2015. URL: http://scg.unibe.ch/archive/projects/Seth15a.pdf.
- Dominic Sina. TestView plugin — a Nautilus plugin to facilitate unit testing. Bachelor's thesis, University of Bern, February 2016. URL: http://scg.unibe.ch/archive/projects/Sina16a.pdf.
- Thomas Steinmann. Adding class support and global methods to Polite Smalltalk. Bachelor's thesis, University of Bern, May 2016. URL: http://scg.unibe.ch/archive/projects/Stei16a.pdf.
- Theodor Truffer. A Polite solution to interact with EV3 robots. Bachelor's thesis, University of Bern, September 2016. URL: http://scg.unibe.ch/archive/projects/Truf16a.pdf.
- Cédric Walker. Recognising structural patterns in code — a k-means clustering approach. Bachelor's thesis, University of Bern, August 2016. URL: http://scg.unibe.ch/archive/projects/Walk16a.pdf.
- Pascal Zaugg. Cognitive defusion mobile application — developing a single page application for cognitive defusion exercises. Bachelor's thesis, University of Bern, August 2015. URL: http://scg.unibe.ch/archive/projects/Zaug15a.pdf.

7.7 Awards

- SPLASH 2015 Distinguished Demo Award for GTInspector: A Moldable Domain-Aware Object Inspector by Andrei Chiş, Tudor Girba, Oscar Nierstrasz, Aliaksei Syrel
- European Smalltalk User Group 2015 Technology Innovation Award (1st prize) for GT Spotter by Aliaksei Syrel, Andrei Chiş, Tudor Girba, Juraj Kubelka and Stefan Reichhart

7.8 Further Activities

Invited Talks

Oscar Nierstrasz

- Invited Speaker at FASE-ETAPS 2016 (19th International Conference on Fundamental Approaches to Software Engineering (FASE) – Eindhoven, The Netherlands, April 4-7, 2016)
- Invited Speaker at SATToSE 2016 (9th Seminar Series on Advanced Techniques & Tools for Software Evolution – Bergen, Norway, July 11-13, 2016)

Editorial Boards and Steering Committees

Oscar Nierstrasz

- AITO – Association Internationale pour les Technologies Objets (Member)
- CHOOSE – Swiss Group for Object-Oriented Systems and Environments (President)
- Elsevier Science of Computer Programming (Advisory Board Member, Software Section)
- JOT — Journal of Object Technology (Steering Committee Member)
- Moose Association (Board Member)
- PeerJ Computer Science Journal (Editorial 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)

Program Committees

Oscar Nierstrasz

- Co-organizer of Engineering Academic Software (Dagstuhl Perspectives Workshop 16252 – Dagstuhl, Germany, June 19-24, 2016)
- PC Member of BENEVOL 2015 (BElgian-NEtherlands software eVOLution seminar – Lille, France, Dec 3-4, 2015)
- PC Member of ICSME 2015 (International Conference on Software Maintenance and Evolution – Bremen, Germany, Sept 27-Oct 3, 2015)
- PC Member of ICSE 2015 (37th International Conference on Software Engineering – Florence, Italy, May 16-24, 2015)
- 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)

Andrei Chiş

- PC Member of VISSOFT 2016 - NIER and Tools Tracks (4rd IEEE Working Conference on Software Visualization – Raleigh, North Carolina, USA, October 3-4, 2016)
- PC Member of IWST 2016 (International Workshop in Smalltalk Technologies – Prague, Czech Republic, August 23-25, 2016)
- PC Member of VEM 2016 (4th Workshop on Software Visualization, Evolution and Maintenance – Maringa, Brazil, September 21, 2016)
- Publicity Chair for SLE 2016 (9th ACM SIGPLAN International Conference on Software Language Engineering, October 31 - November 1, 2016, Amsterdam, Netherlands)

Haidar Osman

- PC Member and Proceedings Chair of SATToSE 2016 (9th Seminar Series on Advanced Techniques & Tools for Software Evolution – Bergen, Norway, July 11-13, 2016)

Leonel Merino

- PC Member of VISSOFT 2016 - Artifact Evaluation Committee (4th IEEE Working Conference on Software Visualization – Raleigh, North Carolina, USA, October 3-4, 2016)

Yuriy Tymchuk

- PC Member of VISSOFT 2016 - NIER and Tools Tracks (4rd IEEE Working Conference on Software Visualization – Raleigh, North Carolina, USA, October 3-4, 2016)

Reviewing Activities

Oscar Nierstrasz

- Elsevier Computer Languages, Systems & Structures
- FWO (Research Foundation Flanders)
- IEEE Transactions on Software Engineering
- NWO (Netherlands Organisation for Scientific Research)

Mohammad Ghafari

- ICSME 2016, SANER 2016

Haidar Osman

- SATToSE 2016, Onward! 2016 Essays, ICSME 2016, PeerJ

Andrei Chiş

- Elsevier Science of Computer Programming
- ICSME 2016, SANER 2016, Onward! 2016

Nevena Milojkovic

- Onward! 2016, SANER 2016, TSE

Jan Kurs

- IWST 2016, Onward! 2016 Essays, VISSOFT NIER 2015

Leonel Merino

- ICSME 2016, SANER 2016

Claudio Corrodi

- ICSME 2016, IWST 2016

7.9 Publications

Journal Papers

- Andrei Chiş, Marcus Denker, Tudor Gîrba, and Oscar Nierstrasz. Practical domain-specific debuggers using the Moldable Debugger framework. *Computer Languages, Systems & Structures*, 44, Part A:89–113, 2015. Special issue on the 6th and 7th International Conference on Software Language Engineering (SLE 2013 and SLE 2014). URL: `http://scg.unibe.ch/archive/papers/Chis15c-PracticalDomainSpecificDebuggers.pdf`, `doi:10.1016/j.cl.2015.08.005`.

- Jan Kurš, Mircea Lungu, Rathesan Iyadurai, and Oscar Nierstrasz. Bounded seas. *Computer Languages, Systems & Structures*, 44, Part A:114 – 140, 2015. Special issue on the 6th and 7th International Conference on Software Language Engineering (SLE 2013 and SLE 2014). URL: `http://scg.unibe.ch/archive/papers/Kurs15a-BoundedSeas.pdf`, `doi:10.1016/j.cl.2015.08.002`.

Conference Papers

- Andrea Caracciolo, Bledar Aga, Mircea Lungu, and Oscar Nierstrasz. Marea: a semi-automatic decision support system for breaking dependency cycles. In *Proceedings of the 23rd IEEE International Conference on Software Analysis, Evolution, and Reengineering (SANER)*, March 2016. to appear. URL: `http://scg.unibe.ch/archive/papers/Cara16b.pdf`, `doi:10.1109/SANER.2016.11`.

- Andrei Chiş, Tudor Gîrba, Oscar Nierstrasz, and Aliaksei Syrel. The Moldable Inspector. In *Proceedings of the 2015 ACM International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software*, Onward! 2015, pages 44–60, New York, NY, USA, 2015. ACM. URL: `http://scg.unibe.ch/archive/papers/Chis15a-MoldableInspector.pdf`, `doi:10.1145/2814228.2814234`.

- Claudio Corrodi, Alexander Heußner, and Christopher M. Poskitt. A graph-based semantics workbench for concurrent asynchronous programs. In *Proc. International Conference on Fundamental Approaches to Software Engineering (FASE 2016)*, volume 9633 of

LNCS, pages 31–48, Berlin, Heidelberg, 2016. Springer Berlin Heidelberg. URL: http://arxiv.org/abs/1603.00307, doi:10.1007/978-3-662-49665-7_3.

- Tudor Gîrba and Andrei Chiş. Pervasive Software Visualizations. In *Proceedings of 3rd IEEE Working Conference on Software Visualization*, VISSOFT'15, pages 1–5. IEEE, September 2015. URL: http://scg.unibe.ch/archive/papers/Girb15b-PervasiveSoftwareVisualizations.pdf, doi:10.1109/VISSOFT.2015.7332409.

- Juraj Kubelka, Alexandre Bergel, Andrei Chiş, Tudor Gîrba, Stefan Reichhart, Romain Robbes, and Aliaksei Syrel. On understanding how developers use the Spotter search tool. In *Proceedings of 3rd IEEE Working Conference on Software Visualization - New Ideas and Emerging Results*, VISSOFT-NIER'15, pages 145–149. IEEE, September 2015. URL: http://scg.unibe.ch/archive/papers/Kube15a-OnUnderstandingHowDevelopersUseTheSpotterSearchTool.pdf, doi:10.1109/VISSOFT.2015.7332426.

- Leonel Merino, Mohammad Ghafari, and Oscar Nierstrasz. Towards actionable visualisation in software development. In *VISSOFT'16: Proceedings of the 4th IEEE Working Conference on Software Visualization*. IEEE, 2016. To Appear. URL: http://scg.unibe.ch/archive/papers/Meri16a.pdf.

- Leonel Merino, Mohammad Ghafari, Oscar Nierstrasz, Alexandre Bergel, and Juraj Kubelka. Metavis: Exploring actionable visualization. In *VISSOFT'16: Proceedings of the 4th IEEE Working Conference on Software Visualization*. IEEE, 2016. To Appear. URL: http://scg.unibe.ch/archive/papers/Meri16c.pdf.

- Leonel Merino, Mircea Lungu, and Oscar Nierstrasz. Explora: A visualisation tool for metric analysis of software corpora. In *VISSOFT'15: Proceedings of the 3rd IEEE Working Conference on Software Visualization*, pages 195–199. IEEE, 2015. URL: http://scg.unibe.ch/archive/papers/Meri15b.pdf, doi:10.1109/VISSOFT.2015.7332436.

- Oscar Nierstrasz. The death of object-oriented programming. In Perdita Stevens and Andrzej Wasowski, editors, *FASE 2016*, volume 9633 of *LNCS*, pages 3–10. Springer-Verlag, 2016. URL: http://

scg.unibe.ch/archive/papers/Nier16a-death-of-oop.pdf, doi:10.1007/978-3-662-49665-7_1.

- Haidar Osman, Manuel Leuenberger, Mircea Lungu, and Oscar Nierstrasz. Tracking null checks in open-source Java systems. In *Proceedings of the 23rd IEEE International Conference on Software Analysis, Evolution, and Reengineering (SANER)*, March 2016. URL: http://scg.unibe.ch/archive/papers/Osma16a.pdf, doi:10.1109/SANER.2016.57.

- Teseo Schneider, Yuriy Tymchuk, Ronie Salgado, and Alexandre Bergel. Cuboidmatrix: Exploring dynamic structural connections in software components using space-time cube. In *VISSOFT'16: Proceedings of the 4th IEEE Working Conference on Software Visualization*. IEEE, 2016. To Appear. URL: http://scg.unibe.ch/archive/papers/Schn16a.pdf.

- Boris Spasojević, Mircea Lungu, and Oscar Nierstrasz. A case study on type hints in method argument names in Pharo Smalltalk projects. In *2016 IEEE 23rd International Conference on Software Analysis, Evolution, and Reengineering (SANER)*, volume 1, pages 283–292, March 2016. URL: http://scg.unibe.ch/archive/papers/Spas16a.pdf, doi:10.1109/SANER.2016.41.

- Aliaksei Syrel, Andrei Chiş, Tudor Gîrba, Juraj Kubelka, Oscar Nierstrasz, and Stefan Reichhart. Spotter: towards a unified search interface in IDEs. In *Proceedings of the Companion Publication of the 2015 ACM SIGPLAN Conference on Systems, Programming, and Applications: Software for Humanity*, SPLASH Companion 2015, pages 54–55, New York, NY, USA, 2015. ACM. URL: http://scg.unibe.ch/archive/papers/Syre15a-SpotterPosterAbstract.pdf, doi:10.1145/2814189.2817269.

- Yuriy Tymchuk, Leonel Merino, Mohammad Ghafari, and Oscar Nierstrasz. Walls, pillars and beams: A 3d decomposition of quality anomalies. In *VISSOFT'16: Proceedings of the 4th IEEE Working Conference on Software Visualization*. IEEE, 2016. To Appear. URL: http://scg.unibe.ch/archive/papers/Tymc16a.pdf.

Book Chapters

- Julien Deantoni, Cédric Brun, Benoit Caillaud, Robert B. France, Gabor Karsai, Oscar Nierstrasz, and Eugene Syriani. Domain

globalization: Using languages to support technical and social coordination. In Benoit Combemale, Betty H.C. Cheng, Robert B. France, Jean-Marc Jézéquel, and Bernhard Rumpe, editors, *Globalizing Domain-Specific Languages*, volume 9400 of *Lecture Notes in Computer Science*, pages 70–87. Springer International Publishing, 2015. doi:10.1007/978-3-319-26172-0_5.

Workshop Papers

- Andrea Caracciolo. On the evaluation of a DSL for architectural consistency checking. In *Extended Abstracts of the Eighth Seminar on Advanced Techniques and Tools for Software Evolution (SATToSE 2015)*, pages 55–57, July 2015. URL: http://scg.unibe.ch/archive/papers/Cara15c.pdf.

- Andrea Caracciolo, Mircea Lungu, Oskar Truffer, Kirill Levitin, and Oscar Nierstrasz. Evaluating an architecture conformance monitoring solution. In *Proceedings of the 7th IEEE International Workshop on Empirical Software Engineering in Practice (IWESEP)*, March 2016. URL: http://scg.unibe.ch/archive/papers/Cara16c.pdf, doi:10.1109/IWESEP.2016.12.

- Andrei Chiş, Tudor Gîrba, Juraj Kubelka, Oscar Nierstrasz, Stefan Reichhart, and Aliaksei Syrel. Exemplifying moldable development. In *Proceedings of the 1st Edition of the Programming Experience Workshop*, PX/16, page to appear, New York, NY, USA, 2016. ACM. URL: http://scg.unibe.ch/archive/papers/Chis16b-ExemplifyingMoldableDevelopment.pdf, doi:10.1145/2984380.2984385.

- Andrei Chiş, Tudor Gîrba, and Oscar Nierstrasz. Towards moldable development tools. In *Proceedings of the 6th Workshop on Evaluation and Usability of Programming Languages and Tools*, PLATEAU '15, pages 25–26, New York, NY, USA, 2015. ACM. URL: http://scg.unibe.ch/archive/papers/Chis15d_TowardsMoldableDevelopmentTools.pdf, doi:10.1145/2846680.2846684.

- Andrei Chiş, Tudor Gîrba, Oscar Nierstrasz, and Aliaksei Syrel. GTInspector: A moldable domain-aware object inspector. In *Proceedings of the Companion Publication of the 2015 ACM*

SIGPLAN Conference on Systems, Programming, and Applications: Software for Humanity, SPLASH Companion 2015, pages 15–16, New York, NY, USA, 2015. ACM. URL: http://scg.unibe.ch/archive/papers/Chis15b-GTInspector.pdf, doi:10.1145/2814189.2814194.

- Claudio Corrodi. Towards efficient object-centric debugging with declarative breakpoints. In *Extended Abstracts of the Ninth Seminar on Advanced Techniques and Tools for Software Evolution (SATToSE 2016)*, July 2016. URL: http://scg.unibe.ch/archive/papers/Corr16b-DeclarativeBreakpoints.pdf.

- Max Leske, Andrei Chiş, and Oscar Nierstrasz. A promising approach for debugging remote promises. In *Proceedings of the International Workshop on Smalltalk Technologies*, IWST' 16, page to appear, 2016. URL: http://scg.unibe.ch/archive/papers/Lesk16b.pdf.

- Leonel Merino, Dominik Seliner, Mohammad Ghafari, and Oscar Nierstrasz. Communityexplorer: A framework for visualizing collaboration networks. In *Proceedings of International Workshop on Smalltalk Technologies (IWST 2016)*, 2016. To Appear. URL: http://scg.unibe.ch/archive/papers/Meri16b.pdf, doi:10.1145/2991041.2991043.

- Nevena Milojković, Clément Béra, Mohammad Ghafari, and Oscar Nierstrasz. Inferring types by mining class usage frequency from inline caches. In *Proceedings of International Workshop on Smalltalk Technologies (IWST 2016)*, 2016. To Appear. URL: http://scg.unibe.ch/archive/papers/Milo16a.pdf.

- Haidar Osman. Against the mainstream in bug prediction. In *Extended Abstracts of the Ninth Seminar on Advanced Techniques and Tools for Software Evolution (SATToSE 2016)*, July 2016. URL: http://scg.unibe.ch/archive/papers/Osma16b.pdf.

- Boris Spasojević. Building ecosystem-aware tools using the ecosystem monitoring framework. In *Extended Abstracts of the Ninth Seminar on Advanced Techniques and Tools for Software Evolution (SATToSE 2016)*, July 2016. URL: http://scg.unibe.ch/archive/papers/Spas16c.pdf.

- Boris Spasojević, Mohammad Ghafari, and Oscar Nierstrasz. The object repository, pulling objects out of the ecosystem. In *Proceedings of International Workshop on Smalltalk Technologies (IWST 2016)*, 2016. To Appear. URL: `http://scg.unibe.ch/archive/papers/Spas16b.pdf`.

- Yuriy Tymchuk, Mohammad Ghafari, and Oscar Nierstrasz. When qualityassistant meets pharo: Enforced code critiques motivate more valuable rules. In *IWST '16: Proceedings of International Workshop on Smalltalk Technologies*, 2016. To Appear. URL: `http://scg.unibe.ch/archive/papers/Tymc16b.pdf`, `doi:10.1145/2991041.2991046`.

8 Administration

University:

T. Braun:	Member of the Committee for Computing Services (Kommission für Informatikdienste)
	Representative of University of Bern in SWITCH Stiftungsrat
G. Jaeger:	Member of Kantonale Maturitätskommission
Th. Strahm:	Board member of Mittelbauvereinigung of University of Bern (until 12.15)
	Member of Senate (until 12.15)
	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
P. Favaro:	Member of the Board of Studies
	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
	Joint Master in Computer Science of the Universities of Bern, Fribourg and Neuchatel: Member of the Branch Committee
Th. Strahm:	Member of the Finance Board
	President of library commission Exakte Wissenschaften Plus

Th. Studer:	Member of the Strategy Board

Institute:

T. Braun :	Member of Hauskommission Engehalde (until 20.5.16)
P. Favaro:	Director of Studies
O. Nierstrasz:	Managing Director of INF, Member of Hauskommission Engehalde (as of 21.5.16)
Th. Strahm:	Member of Library Committee Exakte Wissenschaften
Th. Studer:	Member of Hauskommission Exakte Wissenschaften
M. Zwicker:	Deputy Director of INF