

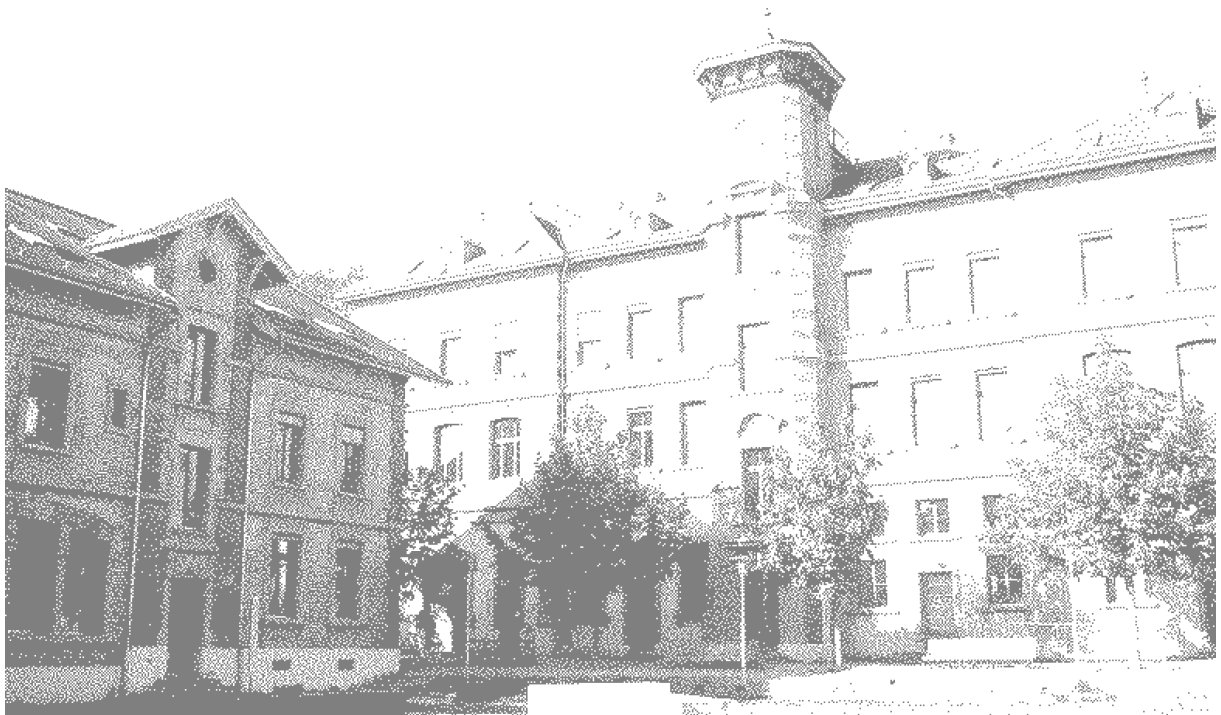
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**UNIVERSITÄT
BERN**

Institut für Informatik
Universität Bern

www.inf.unibe.ch

INF Annual Report 2016/2017



INF Annual Report
Academic Year 2016/2017

September, 2017

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1 Institute of Computer Science (INF)

1.1 Address

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

1.2 Personnel

Members

Dr. M. Anwander; S. Arjomand Bigdeli; M. Bärtschi; P. Bertholet; Dr. P. Brambilla; Prof. Dr. T. Braun; 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; S. Jenni; M. Jin; E. Kalogeiton; M. Karimzadeh; A. Kashev; I. Keller; J. Kurš; E. Lehmann; M. Leuenberger; M. Manzi; A. Marandi; M. Marti; G. Meishvili; L. Merino del Campo; N. Milojkovic; Prof. Dr. O. Nierstrasz; M. Noroozi; H. Osman; T. Portenier; Dr. D. Probst; T. Rosebrock; J. Saltarin; Dr. K. Sato; N. Savić; Dr. E. Schiller; D. S. Schroth; B. Spasojević; Dr. Th. Staub; Dr. S. Steila; 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 (until 12/16)

Managing director

Prof. Dr. Oscar Nierstrasz

Director of studies

Prof. Dr. Paolo Favaro

Administration

Bettina Choffat; Dragana Esser; Iris Keller (until 2/17); Daniela Schroth

Technical staff

Dr. Peppo Brambilla; Alexander Kashev (until 12/16); Tiziano Portenier (as of 1/17)

2 Teaching Activities

2.1 Courses for Major and Minor in Computer Science

Autumn Semester 2016

- Bachelor 1st Semester

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

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

Programmierung 1 (P. Brambilla, 5 ECTS)

- Bachelor 3rd Semester

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

Computernetze (T. Braun, 5 ECTS)

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

- Bachelor 5th Semester

Computergrafik (M. Zwicker, 5 ECTS)

Mensch-Maschine-Schnittstelle (K. Riesen, 5 ECTS)

Machine Learning (P. Favaro, 5 ECTS)

Anleitung zu wissenschaftlichen Arbeiten (Die Dozenten der Informatik, 5 ECTS)

- Master Courses

Software Modeling and Analysis (O. Nierstrasz, 5 ECTS)

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

Justification Logic (T. Studer, 5 ECTS)

Computational Photography (M. Zwicker, 5 ECTS)

Computer Vision (P. Favaro, 5 ECTS)

Working Group: Operations, Sets, and Types (G. Jäger, 5 ECTS)

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

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

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

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

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

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

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

- Service Courses

Anwendungssoftware (T. Studer, 3 ECTS)

Spring Semester 2017

- Bachelor 2nd Semester

Datenbanken (T. Studer, 5 ECTS)

Datenstrukturen und Algorithmen (P. Brambilla, 5 ECTS)

Computer Architecture (P. Favaro, 5 ECTS)

Programmierung 2 (O. Nierstrasz, 5 ECTS)

- Bachelor 4th Semester

Praktikum in Software Engineering (T. Studer, 5 ECTS)

Betriebssysteme (T. Staub, M. Anwander, 5 ECTS)

Berechenbarkeit und Komplexität (D. Probst, 5 ECTS)

Automaten und formale Sprachen (G. Jäger, 5 ECTS)

- Bachelor 6th Semester
 - Anleitung zu wissenschaftlichen Arbeiten (5 ECTS)

- Master Courses
 - Compiler Construction (O. Nierstrasz, 5 ECTS)
 - Advanced Topics in Machine Learning (P. Favaro, 5 ECTS)
 - Working Group: Operations, Sets and Types (G. Jäger, 5 ECTS)
 - Complexity Theory (D. Probst, 5 ECTS)
 - Seminar: Software Composition (O. Nierstrasz, 5 ECTS)
 - Seminar: Communication and Distributed Systems (T. Braun, 5 ECTS)
 - Seminar: Logic and Theoretical Computer Science (G. Jäger, 5 ECTS)
 - Seminar: Computer Vision (P. Favaro, 5 ECTS)
 - Graduate Seminar Logic and Information (G. Jäger, G. Metcalfe, K. Stoffel, U. Ultes-Nitsche, 5 ECTS)

- Service Courses
 - Anwendungssoftware (M. Marti, 3 ECTS)

2.2 Students

- Major Subject Students: AS 2016: 230, SS 2017: 214
- Minor Subject Students: AS 2016: 147, SS 2017: 137
- Ph.D. Candidates: AS 2016: 37, SS 2017: 33

2.3 Degrees and Examinations

- PhD: 9
- Master: 19
- Bachelor: 23

- Completion of Minor Studies: 21 (90E:0, 60E: 4, 30E: 13, 15E: 4, 690 ECTS)
- Semester Examinations AS 2016: 707 (2704 ECTS)
- Bachelor's/Master's Theses AS 2016: 16 (340 ECTS)
- Semester Examinations SS 2017: 444 (1868 ECTS)
- Bachelor's/Masters Theses SS 2017: 13 (270 ECTS)

2.4 Activities

- Contributions to the Schweizer Jugend Forscht Studienwoche, Bern, September 11-17, 2016
- Contribution to the "National Future Day for Girls", Bern, November 10, 2016
- Contribution to the "Bachelor Infotage", December 5+6, 2016
- Contribution to the "Master Infotage", March 8, 2017
- Taster course for female students, Bern, March 23, 2017
- Visitor Program, Gymnasium Thun, Bern, July 4, 2017

2.5 Awards

- PhD INF for "Uncertain Reasoning in Justification Logic", by Ioannis Kokkinis
- Master INF for "Improving live debugging of concurrent threads", by Max Leske
- Bachelor INF for "Universal Large Scale Sensor Network", by Jakob Schaerer and Severin Zumbrunn

3 Communication and Distributed Systems Group

3.1 Personnel

Head:	Prof. Dr. T. Braun	Tel.: +41 31 511 2631 email: braun@inf.unibe.ch
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	M. Gasparyan*	Tel.: +41 31 511 7645 email: gasparyan@inf.unibe.ch
	A. Gomes*	Tel.: +41 31 511 2636 email: gomes@inf.unibe.ch (until 31.10.2016)
	E. Kalogeiton*	Tel.: +41 31 511 2638 email: kalogeiton@inf.unibe.ch
	M. Karimzadeh	Tel.: +41 31 511 7645 email: karimzadeh@inf.unibe.ch
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	J. Saltarin*	Tel.: +41 31 511 7631 email: saltarin@inf.unibe.ch
	Dr. E. Schiller*	Tel.: +41 31 511 2633 email: schiller@inf.unibe.ch
	Dr. Z. Zhao*	Tel.: +41 31 511 2639 email: zhao@inf.unibe.ch

External Ph.D. Students:

M. Thoma email: thoma@inf.unibe.ch
(until 21.12.16)
L. Luceri email: luceri@inf.unibe.ch
G. Manzo email: gaetanomanzo@gmail.com

Teaching:

Dr. M. Anwander email: anwander@inf.unibe.ch
(01.02.17-31.07.17)
Dr. Th. Staub email: staub@inf.unibe.ch
(01.02.17-31.07.17)

* 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 is an SNF funded Sinergia project including Universities of Bern and Geneva, SUPSI Lugano, and Chalmers University. This project targets at establishing a synergistic platform, which consists of a testbed, based on mobile crowd-sensing and Internet of Things, a data model for representing the various types of collected data, and an on-line localization and mobility prediction engine for producing insights. During the past year, the SwissSenseSynergy project continued to develop the proposed framework for delivering secure localization and location-based services (LBS) to users. Individual components of the designed synergistic platform have been successfully implemented, and research activities have been conducted mainly in four sub-projects, following the original proposal planning.

The CDS group is leading the sub-project of “mobility, localization and tracking”, in which our tasks are indoor localization/tracking and mobility prediction. For indoor localization, we have set up an active positioning

system for mobile devices in Wi-Fi indoor environments. Our system extracts the Received Signal Strength from the MAC layer to implement enhanced methods for ranging and positioning. Additionally, our positioning system includes machine learning techniques to estimate the position of the target object. To fuse multi-lateration and fingerprinting techniques, we have designed an enhanced particle filter method. For indoor tracking, we mainly worked on active tracking of Wi-Fi targets and extended the aforementioned active positioning system to support tracking mobile targets by designing an enhanced particle filter. The enhanced particle filter is relying on range-based signal power information, machine learning algorithms such as Support Vector Machines and K-nearest neighbors, inertial sensors (IMUs), barometer, magnetometer and physical information of the environment. We provide an efficient double resampling method to mitigate errors caused by off-the-shelf IMUs and Wi-Fi sensors embedded in commodity smartphones. The terminal-based tracking system contains some anchor nodes, which are commodity Wi-Fi access points, and the target smartphone. The fingerprinting database and floor plan are uploaded to the system as known information. With this system, we are able to achieve a mean accuracy of $1.1m$ and a 90% accuracy of $1.7m$. All the tracking and positioning algorithms run on the smartphone. Moreover, we worked on some techniques to reduce the computation effort on the smartphone by keeping the accuracy and stability of the approach. Specifically, we worked on a method to define the state space as a discrete set of states. We proposed to rely on a graph-based approach to define the set of states. In addition, we worked on machine learning approaches for efficient landmark recognition. We have worked on the particle filter method to integrate all the mentioned information for the tracking process. Latest results of indoor location and tracking have been published in [Carrera et al., 2016a, Carrera et al., 2016b, Carrera et al., 2017].

In the task of mobility prediction, our goal is to predict the future locations of mobile users based on their historical and current context, such as GPS locations, frequency and duration of visiting a place, and the smartphone system information, such as WLAN connections, movement acceleration, running applications, etc. In the past year, we applied WEKA, an open source machine learning software to predict a user's future locations. We applied the J48 and Random forest, the Bayes network and Naive Bayes as well as Multilayer perceptron algorithms to solve the mobility prediction problem. We have utilized the mobility data trace provided by the Nokia Mobile Data Challenge (MDC) to extract relevant features and evaluate the performance of algorithms. We defined temporal, spatial and system information of places visited by the users during the prediction

procedure. The results show that, when using temporal, spatial and system information, prediction accuracy is improved by 20% to 45% compared to temporal features for individual algorithms. Moreover, algorithms relying on the decision tree family outperform others when the quality of data trace is low (e.g., with 100 – 500 instances), and the Bayes network scheme provides better performance (> 84% accuracy) when the movement trace is of high quality (e.g., with 700 – 1500 instances). Furthermore, evaluation results of ensemble learning show that when using the Boosting approach, prediction accuracy could be improved by 5% to 10% compared to individual algorithms. In detail, by integrating J48 and MLP, the prediction performance is improved by 10% to 14% compared to individual algorithms even for lower quality traces. Even more improvement is seen when we integrated J48, Bayes network and MLP mechanisms. The latest results can be found in our submission [Zhao et al., 2017d].

In addition to our own individual research progress, the CDS group has collaborated with other project partners. For instance, we have successfully integrated our indoor localization system with the wireless sensor and actuator network (WSAN) management system from a project partner to support indoor location-based WSAN appliance automation.

Moreover, the SwissSenseSynergy project has been featured in the press release of Swiss National Science Foundation news¹.

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

Financial support: Swiss National Science Foundation Sinergia, no. 154458

FIRE LTE testbeds for open EXperimentation

FIRE LTE testbeds for open EXperimentation (FLEX)² was a large-scale Integrating Project (IP) funded by the European Commission within the 7th European Union Framework Programme. CDS joined FLEX through the Second Open Call for 10 months between April 1, 2016 and January 31, 2017. FLEX aimed to provide fully open and operational LTE experimental facilities. Based on the combination of configurable commercial equipment, configurable core network software, open source components, and emulation and mobility functionalities, the FLEX facility allowed researchers from academia and industry to test services and applications

¹<http://www.snf.ch/en/researchinFocus/newsroom/Pages/news-170612-press-release-smarter-use-of-mobile-data.aspx>

²<http://flex-project.eu/>

over real LTE infrastructures, or experiment with alternative algorithms and architectures of the core and access networks. In the scope of the FP7 FLEX project, CDS implemented and evaluated a Mobile Edge Computing (MEC) caching framework. The MEC server was collocated with the evolved Node B (eNB) of the LTE network. The MEC caching application was provided as a Virtual Network Function (VNF) on top of a cloud environment. The traffic was managed through Software Defined Networking (SDN) [Katsalis et al., 2017].

Research staff: E. Schiller, T. Braun.

Financial support: EU FP7 Large-scale Integrating Project (IP), no. 612050

Network Coding Based Multimedia Streaming in Content Centric Networks

This project proposed the use of network coding to optimize content delivery in Named Data Networking (NDN), and, it also proposed the use of Bloom filters to improve content discovery in NDN. Below we describe the two main contributions of this project, making emphasis on contributions developed during the third year of the project, which falls under the reporting period covered in this report.

Network Coding has shown benefits in the transmission of content in multi-client and multi-source networks. In particular, some of the reported benefits are increased throughput, decreased delay, enhanced data loss resilience, removing the need for coordination between the network nodes, etc. Since NDN is presented as one of the main future Internet architectures, it is interesting to investigate the benefits that network coding could bring, and the best way to integrate it into the NDN architecture. For this reason, during the second year of this project we proposed NetCodNDN, a novel architecture that enables network coding in NDN. Our proposed solution solves the shortcomings present in previous attempts to introduce network coding into NDN. In the third year of the project, we have used the NetCodNDN architecture to study in more detail the benefits that network coding brings to NDN. Further, we have focused on studying the benefits that network coding brings to video streaming over NDN. We have also studied caching strategies adapted to network coded data delivery, which help to maintain the benefits that network coding brings to NDN in the case in which caches have limited capacity.

First, we have proposed a solution based on the NetCodNDN architecture, called Dynamic Adaptive Streaming over NetCodNDN (DAS-NetCodNDN) [Saltarin et al., 2017]. This work is based on the Dynamic Adaptive Streaming over HTTP (DASH) standard. We have designed new client and source applications that run on top of NetCodNDN and that implement the adaptive streaming layer. Furthermore, we have updated the NetCodNDN architecture, in particular, modifying the data structures of NetCodNDN, in order to provide better support for the network coding functionalities and for data intensive applications like video streaming. Our results demonstrate that by using network coding, our proposed video streaming architecture achieves a higher cache hit rate in the router nodes. This translates into lower bandwidth consumption at the source, as well as higher bitrate seen at the clients. As a result, clients can reach their desired video quality faster.

Second, we proposed the use of Scalable Video Coding (SVC) to deal with the heterogeneous requests of users with diverse demands in terms of the video quality. The new features of our network coding-enabled NDN architecture include the appropriate naming scheme and the processing functions that permit to handle both the Interest and Data packets when the intermediate nodes perform network coding. To deal with the ambiguity that arises from the use of content names that do not specify unique Data packets but rather a set of network coded packets belonging to the same class and generation, we propose the use of Bloom filters that compactly store additional information about the Interest and Data packets. We then derive the optimal rate allocation for the transmission of Interests in order to achieve the flow of Data packets that maximizes the average video quality in the client population. Further, we design the optimal content-aware Interest forwarding strategy based on the solution of the rate allocation problem. The forwarding strategy guarantees that a sufficient number of Interest packets will be optimally forwarded so that the innovative rate of Data packets remains sufficiently high. The evaluation shows that the proposed method results in close to optimal performance in terms of the achieved video quality [Bourtsoulatze et al., 2017].

Third, we proposed a popularity based caching policy for NetCodNDN. The proposed caching policy is distributed: each router measures the popularity of the Interests for video segments that it receives, and uses this information to decide which Data packets it will cache or evict from the content store. This naturally enables partial caching of video segments. The proposed caching policy keeps the most popular Data packets closer to the network edges, which is beneficial to the content delivery process. The results show that, in comparison with the most common caching poli-

cies used in NDN, our caching policy achieves a higher cache-hit, which reduces the number of Interests that the source should satisfy, and also increases the goodput seen by the clients. Thus, our caching policy presents benefits for the content providers, by reducing the load that its servers receive and hence its operative costs, and for the end-users, which are able to watch higher quality videos. This work is currently under submission.

Fourth, we have also worked on improving content discovery in NDN through the use of Bloom filters. We have proposed a Bloom filter-based routing scheme called BFR [Marandi et al., 2017] at the intra-domain level. BFR permits content providers to advertise their produced content objects using Bloom filters. Our results showed that using Bloom filters for content advertisements result in reasonably low signaling and storage overhead. We used the GEANT topology as the core topology for evaluation and then we performed a comparative analysis of BFR performance with flooding and shortest path routing approaches. We observed that BFR outperforms its counterparts in terms of average round-trip delay, normalized communication overhead, and robustness to topology changes. Further, BFR does not need any information regarding the topology of the network in contrast to shortest path routing.

To complete our research activities on Bloom filter-based content discovery, we compared the performance of BFR with other Bloom filter-based routing approaches proposed for NDN and we observed that BFR outperforms its counterparts in terms of average round-trip delay, normalized communication overhead, and total communication overhead. Further, we tested BFR with the grid topology to measure the communication overhead required for propagating content advertisement Bloom filters in very dense topologies. Our results shows that this overhead is still reasonable. Finally, we have implemented Bloom filter aggregation strategies to further lessen the communication overhead needed for distributing content advertisement Bloom filters.

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

Financial support: Swiss National Science Foundation, no. 149225

Service-Centric Networking

In ICN, the content is the main building block of the architectural design. However, the ICN paradigm does not consider service support in its design. We believe that the future Internet will be more and more service oriented, which requires a service-oriented future Internet architec-

ture. Service-Centric Networking (SCN) is a future Internet architecture paradigm derived from ICN. SCN extends the Content-Centric Networking (CCN) approach by integrating service support [Gasparyan et al., 2017a]. Our research aims at building a SCN architecture based on ICN with extensions regarding service requirements such as load-balancing and session support. We have designed the first SCN session support mechanism [Gasparyan et al., 2017b]. Our design makes use of hierarchical naming to establish sessions through a two-way handshake. It uses the existing ICN scheme with respect to the forwarding mechanism and storage. We have implemented and evaluated our service session support concept in ndnSIM. It provides promising preliminary results. We have designed a routing architecture for SCN called Intra-Domain Routing Architecture for SCN (IaDRA-SCN) based on NLSR, which is a link-state routing protocol for NDN. We have extended NDN and NLSR with the ability to support services. NLSR was extended with the capability to advertise also information about available resources in the network. Our design uses the NLSR Data and Interest messages to disseminate information about service provider resource availability information to the intra-domain network. Resource availability information is important for service request load-balancing because service requests require processing at the end node. SCN allows clients to request services, while these services are not coupled to specific servers. Therefore, we have to deal with authentication challenges since legacy authentication techniques do not apply. To cope with these challenges, we proposed and evaluated three generic SCN use cases and their corresponding authentication methods [Aad et al., 2016].

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)

Efficient communication in Vehicular Ad Hoc Networks (VANETs) has been researched during the last years due to the particular characteristics of VANETs. Firstly, in VANETs vehicles may communicate in an opportunistic way to exchange information. This information exchange is necessary in order to provide applications that are developed for a VANET environment the necessary Quality of Service (QoS). VANETs were conceived

with focus in a large set of applications including information about traffic jams, accidents, unsafe road conditions, weather conditions, location of facilities, shorter riding times, pollution, etc. However, the fact that unlike other types of mobile devices, vehicles are robust in terms of processing power, energy and storage capacity also allows for the development of infotainment based applications such as video streaming and online gaming that are more resource consuming.

The main objective of the CONTACT project is to ensure Quality of Service (QoS) in VANET communications by exploiting the combinations of NDN, SDN and Floating Content (FC) to address the problems induced by the high mobility of VANETs, which causes constant topology changes, frequent disconnections and variable network densities as well as the problems that are due to the unreliability of the wireless communication medium.

NDN provides a new communication approach that is different from traditional communication paradigms, since content objects are exchanged based on their unique names and not on the location of the producer hosts. SDN separates the networks 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.

In this project, we combine NDN, SDN, and FC paradigms to establish communication between vehicles by using either Vehicle-to-Vehicle communication (V2V) or Vehicle-to-Infrastructure communication (V2I). Together with the partners in this project, we propose solutions for the existing communication problems that exist in VANETs by using NDN, SDN and FC [Soua et al., 2016b, Duarte et al., 2017a]. In particular, during the first year of this project we identified the main factors that lead to performance degradation in VANETs, we developed a V2V routing protocol that enables V2V communication in an opportunistic way by reducing the transmissions that occur in a Wi-Fi scenario and thus optimizing the network usage [Kalogeiton et al., 2017a]. We tested our protocol in a scenario where vehicles are moving within a grid, without prior knowledge of the network topology, or the characteristics of vehicles (speed and direction). Our results indicate improved network performance in terms of message delivery and delay of the requested information. Further, we propose solutions for VANETs by using SDN in a V2I and V2V communication way [Kalogeiton et al., 2017b]. In addition, we studied the receiver

[Duarte et al., 2017b] and source mobility problems [Duarte et al., 2017c] in a VANET scenario using NDN in both V2I and V2V communication. We propose solutions to eliminate broadcast storms, network partitions, single points of failure and high overhead in the wireless communication medium as well as reverse path partitioning. Moreover, we focused on the low density of vehicles that occur in a VANET by using NDN [Duarte et al., 2017d]. We propose two approaches: one V2I and one V2V. For the first, we propose the delegation of content to Road Side Units (RSUs) and develop a mechanism for this content retrieval in the RSUs. For the second approach where no infrastructure is available, we proposed a store-carry-forward mechanism (VNDN-SCF). In VNDN-SCF, we develop a new store-carry-forward mechanism for NDN message retransmissions by vehicles. We test our approaches in a highly mobile sparse VANET. Our results show that both solutions are scalable and efficient for mitigating the negative effects on communication links between vehicles.

Moreover, we have investigated how to efficiently support proactive caching for NDN in vehicular networks. Proactive caching can be a key enabler for reducing the latency of retrieving predictable content requests, alleviating backhaul traffic and mitigating latency caused by handovers. In mobile networks, proactive caching relies on mobility prediction to locate the mobile device's next location and hence the node that must prefetch the content. Previously proposed proactive caching strategies use exclusively edge caching and cache redundant copies on multiple edge nodes to address prediction uncertainty. We developed a proactive caching strategy that leverages NDN's flexibility of caching data anywhere in the network, rather than just at the edge, like conventional content delivery networks [Abani et al., 2017]. We use an entropy-based metric to measure mobility prediction uncertainty and locate the best prefetching node, thus eliminating redundancy. While prefetching at levels higher in the network hierarchy incurs higher delays than at the edge, our evaluation results show that the increase in latency does not negate the performance gains of proactive caching. Moreover, the gains are amplified by the reduction in server load and cache redundancy achieved.

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

Financial support: Swiss National Science Foundation (SNSF), no. 164205

High Mobility Support in Recursive InterNetwork Architecture

The current TCP/IP based Internet architecture has shortcomings in various aspects such as security, support of mobile users, addressing concept limited to host identifiers, lacking multipath communication and multi-homing support etc. There have been many projects worldwide, many in the US, which develop new clean-slate architectures for the Future Internet to address these shortcomings of the current TCP/IP architecture. One of the most popular Future Internet architectures is NDN, which evolved from CCN. Another approach is the Recursive InterNetwork Architecture (RINA), which was been designed and developed by the research group of Prof. Ibrahim Matta, Network Research Group, Department of Computer Science, Boston University. RINA uses the concept of Distributed Inter-process communication Facility (DIF) to divide communication processes into manageable scopes across network subsystems. This results in reduced routing table sizes per DIF. RINA routes hop-by-hop based on the destination's node address. At each hop, the next-hop node address is mapped to the interface to that next-hop node. This late binding of a node's address to its interface and path allows RINA to effectively deal with interface changes due to multi-homing or mobility. Moreover, RINA has built-in security mechanisms. Certain issues such as performance in vehicular networks or multipath communication support have not been investigated in depth for RINA. Thus, we have investigated mechanisms addressing these issues in more detail. In particular, we investigated how vehicular networks can be supported by RINA and how a RINA based vehicular network architecture can be designed in order to support efficient management of mobile vehicles. A first analytical performance evaluation of the signaling overhead has been performed.

In another activity with Boston University, we investigated how to support service chaining in next generation mobile networks. Such next-generation mobile networks (5G and beyond) are expected to provide higher data rates and ultra-low latency in support of demanding applications, such as virtual and augmented reality, robots and drones, etc. To meet these stringent requirements, edge computing constitutes a central piece of the solution architecture wherein functional components of an application can be deployed over the edge network so as to reduce bandwidth demand over the core network while providing ultra-low latency communication to users. We investigated the joint optimal placement of virtual service chains consisting of virtual application functions (components) and the steering of

traffic through them over a 5G multi-technology edge network model consisting of both Ethernet and millimeter wave (mmWave) links. Our workload model captures virtual service chains that correspond to the needs of virtual and augmented reality applications over the edge network. Extensive evaluations demonstrate the benefits of managing virtual service chains (by distributing them over the edge network) compared to a baseline middlebox approach in terms of overall admissible virtual capacity. Moreover, we observe significant gains when deploying mmWave links that complement the Ethernet physical infrastructure.

Research staff: T. Braun.

Financial support: Swiss National Science Foundation Project, no. 175514

Multipath-TCP in Satellite Networks

Naval fleets often rely on multiple satellite communication systems (SATCOM) for on-board communication with other entities such as ships, shore nodes and hosts from external networks. Current practice is for an on-board ship router to select a particular SATCOM link for each outgoing traffic flow based on a mission-specific routing policy. We propose an alternative solution by viewing the multi-SATCOM link utilization task as a traffic engineering and load balancing problem, in particular, as a Multi-Commodity Flow (MCF) optimization problem. We propose using the Flow Deviation Method (FDM) as a network-wide optimal load-balancing solution that maximizes total throughput and minimizes traffic flow delay and jitter [Du et al., 2017]. Our approach is equally valid for both UDP and TCP flows. Network-wide global optimization is carried out via a central controller in a Software Defined Networking (SDN) framework. For TCP flows we propose a novel solution that combines the best attributes of Multi-Path TCP, SDN and FDM. Compared to single-path TCP or MPTCP-SDN without FDM-based traffic optimizer, our proposed combined scheme is more efficient in bandwidth utilization, delay/jitter minimization and also robust against jamming and intermittent link failure. Network performance results are validated via Mininet emulation tests.

Research Staff: T. Braun

Financial Support: University of California, Los Angeles (UCLA)

Testbeds

The CDS group owns and operates 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 SDN switches with 48 10 GbE-T ports and 80 Gb/s backbone connection. The infrastructure supports the following services fully 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 administration purposes, we use:

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

CDS owns an **IoT testbed** of 47 sensor 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 network, which connects the 47 sensor nodes, 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.

3.4 Ph.D. Theses

- André Gomes, “Performance Enhancement of Content Delivery in Mobile Networks”, October, 2016
- Matthias Thoma, “Rest-Based Internet of Things-Services and Applications in a semantics-Aware Enterprise Context”, December, 2016

3.5 Bachelor’s Theses

- Guillaume Corsini, “Implementation of Session Support in ndnSIM”, December, 2016
- Thomas Kolonko, “Multipath transmission for Content-Centric Networking in vehicular ad-hoc networks”, April, 2017

3.6 Ph.D. Dissertation Award

- Zan Li, “Fine-grained Indoor Positioning and Tracking Systems”, Fritz Kutter award, 2016.

3.7 Further Activities

Memberships

Torsten Braun

- Erweitertes Leitungsgremium Fachgruppe “Kommunikation und Verteilte Systeme”, Gesellschaft für Informatik
- SWITCH Stiftungsrat
- SWITCH Stiftungsratsausschuss
- Vice President of SWITCH foundation
- Kuratorium Fritz-Kutter-Fonds
- Expert for Diploma Exams at Fachhochschule Bern
- 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)

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

- 2nd International INFOCOM Workshop on Software-Driven Flexible and Agile Networking, Steering committee, Atlanta, GA, USA, May 1st, 2017
- Wired/Wireless Internet Communications, Steering committee, St. Petersburg, Russia, June 21-23, 2017

Conference Program Committees

Torsten Braun

- 10th International Workshop on Communication Technologies for Vehicles (Nets4Cars 2016), Donostia – San Sebastián, Spain, June 6-7, 2016
- 8th ICT Innovations Conference 2016, Ohrid, Macedonia, September 3-5, 2016
- 27th IEEE Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC 2016), Valencia, Spain, September 4-7, 2016
- 17th International Conference on Next Generation Wired/Wireless Advanced Networks and Systems (NEW2AN 2016), St. Petersburg, Russia, September 26-28, 2016
- IEEE 13th International Conference on Mobile Ad hoc and Sensor Systems (MASS), Brasília, Brazil, October 10-13, 2016
- 8th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT), Lisbon, Portugal, October 18-20, 2016
- 41th IEEE Local Computer Networks Conference (LCN 2016), Dubai, UAE, November 7-10, 2016
- IEEE Global Communications Conference (GLOBECOM), Washington, DC, USA, December 4-8, 2016
- 14th IEEE Consumer Communications and Networking Conference (CCNC 2017), January 8-11, 2017, Las Vegas, USA
- International Conference on Networked Systems (NetSys 2017), Göttingen, Germany, March 13-16, 2017
- IFIP/IEEE Wireless Days 2017 Conference, Porto, Portugal, March 29-31, 2017
- 32st ACM Symposium on Applied Computing (SAC 2017), Marrakech, Morocco, April 4-6, 2017
- IEEE International Conference on Communications (ICC 2017), Paris, France, 21-25 May 2017

- 3rd International Conference on Smart Computing (SMARTCOMP 2017), 29-31 May, 2017, Hong Kong, China
- IFIP Networking Conference 2017 (Networking 2017), Stockholm, Sweden, June 12-15, 2017
- IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM 2017), Macao, China, June 12-15, 2017
- IEEE/ACM International Symposium on Quality of Service (IWQoS), Vilanova i la Geltru, Barcelona, Spain, June 14-16, 2017
- IFIP International Conference on Wired and Wireless Internet Communications (WWIC), St. Petersburg, Russia, June 21-23, 2017

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

Journal Article Reviewing Activities

Torsten Braun

- Elsevier Computer Networks
- Elsevier Future Generation Computer Systems
- IEEE Wireless Communications Magazine

Eryk Schiller

- IEEE Wireless Communications Magazine
- Elsevier Ad-hoc Networks

Ali Marandi

- Elsevier Computer Communications

Talks and Tutorials

Torsten Braun

- Invited talk: “Content-Centric Networking in Wireless and Mobile Networks”, RECODIS MC Meeting Halmstad, Sweden, September 13, 2016
- Keynote talk: “Mobile Edge Computing”, International Congress on Development and Technology Transfer, Quito, Ecuador, October 25, 2016
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, University of California Los Angeles, January 18, 2017
- Keynote talk: “Mobile Follow-Me Cloud”, 2nd International INFO-COM Workshop on Software-Driven Flexible and Agile Networking (SWFAN), Atlanta, GA, USA, May 1, 2017
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, Northeastern University, August 9, 2017
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, University of Massachusetts, Amherst, August 14, 2017
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, Boston University, August 16, 2017

3.8 Publications

Journal Papers

- Bourtsoulatze, E., Thomos, N., Saltarin, J. E., Braun, T. (2017). Content-Aware Delivery of Scalable Video in Network Coding Enabled Named Data Networks. *IEEE Transactions on Multimedia*, 19, 1-13. Doi: 10.7892/boris.72370 ISSN: 1520-9210
- Carrera, J., Zhao, Z., Braun, T., Li, Z., and Neto, A. (2016a). A Real-time Robust Indoor Tracking System in Smartphones. *Computer Communications*. Doi: 10.1016/j.comcom.2017.09.004

- Duarte, J., Kalogeiton, E., Souza, R., Manzo, G., Palattella, M. R., Maio, A., Braun, T., Engel, T., Villas, L., and Rizzo, G. A. (2017a). A multi-pronged approach to adaptive and context aware content dissemination in VANETs. *Mobile Networks and Applications*, 1-13. Doi:10.1007/s11036-017-0816-y
- Gomes, A., Sousa, B., Palma, D., Fonseca, V., Zhao, Z., Monteiro, E., Braun, T., Simoes, P., and Cordeiro, L. (2016). Edge caching with mobility prediction in virtualized LTE mobile networks. *Future Generation Computer Systems*, 70, 148-162. Doi: 10.1016/j.future.2016.06.022
- Katsalis, K., Nikaein, N., Schiller, E. J., Ksentini, A., and Braun, T. (2017). Network Slices Towards 5G Communications: Slicing the LTE Network. *IEEE Communications Magazine*, 55, 146-154. Doi: 10.1109/MCOM.2017.1600936
- Kurtz, W., Lapin, A., Schilling, O. S., Tang, Q., Schiller, E. J., Braun, T., Hunkeler, D., Vereecken, H., Sudicky, E., and Kropf, P. (2017). Integrating hydrological modelling, data assimilation and cloud computing for real-time management of water resources. *Environmental modelling and software*, 93, 418-435. Doi:10.1016/j.envsoft.2017.03.011
- Li, Z., Braun, T. (2017). Passively Track WiFi Users With An Enhanced Particle Filter Using Power-based Ranging. *IEEE Transactions on Wireless Communications*, 99, 1-14. Doi:10.1109/TWC.2017.2746598
- Saltarin, J. E., Bourtsoulatze, E., Thomos, N., Braun, T. (2017). Adaptive Video Streaming with Network Coding Enabled Named Data Networking. *IEEE Transactions on Multimedia*, 19, 1-14. Doi: 10.1109/TMM.2017.2737950
- Sousa, B., Cordeiro, L., Simoes, P., Edmonds, A., Ruiz, S., Carella, G., Corici, M., Nikaein, N., Gomes, A. S. N., Schiller, E. J., Braun, T., Bohnert, T. M. (2017a). Towards a Fully Cloudified Mobile Network Infrastructure. *IEEE Transactions on Network and Service Management*, 3, 547-563. Doi: 10.1109/TNSM.2016.2598354
- Zhao, Z., Schiller, E., Kalogeiton, E., Braun, T., Stiller, B., Garip, M. T., Joy, J., Gerla, M., Akhtar, N., Matta, I (2017a). Autonomic Communications in Software-driven Networks. *IEEE Journal on Selected Areas in Communications, Special issue on Emerg-*

ing Technologies in Software-driven Communication, 35, 1-12. Doi: 10.7892/boris.100956 ISSN: 0733-8716

Book Chapters

- Nikaein, N., Schiller, E. J., Favraud, R., Knopp, R., Alyafawi, I., and Braun, T. (2016). Towards a Cloud-Native Radio Access Network. *Advances in Mobile Cloud Computing and Big Data in the 5G Era*, 22, 171-202. Doi: 10.1007/978-3-319-45145-9_8
- Schiller, E. J., Kalogeiton, E., Braun, T., Gomes, A. S. N., and Nikaein, N. (2017). ICN/DTN for Public Safety in Mobile Networks. *Wireless Public Safety Networks 3*, 231-247. Doi: 10.1016/B978-1-78548-053-9.50011-1
- Zhao, Z., and Braun, T. (2017b). Mobile Cloud Networking: Future Communication Architecture for Mobile Cloud. *Network as a Service for Next Generation Internet*. Doi: 10.1049/PBTE073E_ch

Conference Papers

- Aad, I. R., Braun, T., Mansour, D. (2016). Authentication and Trust in Service-Centric Networking. In *Local Computer Networks (LCN), 2016 41st IEEE Conference on, Singapore, October 9-12, 2017*. Doi: 10.1109/LCN.2016.93
- Abani, N., Braun, T., and Gerla, M. (2017). Proactive Caching with Mobility Prediction under Uncertainty in Information-Centric Networks. In *Information-Centric Networking (ICN), 2017 4th ACM Conference on, Berlin, Germany, September 26-28, 2017*. Doi: 10.7892/boris.105383
- Carrera, J., Zhao, Z., Braun, T., and Li, Z. (2016b). A Real-time Indoor Tracking System by Fusing, Inertial Sensor, Radio Signal and Floor Plan. In *Indoor Positioning and Indoor Navigation (IPIN), 2016 IEEE Conference on, Alcalá de Henares (Madrid), Spain, October 4-7, 2016*. Doi: 10.1109/IPIN.2016.7743701
- Carrera, J., Zhao, Z., Braun, T., and Neto, A. (2017). A Real-time Indoor Tracking System in Smartphones. In *Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM), 2016*

19th ACM Conference on, Malta, November 13-17, 2016. Doi: 10.1145/2988287.2989142

- Du, P., Pang, F., Braun, T., Gerla, M., Hoffmann, C., Jae, K. H. (2017). Traffic Optimization in Software Defined Naval Network for Satellite Communications In *International Conference for Military Communications (MILCOM), 2017 Conference on, Baltimore, MD, USA, October 23-25, 2017*. Doi: 10.7892/boris.105143
- Duarte, J., Braun, T., and Villas, L. (2017b). Receiver Mobility in Vehicular Named Data Networking. In *Mobility in the Evolving Internet Architecture (MobiArch), 2017 ACM SIGCOMM Workshop on, Los Angeles, CA, USA, August 21-25, 2017*. Doi: 10.1145/3097620.3097628
- Duarte, J., Braun, T., and Villas, L. (2017c). Source Mobility in Vehicular Named-Data Networking: An Overview. In *Ad Hoc Networks (Ad-hocnets), 2017 9th EAI International Conference on, Niagara Falls, Canada, September 28-29, 2017*. Doi: 10.7892/boris.101201
- Duarte, J., Braun, T., and Villas, L. (2017d). Addressing the Effects of Low Vehicle Densities in Highly Mobile Vehicular Named-Data Networks. In *Modeling, Analysis and Simulation of Wireless and Mobile Systems, 20th ACM International Conference on, Miami Beach, USA, November 21-25, 2017*. Doi: 10.7892/boris.101200
- Kalogeiton, E., Kolonko, T., and Braun, T. (2017a). A Multihop and Multipath Routing Protocol Using NDN for VANETs. In *Mediterranean Ad-Hoc Networking (Med-Hoc-Net), 2017 IEEE 16th Annual Workshop on, Budva, Montenegro, June 28-30, 2017*. Doi: 10.1109/Med-HocNet.2017.8001640
- Kalogeiton, E., Zhao, Z., and Braun, T. (2017b). Is SDN the Solution for NDN-VANETs? In *Mediterranean Ad-Hoc Networking (Med-Hoc-Net), 2017 IEEE 16th Annual Workshop on, Budva, Montenegro, June 28-30, 2017*. Doi: 10.1109/MedHocNet.2017.8001643
- Gasparyan, M., Corsini, G., Braun, T., and Schiller, E. J. (2017a). L-SCN: Layered SCN architecture with Supernodes and Bloom Filters. In *Consumer Communications and Networking Conference (CCNC), 2016 IEEE 14th Annual International Conference on, 899-904, Las Vegas, Nevada, USA, January 9-12, 2016*. Doi: 10.1109/CCNC.2017.7983252

- Gasparyan, M., Braun, T., Schiller, E. J., and Saltarin, J. E. (2017b). Session Support for SCN. In *Information-Centric Fog Computing (ICFC), 2017 IFIP Networking Workshop on, Stockholm, Sweden, June 12, 2017*. Doi: 10.7892/boris.99486 ISBN: 978-3-901882-94-4
- Marandi, A., Braun, T., Salamatian, K., and Thomos, N. (2017). BFR: a Bloom filter-based routing approach for Information-Centric Networks In *Networking, 2017 IFIP Conference on, Stockholm, Sweden, June 12-15, 2017*. Doi: 10.7892/boris.100186 ISBN: 978-3-901882-94-4
- Soua, R., Kalogeiton, E., Manzo, G., Duarte, J., Palattella, M. R., Maio, A. , Braun, T., Engel, T., Villas, L., and Rizzo, G. A. (2016b). SDN Coordination for CCN and FC Content Dissemination in VANETs. In *Ad Hoc Networks (AdHocNets 2016), 2016 7th International Conference on, Ottawa, Canada, September 26–27, 2016*. Doi: 10.1007/978-3-319-51204-4_18
- Sousa, B., Zhao, Z., Karimzadeh, M., Palma, D., Fonseca, V., Simoes, P., Braun, T., van den Berg, H., Pras, A., and Cordeiro, L. (2016c). Enabling a Mobility Prediction-aware Follow-Me Cloud. In *Local Computer Networks (LCN), 2016 41st IEEE Conference on, Singapore, October 9-12, 2017*. Doi: 10.1109/LCN.2016.77
- Tornatore, M., Andre, J., Babarczy, P., Braun, T., Følstad, E., Heegaard, P., Hmaity, A., Furdek, M., Jorge, L., Kmiecik, W., Mas Machuca, C., Martins, L., Medeiros, C., Musumeci, F., Pasi, A., Rakk, J., Simpson, S., Travanca, R., Voyiatzis, A. (2016). A survey on network resiliency methodologies against weather-based disruptions. In *Resilient Networks Design and Modeling (RNDM), 2016 8th IEEE Workshop on, Halmstad, Sweden, September 13-15, 2016*. Doi: 10.1109/RNDM.2016.7608264
- Zhao, Z. , Karimzadeh, M., Braun, T., Pras, A., and Berg, H. (2017c). Cloudified Mobility and Bandwidth Prediction in Virtualized LTE Networks. In *Integrated Network Management (IM), 2017 IEEE/IFIP Symposium on, Lisbon, Portugal, May 8-12, 2017*. Doi: 10.23919/INM.2017.7987321

Technical Reports

- Zhao, Z., Karimzadeh, M., and Braun, T. (2017d). Mobile Crowd Location Prediction with Hybrid Features using Ensemble Learning, Technischer Bericht, INF - Institut für Informatik, Universität Bern. Doi: 10.7892/boris.98674

4 Computer Graphics Group

4.1 Personnel

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	T. Portenier*	+41 31 511 76 01 email: portenier@inf.unibe.ch
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* with financial support from a third party

4.2 Overview

Prof. Zwicker left the Institute of Computer Science in January 2017 to take on a new position at the University of Maryland, College Park, USA. He would like to thank all his colleagues, the staff, and students at the institute for the constructive collaboration during his tenure at the University of Bern. The institute always provided a great environment for all aspects of academic life, including research, teaching, and discourse about any matter of interest. In short, the decision to leave was not an easy one.

4.3 Research Projects

Gradient-domain Monte Carlo Rendering

In this project we are developing new algorithms to generate realistic images using computer simulations. Applications of such algorithms include movie production, computer games, medical imaging, scientific visualization, or geographic information systems. Computer graphics is concerned with using computers to create images. Research in this area has been

so successful that computer generated images have become ubiquitous. Applications of computer graphics range from the entertainment industry, communication technologies, medical visualization and scientific applications to everyday tools like digital maps. In this project we tackle research challenges that are still limiting the capabilities of computer graphics technology. In particular, we will develop more efficient algorithms for image synthesis. Image synthesis is the task to create images of three dimensional scenes that are stored digitally in computers. Images represent distributions of light. While light in the physical world can be interpreted as a continuous quantity, it needs to be represented discretely for computer processing. This leads to the problem of sampling, which is at the core of this proposal. Computer graphics deals with various forms of sampled light to achieve realistic and efficient image synthesis. This includes, for example, the notion of light paths that store the amount of light transmitted along paths including several reflections at surfaces; the concept of transport operators that describe how light is passed between pairs of surface points; or radiance distributions that represent the light that is reflected in each direction at each surface point. In this project we are investigating efficient techniques to sample these quantities using correlated samples, which we relate to differences between image pixels called gradients. We will show in a theoretical analysis how correlated samples can reduce the error in image synthesis. We will develop improved algorithms for image synthesis that reduce the computation time to obtain results without visual artifacts, and that will enable more natural and effective interactive applications.

Research staff: Marco Manzi, Matthias Zwicker

Financial support: Swiss National Science Foundation, grant nr. 163045

Data-driven Modeling of 3D Objects with Functional Parts

This project addresses the modeling bottleneck in Computer Graphics. Today, the design and construction of 3D Computer Graphics content such as 3D shapes and animations is complicated and expensive. The goal of this project is to simplify the content creation process by acquiring and processing 3D data from the physical world. We will develop sophisticated mathematical and algorithmic tools to allow users to create novel shapes and animations including 3D objects with functional parts.

3D content creation with today's computer graphics tools is highly laborious and requires expert knowledge and training. For example, generating computer graphics imagery (CGI) for movie production involves sophisticated and complex content creation pipelines. Highly skilled and specialized artists perform significant amounts of manual labor to model, texture, and animate the 3D objects required in these applications. This time consuming and costly process often limits the use of computer graphics techniques to large companies with sufficient funding sources. The proliferation of effective computer graphics applications, however, is severely limited by this modeling bottleneck. Usage of CGI is much less widespread in many other types of visual media with smaller production budgets, such as educational media, blogs, or journalism.

Hence, the objective of the proposed project is to simplify the modeling process for computer graphics content. Ultimately, the outcomes of this project will 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. This means that users can browse, retrieve, edit, and recombine content stored in rich databases in intuitive ways, instead of modeling desired objects from scratch. In general, the challenges for data-driven modeling include data acquisition, the development of mathematical representations that expose the variability and the degrees of freedom inherent in the data, and the design of intuitive, interactive editing tools.

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

Financial support: Swiss National Science Foundation, grant nr. 169151

Sketch-Based Image Synthesis

This research aims at generating realistic pictures from sketches. The proposed system should also correct for inaccuracies in the initial sketch (such as asymmetries, incorrect perspective, distorted repeating patterns etc).

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 the 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

- Marco Manzi, Advanced Techniques in Gradient-Domain Rendering (October 2016)

4.5 Master's Theses

- Michael Single, Motion Segmentation on RGB-D Sequences using Optical Flow Fields (September 2016)
- Stefan Moser, Sketch Based Image Synthesis Using Conditional Adversarial Neural Network (January 2017)
- Paul Frischknecht, Volumetric 3D Reconstruction from RGB-D Images with Shading-based Refinement (Mai 2017)

4.6 Bachelor's Theses

- Nils Schnabel, VR Rendering for Visualizing Comets (September 2016)
- Timotheos Kousadianos, Auto-Scan: Scanning Objects with the Voxel Hashing Algorithm (March 2017)
- Marc Schneider, Study of a Deep Q-Learning Algorithm with Games of the Atari 2600 Console (June 2017)

4.7 Further Activities

Editorial Boards

Matthias Zwicker

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

Conference Organization

Matthias Zwicker

- STAR (state of the art reports) co-chair, Eurographics 2017, Annual Conference of the Eurographics Association for Computer Graphics, April 24 – 28, 2017, Lyon, France
- Papers co-chair, Eurographics Symposium on Rendering, June 19 – 21, 2017, Helsinki, Finland

Conference Program Committees

Matthias Zwicker

- ACM SIGGRAPH Asia, November 27 – 30, Bangkok, Thailand

Ph.D. and Habilitation Jury Memberships

Matthias Zwicker

- Nicola Pierazzo, external co-referee, Ecole Normale Superieure de Cachan, France
- 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

- 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

4.8 Publications

Journal Publications

- Peter Bertholet, Alexandru-Eugen Ichim, Matthias Zwicker: Temporally Consistent Motion Segmentation from RGB-D Video, Computer Graphics Forum, accepted with minor revisions.
- Shihao Wu, Peter Bertholet, Hui Huang, Daniel Cohen-Or, Minglun Gong, Matthias Zwicker: Structure-aware Data Consolidation, IEEE Transactions on Pattern Analysis and Machine Intelligence, preprint, 2017.
- Xuequan Lu, Shihao Wu, Honghua Chen, Sai-Kit Yeung, Wenzhi Chen, Matthias Zwicker: GPF: GMM-inspired Feature-preserving Point Set Filtering, IEEE Transactions on Visualization and Computer Graphics, preprint, 2017.
- Daljit Singh Dhillon, Michel C. Milinkovitch, Matthias Zwicker: Bifurcation analysis of reaction diffusion systems on arbitrary surfaces, Bulletin of mathematical biology 79(4), February 2017.
- Siavash Arjomand Bigdeli, Gregor Budweiser, Matthias Zwicker: Temporally coherent disparity maps using CRFs with fast 4D filtering, IPSJ Transactions on Computer Vision and Applications, December 2016.
- Marco Manzi, Markus Kettunen, Fredo Durand, Matthias Zwicker, Jaakko Lehtinen: Temporal Gradient-domain Path Tracing, ACM Transactions on Graphics, 35(6), November 2016.

Refereed Conference Proceedings

- Tiziano Portenier, Qiyang Hu, Paolo Favaro, Matthias Zwicker: Fine-Grained Retrieval with Autoencoders, VISAPP 2018, to appear, January 2018.
- Siavash Arjomand Bigdeli, Matthias Zwicker: Image Restoration using Autoencoding Priors, VISAPP 2018, to appear, January 2018.
- Siavash Arjomand Bigdeli, Meiguang Jin, Paolo Favaro, Matthias Zwicker: Deep Mean-Shift Priors for Image Restoration, Proceedings of NIPS 2017, to appear, December 2017.
- Tiziano Portenier, Qiyang Hu, Paolo Favaro, Matthias Zwicker: SmartSketcher: sketch-based image retrieval with dynamic semantic re-ranking, Proceedings of the Symposium on Sketch-Based Interfaces and Modeling, July 2017.
- Qiyang Hu, Paolo Favaro, Matthias Zwicker: 3D Face Reconstruction with Silhouette Constraints, Vision, Modeling, and Visualization, October 2016.

Technical Reports

- Siavash Arjomand Bigdeli, Meiguang Jin, Paolo Favaro, Matthias Zwicker: Deep Mean-Shift Priors for Image Restoration, technical report, arXiv:1709.03749, September 2017.
- Siavash Arjomand Bigdeli, Matthias Zwicker: Image Restoration using Autoencoding Priors, technical report, arXiv:1703.09964, March 2017.
- Peter Bertholet, Alexandru-Eugen Ichim, Matthias Zwicker: Temporally Consistent Motion Segmentation from RGB-D Video, technical report, arXiv:1608.04642, August 2016.

5 Computer Vision Group

5.1 Personnel

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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

Noise-Blind Image Deblurring

Non-blind image deblurring has been studied extensively in the literature. Its principal assumption is that the blur kernel affecting the image is known ahead of time. While this may seem limiting, the blur may be known from the design of the imaging system or can be estimated through other modalities, e.g., inertial sensors.

Even if the blur kernel is known, image deblurring is still difficult due to the loss of high-frequency information and the sensor noise. Moreover, noise cannot be avoided even with the best image sensors. Although we might theoretically calibrate the noise level for each camera and each ISO level, this quickly becomes infeasible in practice.

To this end, we present a novel approach to noise-blind deblurring, the problem of deblurring an image with known blur, but unknown noise level. We introduce an efficient and robust solution based on a Bayesian framework using a smooth generalization of the 0-1 loss. A novel bound allows the calculation of very high-dimensional integrals in closed form. It avoids the degeneracy of Maximum A Posteriori (MAP) estimates and leads to an effective noise-adaptive scheme. Moreover, we drastically accelerate our algorithm by using Majorization Minimization (MM) without introducing any approximation or boundary artifacts. We further speed up convergence by turning our algorithm into a neural network termed GradNet, which is highly parallelizable and can be efficiently trained. We demonstrate that our noise-blind formulation can be integrated with different priors and significantly improves existing deblurring algorithms in the noise-blind and in the known-noise case. Furthermore, GradNet leads to state-of-the-art performance across different noise levels, while retaining high computational efficiency.

Research staff: Meiguang Jin, 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

Disentangling Independent Factors of Variation

The aim of this project is to propose a learning method to build models that disentangle independent factors of variation on a given labeled training set. These models can be designed to control what factors they depend on and do not require additional assumptions on their probability distribution.

As model we use an autoencoder and as labeling we consider both indication of what category a sample belongs to as well as indication of what

single factor has changed between two samples, albeit without quantification of the change. In particular, the latter labeling may incur in almost no manual annotation cost. For example, collecting data with a stereo camera automatically gives information about a change of viewpoint (although it may be different for objects at different depth in the scene). We introduce independence in our models by using adversarial training. We build two sets of artificial examples, one with explicit dependency on known factors of variation and one without. We show formally that the optimal solution of this training method satisfies the independence constraints and demonstrate it also experimentally through classification and clustering, and image rendering.

Research staff: Qiyang Hu, Attila Szabó, 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. In computer vision, we are interested in a representation space in which the semantically related tasks, like classification, detection, are easier. The representations learned by Convolutional Neural Networks (CNN) have demonstrated an impressive performance in many computer vision tasks when trained on large labeled datasets. However, 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. The goal of this project is to develop methods to learn efficient representations from large scale unlabeled training data.

To this end, we introduce a novel method for representation learning that uses an artificial supervision signal based on counting visual primitives. This supervision signal is obtained from an equivariance relation, which does not require any manual annotation. We relate transformations of images to transformations of the representations. More specifically, we look for the representation that satisfies such relation rather than the transformations that match a given representation. We use two image transformations in the context of counting: scaling and tiling. The first transformation

exploits the fact that the number of visual primitives should be invariant to scale. The second transformation allows us to equate the total number of visual primitives in each tile to that in the whole image. These two transformations are combined in one constraint and used to train a neural network with a contrastive loss. The proposed task produces representations that perform on par or exceed the state of the art in transfer learning benchmarks.

Research staff: Mehdi Noroozi, Paolo Favaro

Unsupervised Viewpoint Estimation

A feature representation is said to be equivariant with respect to a transformation if transforming the input causes a predictable change in the features. We developed a method, where the feature transformation is fixed and known before training. The features therefore represent the absolute value of the attribute (e.g. viewpoint) corresponding to the transformation (e.g. rotation). This technique allows us to learn the attributes without using absolute labels, only the relative transformations are needed. We showed how we can use this technique in a semi-supervised setting, and learn a viewpoint estimator for the ShapeNet dataset. A special case of equivariance is invariance, where the features do not change when the input is transformed. With invariance our method can be used for clustering, where the cluster labels and the feature representation is learned jointly. We achieve state of the art clustering performance on the MNIST dataset, however our method does not scale to larger datasets like CIFAR and ImageNet.

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

Blind 3D Face Deblurring

The aim of this project is to restore images depicting blurred faces. Parents like to capture pictures of important events of their little ones: a birthday party, the first day at school, the first time on a bicycle and so on. However, these ever so special memories are often completely spoiled by motion blur. Typically, the details that matter the most to parents, such as the face, are completely blurred. This blurriness is not caused by the shaky hands of the photographer, but by the subjects, with whom cooperation cannot always be established.

The main difficulty with removing blur from an articulated or deforming body is that blur is typically non-smooth, space-varying and characterized by occlusions. Consider for example the picture of a rotating head. The area around the nose will be the combination of a partial occlusion and disocclusion process. Another issue is that the blurry input image provides limited and low-quality data to make decisions about the 3D geometry of an object, its 3D motion trajectory, and its texture. Thus, the challenge is that the process is highly nonlinear, one needs to determine its model with high precision, and there is only limited and ambiguous information (the blurry input image) to make such decisions.

We study this category of blind deconvolution problems with a model-based approach by exploiting user interaction and efficient search in pa-

parameter space. We envision a system where the user can help select and align (to different degrees) a 3D model on top of the blurry image. Given the 3D model, we then design an efficient algorithm to find the motion parameters of the model and to recover its texture. To cope with the data limitations and to break down the parameter search complexity, we consider building and using datasets of sharp images of faces.

Research staff: Givi Meishvili, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 165845

Feature Learning

Recent developments in deep learning have demonstrated impressive capabilities in learning useful features from images, which could then be transferred to several other semantically-driven tasks. These systems rely on large annotated datasets, which require expensive and time-consuming human labor. A growing number of methods addresses these issues by learning features from images without annotated data. These methods introduce a *pretext-task* that somehow relates to the semantic content of the scene. The challenge is then to choose the task that can teach the most about semantic content in images.

As a pretext-task we propose to classify images as semantically sound or defective. Defective (or *pseudo-real*) images are, for example, images where the eyes, the mouth and the nose were removed from a face and substituted with some plausible low-level texture, *e.g.*, skin texture. More in general, we would like to remove or distort image details and substitute them with texture that is inconspicuous, but not at the semantic level. This process should create a *semantic deficiency*, which we could exploit to learn how objects are made beyond low-level appearance statistics. In our example, it should then be possible to learn that faces typically have eyes, a mouth, and a nose unless they are occluded by other objects. We propose a simple procedure to arrive at such image transformations by taking inspiration from recent work on *learning via reconstruction*.

Our contributions can be summarized as follows: 1) we introduce a novel feature learning framework based on semantic defects, which does not require human annotation; 2) we introduce a methodology to efficiently create images with semantic defects; 3) we demonstrate that these features achieve state of the art performance on transfer learning evaluations

(ILSVRC2012, Pascal VOC07 and STL-10).

Research staff: Simon Jenni, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 169622

Learning Correspondence

We aim to build a system that is able to find correspondences between images of the same object category but across different instances. Given a region of interest in image A, the system should be able to find the corresponding region in image B (where A and B contain the same object category). Since supervision is extremely costly for this task we are looking for methods with no or only weak supervision (in the form of category labels and/or coarse viewpoint annotation).

Research staff: Simon Jenni, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 169622

5.4 Master's Theses

- Nina Mujkanovic, "Automatic and Large-Scale Assessment of Fluid in Retinal OCT Volume", December 2016 (ARTORG).

5.5 Bachelor's Theses

- Lucas Husi, "Self-Similarity as a Meta Feature", April 2017.
- Sammer Puran, "A Study of the Importance of Parts in the Deformable Parts Model", June 2017.

5.6 Further Activities

Ph.D. Thesis Examiner

Paolo Favaro

- “Half-Quadratic Inference and Learning for Natural Images”, U. Schmidt, TU Darmstadt, 2016
- “Sparse Gradient Optimization and its Applications in Image Processing”, N. A. Darginis, EPFL, 2017
- “Face Recognition, Super-Resolution, and Dynamic Object Segmentation for Moving Cameras”, A. Punnappurath, IIT Madras, 2017

Master’s Thesis Examiner

Paolo Favaro

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

Invited Talks

Paolo Favaro

- Invited Talk at UniBe, Microscopy Workshop, 2017
- Invited Talk at Fribourg, Swiss Nano Convention, 2017

Conference Program Committees

Paolo Favaro

- Area chair of ICCV 2017 and CVPR 2016

Journal Committees

Paolo Favaro

- Associate Editor for IEEE Transactions on Pattern Analysis and Machine Intelligence 2017

Reviewing Activities

Paolo Favaro

- DSP 2016
- CVPR 2017
- GCPR 2017
- SIGGRAPH ASIA 2017

Paramanand Chandramouli

- IEEE Transactions on Pattern Analysis and Machine Intelligence 2017
- IEEE Transactions on Computational Imaging 2017

5.7 Publications

Refereed Conference Proceedings

- M. Jin, S. Roth and P. Favaro, “Noise-blind Image Deblurring”, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), 2017.
- M. Noroozi, P. Chandramouli and P. Favaro, “Motion Deblurring in the Wild”, German Conference on Pattern Recognition (GCPR), 2017.
- T. Portenier, Q. Hu, P. Favaro and M. Zwicker, “SmartSketcher: Sketch-based Image Retrieval with Dynamic Semantic Re-ranking”, Expressive 2017.
- M. Noroozi, H. Pirsiavash and P. Favaro, “Learning Representations by Learning to Count”, International Conference on Computer Vision (ICCV), 2017.

Technical Reports

- M. Noroozi, S. Fazeli, M. K. Tabrizi and P. Favaro, “Learning Visual Representations and Room Layouts from RGB-D Data”, Technical Report, 2017.

- S. Jenni and P. Favaro, “Learning Features by Exploiting Semantic Soundness”, Technical Report, 2017.
- M. Jin and P. Favaro, “A Study of Blur Normalization in Blind Deconvolution”, Technical Report, 2017.
- M. Jin, M. Hirsch and P. Favaro, “Wide Receptive Field Networks for Face Deblurring and Demosaicking”, Technical Report, 2017.
- A. Szabó , Q. Hu, T. Portenier, M. Zwicker and P. Favaro, “Learning to Disentangle Independent Factors of Variation”, Under Review, NIPS 2017
- S. Bigdeli, M. Zwicker and P. Favaro, “Deep Mean-Shift Priors for Image Restoration”, Under Review, NIPS 2017

6 Logic and Theory Group

6.1 Personnel

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Guests:

Dr. M. Ghari	Institute for Research in Fundamental Sciences, School of Mathematics (Isfahan Branch), Iran August 2016
Dr. B. Afshari	University of Gothenburg, Department of Computer Science and Engineering, Sweden March 2017
Dr. G. Leigh	University of Gothenburg, Department of Philosophy, Linguistics and Theory of Science, Sweden March 2017

* with financial support from a third party

6.2 Overview

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

Computational Logic: Logical formalisms are perfectly suited to the specification of complex systems, the representation of knowledge and information, the description of processes (e.g. in distributed multi-agent systems) and for providing formal proofs of important system properties

such as, for example, correctness and fairness. The research group has long been interested in the deductive, procedural and dynamic aspects of the corresponding formalisms and in the design of modern deductive systems. New approaches are being developed for information update purposes. In addition, the way in which simple, logical formalisms can be extended to become genuine multi-user systems taking into account the dynamic aspects of ontologies in the data mining context and in connection with the semantic web is being investigated.

Proof Theory: This research topic focuses on the development and analysis of formal systems of first and second order arithmetic, set theory and of what are known as logical frameworks (type and set theoretical, explicit, constructive, extensional, intentional). Our interests range from feasible subsystems of arithmetic to highly impredicative set and type theories and deals with the interplay between constructive, recursive and operational approaches. In addition, abstract computations and computable knowledge are being investigated.

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, T. Rosebrock, K. Sato, S. Stella, T. Strahm

Financial support: Swiss National Science Foundation

Justifications and Non-Classical Reasoning

In most situations, the exact actual state of our environment is unknown and we only have incomplete information available when we have to make decisions. Therefore, we often use some form of reasoning under uncertainty in order to make inferences or to plan actions.

This project seeks to develop novel probabilistic justification logics and corresponding non-classical reasoning procedures to model epistemic situations with incomplete information.

Research staff: E. Lehmann, N. Savić, T. Studer

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 μ -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, 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, T. Rosebrock, 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

- A. Kashev: Justification with Nominals
- M. Marti: Contributions to Intuitionistic Epistemic Logic

6.5 Bachelor's Theses

- R. Bucher: Editor for Automata
- F. Walther: Grösste Autobisimulation und Minimales Modell

6.6 Further Activities

Editorial Boards

Gerhard Jäger

- Member of the Editorial Board of Archive for 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

Invited Talks

Michael Bärtschi

- From Transfinite Dependent Choice to Fixpoints of Monotone Operators, Arbeitstagung Bern-München Winter 2016, Ludwig-Maximilians-Universität München, December 2016.

Gerhard Jäger

- About Fixed Points, International Conference "Operations, Sets, and Truth", University of Florence, December 2016.
- Operations and Sets: a Historical Perspective, University of Florence, December 2016, March 2017.
- From Operations to Sets and Back, Graduate Center, City University of New York, May 2017.
- Conceptual Expansions, Solomon Feferman Symposium, Stanford University, June 2017.
- Kripke-Platek and Friends, Humboldt-Kolleg "Proof Theory as Mathesis Universalis", Villa Vigoni, Menaggio, July 2017.

Lukas Jaun

- Constructions for Identity-Elimination in Explicit Mathematics, Arbeitstagung Bern-München Winter 2016, Ludwig-Maximilians-Universität München, December 2016.
- Constructions for Identity-Elimination in Explicit Mathematics, Workshop on Constructivism, Logic and Topology, University of Bern, January 2017.

Alexander Kashev

- Justification with Propositional Nominals, Conference "Logic and Applications 2016", Inter University Centre Dubrovnik, September 2016.

Michel Marti

- Intuitionistic Justification Logics: Atomic Models and Realization without Variables, Arbeitstagung Bern-München Winter 2016, Ludwig-Maximilians-Universität München, December 2016.

- An Intuitionistic Justification Logic, Workshop on Constructivism, Logic and Topology, University of Bern, January 2017.

Timotej Rosebrock

- Recursion Theory in Applicative Theories, Workshop "Operations, Sets, and Types 2017", University of Bern, March 2017.

Kentaro Sato

- A Partial Realization of Hilbert's Program for Brouwer's Intuitionistic Mathematics, Workshop "Operations, Sets, and Types 2017", University of Bern, March 2017.
- Similarities and Dissimilarities between Second Order Number and Set Theories, Workshop "Operations, Sets, and Types 2017", University of Bern, March 2017.

Silvia Steila

- Reverse Mathematical Bounds for the Termination Theorem, Logic, Complexity and Automation - Computational Logic in the Alps 2016, Obergurgl University Center, September 2016.
- On Σ_1 -Fixed Point Statements in Kripke-Platek, Arbeitstagung Bern-München Winter 2016, Ludwig-Maximilians-Universität München, December 2016.
- On Σ_1 -Fixed Point Statements in Kripke Platek, Workshop on Constructivism, Logic and Topology, University of Bern, January 2017.
- The Strength of the SCT Criterion, Japan Advanced Institute of Science and Technology Logic Seminar Series, Nomi, February 2017.
- Playing with Equivalent Forms of CH, Workshop "New Directions in the Higher Infinite", International Centre for Mathematical Sciences, Edinburgh, July 2017.

Thomas Strahm

- Weak Theories of Operations, Types, and Truth, International Conference "Operations, Sets, and Truth", University of Florence, December 2016.
- Weak Applicative Theories with Types and Truth, Workshop on Constructivism, Logic and Topology, University of Bern, January 2017.

Thomas Studer

- The Proof Theory of Common Knowledge, Workshop on Constructivism, Logic and Topology, University of Bern, January 2017.
- Blockchain Logic, Workshop "Computational Epistemic Logic in Lorraine", French National Institute for Computer Science and Applied Mathematics, Nancy, May 2017.
- Blockchain Logic, Seminar for Probability Logic, Serbian Academy of Sciences and Arts, Belgrade, June 2017.

Technical and Research Committees

Gerhard Jäger

- Swiss Delegate to the International Federation for Information Processing Technical Committee 1 (Foundations of Computer Science)
- Member of the Ambizione Panel of the Swiss National Science Foundation
- Member of the Scientific Council of the European Association for Computer Science Logic
- General Chair and Program Chair of Theory and Applications of Models of Computation TAMC 2017
- Member of the Kantonale Maturitätskommission
- Expert for "Maturitätsprüfungen Mathematik und Informatik"

Silvia Steila

- PC Member of Theory and Applications of Models of Computation TAMC 2017

Thomas Strahm

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

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 and Technology
- Board Member of the Platform Mathematics, Astronomy and Physics of the Swiss Academy of Sciences
- PC Member of Theory and Applications of Models of Computation TAMC 2017
- Expert for “Maturitätsprüfungen Mathematik und Informatik”
- Local Organizer of the Swiss Olympiad in Informatics Finals, 2017

Jan Walker

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

Organized Events**Michael Bärtschi**

- Together with B. Karádais. Arbeitstagung Bern-München Winter 2016, Ludwig-Maximilians-Universität München, December 2016.
- Together with G. Jäger and K. Sato. Operations, Sets, and Types (international workshop supported by the John Templeton Foundation), University of Bern, March 2017.

Gerhard Jäger

- Together with H.P. Künzi. Workshop on Constructivism, Logic and Topology, University of Bern, January 2017.
- Together with M. Bärtschi and K. Sato. Operations, Sets, and Types (international workshop supported by the John Templeton Foundation), University of Bern, March 2017.
- Together with S. Steila. Theory and Applications of Models of Computation TAMC 2017, University of Bern, April 2017.

Kentaro Sato

- Together with M. Bärtschi and G. Jäger. Operations, Sets, and Types (international workshop supported by the John Templeton Foundation), University of Bern, March 2017.

Silvia Steila

- Together with G. Jäger. Theory and Applications of Models of Computation TAMC 2017, University of Bern, April 2017.

Thomas Studer

- Logic and Probability (international workshop), University of Bern, October 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*, 82(2):737–753, June 2017.
- Samuel Bucheli, Meghdad Ghari, and Thomas Studer. Temporal Justification Logic. In Sujata Ghosh and R. Ramanujam, editors, *Proceedings of the Ninth Workshop on Methods for Modalities*, volume 243 of *Electronic Proceedings in Theoretical Computer Science*, pages 59–74. Open Publishing Association, 2017.
- Emanuele Frittaion, Silvia Steila, and Keita Yokoyama. The Strength of the SCT Criterion. In T.V. Gopal, Gerhard Jäger, and Silvia Steila, editors, *Theory and Applications of Models of Computation*, volume 10185 of *Lecture Notes in Computer Science*, pages 260–273. Springer International Publishing, 2017.
- T.V. Gopal, Gerhard Jäger, and Silvia Steila, editors. *Theory and Applications of Models of Computation*, volume 10185 of *Lecture Notes in Computer Science*. Springer International Publishing, 2017.
- Gerhard Jäger. Relativizing operational set theory. *The Bulletin of Symbolic Logic*, 22(3):332–352, September 2016.

- Gerhard Jäger and Michel Marti. A Canonical Model Construction for Intuitionistic Distributed Knowledge. In Lev Beklemishev, Stéphane Demri, and András Máté, editors, *Advances in Modal Logic*, volume 11 of *AiML*, pages 420–434. College Publications, 2016.
- Gerhard Jäger and Michel Marti. Intuitionistic common knowledge or belief. *Journal of Applied Logic*, 18:150–163, November 2016.
- Michel Marti and Thomas Studer. Intuitionistic modal logic made explicit. *The IfCoLog Journal of Logics and their Applications*, 3(5):877–901, December 2016.
- Nenad Savić, Dragan Doder, and Zoran Ognjanović. A First-Order Logic for Reasoning About Higher-Order Upper and Lower Probabilities. In Alessandro Antonucci, Laurence Cholvy, and Odile Papini, editors, *Symbolic and Quantitative Approaches to Reasoning with Uncertainty*, volume 10369 of *Lecture Notes in Artificial Intelligence*, pages 491–500. Springer International Publishing, 2017.
- Silvia Steila and Keita Yokoyama. Reverse mathematical bounds for the termination theorem. *Annals of Pure and Applied Logic*, 167(12):1213–1241, December 2016.

7 Software Composition Group

7.1 Personnel

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	C. Corrodi*	Tel: +41 31 511 7639 email: corrodi@inf.unibe.ch
	J. Kurš*	Tel: +41 31 511 7638 email: kurs@inf.unibe.ch
	M. Leuenberger*	Tel: +41 31 511 7636 email: leuenberger@inf.unibe.ch
	L. Merino*	Tel: +41 31 511 7638 email: merino@inf.unibe.ch
	N. Milojković	Tel: +41 31 511 7639 email: nevena@inf.unibe.ch
	H. Osman	Tel: +41 31 511 7644 email: osman@inf.unibe.ch
	B. Spasojević*	Tel: +41 31 511 7636 email: spasojev@inf.unibe.ch
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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.

Jan Kurš completed his PhD on *Parsing for Agile Modeling*. In this work he develops a novel approach to tolerant parsing based on “bounded seas”, a form of island parsing that avoids the usual problems with so-called island parsers, by automatically determining parts of the input to be ignored.

We also continued to explore novel ways of parsing unknown languages by automatically identifying structural patterns in code.

- **Context-Aware Tooling.** Andrei Chiş completed his PhD thesis on *Moldable Tools*. In this work he shows how software development tools can be designed to be easily adaptable to the specific needs of a given application, by making the tool aware of domain objects from the application software. Tools such as debuggers, inspectors and browsers more effectively support development tasks when domain objects can be highlighted and specially handled.

Static analysis tools can offer insights into the state of one’s source code, for example, to detect code smells or bad API usage patterns. However, these analyses can suffer from false positives. Furthermore, these tools tend to be used in batch mode, where the full source code is analyzed at a time. We are currently investigating

several possibilities to improve on this situation. By running analyses continuously, the feedback is more immediate and relevant to one's current task. To achieve this, we plan to enhance debuggers to run static analyses relevant to the code that is currently executing. Furthermore, we think that the additional data available at runtime allows us to verify to some degree whether the reports from the static analysis are in fact true positives. As a result, we hope to obtain reports that are relevant to the current debugging task and more precise.

In a previous study we found that even though multiple media can be used to display a software visualization, the standard computer screen is used the most. We hypothesized that the medium has a role in the effectiveness of visualizations. Consequently, we investigated our hypotheses by conducting a controlled user experiment with twenty-seven participants and deployed visualizations across a standard computer screen, an immersive 3D environment, and a physical 3D printed model.

We also have developed an interactive software visualization tool that implements the city metaphor technique using virtual reality in an immersive 3D environment medium to boost developer engagement in software comprehension tasks.

- **Ecosystem Mining.** In previous studies, we found out that missing to check the returned value of methods against null is one of the most frequent bug patterns in Java systems. To counter this defect, we have developed a tool that collects usage data of a given API, analyzes them, and empirically detects methods that might return null. This information is then harvested in an Eclipse plug-in that warns developers about potential missing and unnecessary null checks.

Programming languages use exceptions to handle abnormal situations during the execution of a program. While programming languages often provide a set of standard exceptions, developers can further create custom exceptions to capture relevant data about project- and domain-specific errors. Analyzing the evolution of exception usage in Java systems, we find that standard exception usage increases more than the custom exception. We also find that the domain, the type, and the development phase of a project affect the exception handling patterns. We observe that applications have significantly more error handling code than libraries and they increasingly rely on custom exceptions. Also, projects that belong to different domains have different preferences of exception types.

For instance, content management systems rely more on custom exceptions than standard exceptions whereas the opposite is true in parsing frameworks.

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 tend to ignore important pre-processing steps that are necessary to improve prediction accuracy. We particularly shed light on the importance of two techniques: feature selection and hyperparameter optimization. We demonstrate that applying automatic feature selection by regularizing the regressors, significantly improves the accuracy of bug prediction. We also run an empirical study on the effect of hyperparameter optimization on five machine learning models. Our results suggest that although some models are less sensitive to this process than others, hyperparameter optimization generally improves the accuracy and stability of bug prediction models.

Nevena Milojković completed her PhD on *Augmenting Type Inference with Lightweight Heuristics*. In her thesis she shows how information mined from the project at hand or from the ecosystem at large can be used to improve lightweight type inference heuristics.

Understanding how to properly use APIs of large libraries is difficult, error prone, and time consuming. Software developers resort to study code examples to learn APIs. Several approaches have been proposed to mine these examples, but the sources from which they mine examples as well as their mining approaches hamper their applicability in some practical scenarios. In particular, existing approaches to find or generate examples assume availability of a reasonable set of client code that uses the API. This assumption does not hold for newly released API libraries, non-widely used APIs, nor private ones. We reuse the important information that is naturally present in test code to circumvent the lack of usage examples for an API in these circumstances. We propose an approach for automatically identifying the most representative API uses within each unit test case. We then develop an approach to synthesize API usage examples by extracting relevant statements representing the usage of such APIs. We compare the output of a prototype implementation of our approach to both human-written examples and to a state-of-the-art approach. The obtained results are encouraging; the examples automatically generated with our approach are superior to the state-of-the-art approach and highly similar to the manually constructed

examples.

- **Evolutionary Monitoring.**

Boris Spasojević completed his PhD on *Developing Ecosystem-aware Tools*. He shows how the task of mining information from the software ecosystem can be largely automated by providing a suitable infrastructure. He validates the approach through a series of analysis tools built on the ecosystem mining platform.

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 see potential problems immediately. Based on our observations live quality feedback brings significant benefits to software developers in comparison with more traditional on-demand tools. Live feedback reveals issues that are close to a contemporary development context and can be addressed with more ease. Additionally, the violations are reported in small batches as they are related only to a small scope on which a developer is working. We also discovered that live feedback could act as an educational instrument, where a developer receives a valuable piece of documentation only when it is needed.

On the global scale of static analysis researchers try to solve two major problems: how to improve algorithmic detection of issues, and now to provide the detected information to a user. Usually, solutions to both problems require a certain level of implementation effort, and at the moment there is a poor support for reuse. For example, it is complicated to reuse a feedback solution for a detection strategy or vice versa. To support this kind of reuse we finalized the model used during our static analysis research as a standard of communication between software analyzers and development tools.

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

- Andrei Chiş. *Moldable Tools*. PhD thesis, University of Bern, September 2016. URL: <http://scg.unibe.ch/archive/phd/chis-phd.pdf>.
- Jan Kurš. *Parsing For Agile Modeling*. PhD thesis, University of Bern, October 2016. URL: <http://scg.unibe.ch/archive/phd/kurs-phd.pdf>.
- Nevena Milojković. *Augmenting Type Inference with Lightweight Heuristics*. PhD thesis, University of Bern, June 2017. URL: <http://scg.unibe.ch/archive/phd/lazarevic-phd.pdf>.
- Boris Spasojević. *Developing Ecosystem-aware Tools*. PhD thesis, University of Bern, December 2016. URL: <http://scg.unibe.ch/archive/phd/spasojevic-phd.pdf>.

7.5 Master's Theses

- Manuel Leuenberger. Nullable method detection — inferring method nullability from API usage. Masters thesis, University of Bern, February 2017. URL: <http://scg.unibe.ch/archive/masters/Leue17a.pdf>.
- Roger Stebler. An empirical investigation into the usage of a live debugger. Masters thesis, University of Bern, June 2017. URL: <http://scg.unibe.ch/archive/masters/Steb17a.pdf>.

7.6 Bachelor's Theses and Computer Science Projects

- Silas David Berger. Visually exploring scientific communities — extending EggShell's model and visualization. Bachelor's thesis, University of Bern, August 2017. URL: <http://scg.unibe.ch/archive/projects/Berg17a.pdf>.
- Stefan Borer. The Lego playground — providing an IDE for live programming Lego Mindstorm robots. Bachelor's thesis, University of Bern, February 2017. URL: <http://scg.unibe.ch/archive/projects/Bore17a.pdf>.

- Mathias Fuchs. Recognising structural patterns in code — a parser based approach. Bachelor’s thesis, University of Bern, May 2017. URL: <http://scg.unibe.ch/archive/projects/Fuch17a.pdf>.
- Jan Luca Liechti. Inferring schemata from semi-structured data with formal concept analysis. Bachelor’s thesis, University of Bern, May 2017. URL: <http://scg.unibe.ch/archive/projects/Liec17a.pdf>.
- Lina Tran. NullSpy – an approach to pinpoint the origin location of a null reference. Bachelor’s thesis, University of Bern, December 2016. URL: <http://scg.unibe.ch/archive/projects/Tran16a-NullSpy.pdf>.

7.7 Awards

- VISSOFT 2016 Best Paper Award for “Towards Actionable Visualisation in Software Development” by Leonel Merino, Mohammad Ghafari and Oscar Nierstrasz
- IWST 2016 Best Paper Award (1st prize) for “Optimizing Parser Combinators” by Jan Kurš, Jan Vransy, Mohammad Ghafari, Mircea Lungu and Oscar Nierstrasz
- IWST 2016 Best Paper Award (2nd prize) for “A Promising Approach for Debugging Remote Promises” by Max Leske, Andrei Chiş and Oscar Nierstrasz
- European Smalltalk User Group 2016 Technology Innovation Award (1st prize) for *Sparta* by Aliaksei Syrel

7.8 Further Activities

Invited Talks

Mohammad Ghafari

- Invited Speaker at TU Darmstadt (The Software Lab Research Group (SOLA) – Darmstadt, Germany, June 2, 2017)

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

- General Co-Chair for SCAM 2016 (International Working Conference on Source Code Analysis and Manipulation — Raleigh, North Carolina, Oct. 2-3, 2016)
- PC Member of ICSME 2016 (International Conference on Software Maintenance and Evolution — Raleigh, North Carolina, Oct. 2-10 2016)
- PC Member of Onward! 2016 Essays Track (Splash / Onward! 2016 — Amsterdam, The Netherlands, Oct. 30 – Nov. 4, 2016)

- PC Member of SANER 2016 (International Conference on Software Analysis, Evolution, and Reengineering — Osaka, Japan, March 14-18, 2016)

Mohammad Ghafari

- PC member of SATToSE 2017 (10th Seminar Series on Advanced Techniques & Tools for Software Evolution – Madrid, Spain, July 7-9, 2017)

Haidar Osman

- PC Chair of SATToSE 2017 (10th Seminar Series on Advanced Techniques & Tools for Software Evolution – Madrid, Spain, July 7-9, 2017)
- Post-proceedings Chair of SATToSE 2016 (9th Seminar Series on Advanced Techniques & Tools for Software Evolution – Bergen, Norway, July 11-13, 2016)
- PC Member of SANER 2017 tool track (24th IEEE International Conference on Software Analysis, Evolution, and Reengineering – Klagenfurt, Austria, February 21-24, 2017)
- PC Member of MaLTeSQuE 2017 (International Workshop on Machine Learning Techniques for Software Quality Evaluation – Klagenfurt, Austria, February 21-24, 2017)

Leonel Merino

- PC Member of VISSOFT 2017 – NIER and Tool Demo Track (5th IEEE Working Conference on Software Visualization – Shanghai, China, September 18-19, 2017)

Yuriy Tymchuk

- PC Member of IWST 2017 – (9th International Workshop on Smalltalk Technologies – Maribor, Slovenia, September 5th, 2017)
- PC Member of VISSOFT 2017 – NIER and Tool Demo Track (5th IEEE Working Conference on Software Visualization – Shanghai, China, September 18-19, 2017)

Nevena Milojković

- PC member of SATToSE 2017 (10th Seminar Series on Advanced Techniques & Tools for Software Evolution – Madrid, Spain, July 7-9, 2017)
- PC Member of IWST 2017 – (9th International Workshop on Smalltalk Technologies – Maribor, Slovenia, September 5th, 2017)

Reviewing Activities

Oscar Nierstrasz

- Deutsche Forschungsgemeinschaft

Mohammad Ghafari

- Journal of Information and Software Technology (IST)
- ICSME 2017
- SANER 2017
- SATToSE 2017

Haidar Osman

- SATToSE 2016 Post-proceedings
- SATToSE 2017
- SANER 2017
- SANER 2017 tool track
- MaLTeSQuE 2017
- Journal of Software: Evolution and Process

Leonel Merino

- Journal of Information and Software Technology (IST)
- SANER 2017

Claudio Corrodi

- SANER 2017

- ICSME 2017

Manuel Leuenberger

- ICSME 2017

Yuriy Tymchuk

- IWST 2017
- VISSOFT 2017

Nevena Milojković

- SANER 2017
- SATToSE 2017
- IWST 2017
- Journal of the Brazilian Computer Society

7.9 Publications

Journal Papers

- Mohammad Ghafari, Konstantin Rubinov, and Mohammad Mehdi Pourhashem K. Mining unit test cases to synthesize API usage examples. *Journal of Software: Evolution and Process*, pages e1841–n/a, 2017. e1841 smr.1841. URL: <http://dx.doi.org/10.1002/smr.1841>, doi:10.1002/smr.1841.
- Carole Goble, James Howison, Claude Kirchner, Oscar Nierstrasz, and Jurgen J. Vinju. Engineering Academic Software (Dagstuhl Perspectives Workshop 16252). *Dagstuhl Reports*, 6(6):62–87, 2016. URL: <http://drops.dagstuhl.de/opus/volltexte/2016/6755>, doi:10.4230/DagRep.6.6.62.

Conference Papers

- Andrei Chiş. Towards object-aware development tools. In *Companion Proceedings of the 2016 ACM SIGPLAN International Conference on Systems, Programming, Languages and Applications: Software for Humanity*, SPLASH Companion 2016, pages

65–66, New York, NY, USA, 2016. ACM. URL: <http://scg.unibe.ch/archive/papers/Chis16e-ObjectAwareDevelopmentTools.pdf>, doi:10.1145/2984043.2998546.

- Andrei Chiş, Tudor Gîrba, Juraj Kubelka, Oscar Nierstrasz, Stefan Reichhart, and Aliaksei Syrel. Moldable, context-aware searching with Spotter. In *Proceedings of the 2016 ACM International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software, Onward! 2016*, pages 128–144, New York, NY, USA, 2016. ACM. URL: <http://scg.unibe.ch/archive/papers/Chis16a-MoldableContextAwareSearchingWithSpotter.pdf>, doi:10.1145/2986012.2986023.
- Mohammad Ghafari and Hamidreza Moradi. A framework for classifying and comparing source code recommendation systems. In *2017 IEEE 24th International Conference on Software Analysis, Evolution and Reengineering (SANER)*, pages 555–556, 2017. URL: <http://dx.doi.org/10.1109/SANER.2017.7884674>, doi:10.1109/SANER.2017.7884674.
- 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. URL: <http://scg.unibe.ch/archive/papers/Meri16a.pdf>, doi:10.1109/VISSOFT.2016.10.
- 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. URL: <http://scg.unibe.ch/archive/papers/Meri16c.pdf>, doi:10.1109/VISSOFT.2016.19.
- Nevena Milojković, Mohammad Ghafari, and Oscar Nierstrasz. Exploiting type hints in method argument names to improve lightweight type inference. In *25th IEEE International Conference on Program Comprehension*, 2017. URL: <http://scg.unibe.ch/archive/papers/Milo17a.pdf>, doi:10.1109/ICPC.2017.33.
- Nevena Milojković, Mohammad Ghafari, and Oscar Nierstrasz. It's duck (typing) season! In *25th IEEE International Conference on Program Comprehension (ERA Track)*, 2017. URL: <http://scg.unibe.ch/archive/papers/Milo17b.pdf>, doi:10.1109/ICPC.2017.34.

unibe.ch/archive/papers/Milo17b.pdf, doi:10.1109/ICPC.2017.10.

- Nevena Milojković and Oscar Nierstrasz. Exploring cheap type inference heuristics in dynamically typed languages. In *Proceedings of the 2016 ACM International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software, Onward! 2016*, pages 43–56, New York, NY, USA, 2016. ACM. URL: <http://scg.unibe.ch/archive/papers/Milo16b.pdf>, doi:10.1145/2986012.2986017.
- Haidar Osman, Andrei Chiş, Claudio Corrodi, Mohammad Ghafari, and Oscar Nierstrasz. Exception evolution in long-lived Java systems. In *Proceedings of the 14th International Conference on Mining Software Repositories, MSR '17*, 2017. URL: <http://scg.unibe.ch/archive/papers/Osma17d-exception-evolution.pdf>, doi:10.1109/MSR.2017.21.
- Haidar Osman, Andrei Chiş, Jakob Schaerer, Mohammad Ghafari, and Oscar Nierstrasz. On the evolution of exception usage in Java projects. In *Proceedings of the 24rd IEEE International Conference on Software Analysis, Evolution, and Reengineering (SANER)*, pages 422–426, February 2017. URL: <http://scg.unibe.ch/archive/papers/Osma17b-exception-usage.pdf>, doi:10.1109/SANER.2017.7884646.

Workshop Papers

- Alice Allen, Cecilia Aragon, Christoph Becker, Jeffrey Carver, Andrei Chiş, Benoit Combemale, Mike Croucher, Kevin Crowston, Daniel Garijo, Ashish Gehani, Carole Goble, Robert Haines, Robert Hirschfeld, James Howison, Kathryn Huff, Caroline Jay, Daniel S. Katz, Claude Kirchner, Kateryna Kuksenok, Ralf Lämmel, Oscar Nierstrasz, Matt Turk, Rob van Nieuwpoort, Matthew Vaughn, and Jurgen Vinju. Lightning talk: “I solemnly pledge” a manifesto for personal responsibility in the engineering of academic software. In Gabrielle Allen, Jeffrey Carver, Sou-Cheng T. Choi, Tom Crick, Michael R. Crusoe, Sandra Gesing, Robert Haines, Michael Heroux, Lorraine J. Hwang, Daniel S. Katz, Kyle E. Niemeyer, Manish Parashar, and Colin C. Venters, editors, *Proceedings of Workshop on Sustainable Software for Science: Practice and Experiences*

(WSSSPE 2016), volume 1686 of *Proceedings of the Fourth Workshop on Sustainable Software for Science: Practice and Experiences (WSSSPE4)*. CEUR, 2016. URL: <http://scg.unibe.ch/archive/papers/Alle16a-WSSPE.pdf>.

- Jan Kurš, Jan Vraný, Mohammad Ghafari, Mircea Lungu, and Oscar Nierstrasz. Optimizing parser combinators. In *Proceedings of International Workshop on Smalltalk Technologies (IWST 2016)*, pages 1:1–1:13, 2016. URL: <http://scg.unibe.ch/archive/papers/Kurs16a-Compiler.pdf>, doi:10.1145/2991041.2991042.
- Nevena Milojković. Improving the precision of type inference algorithms with lightweight heuristics. In *SATToSE'17: Pre-Proceedings of the 10th International Seminar Series on Advanced Techniques & Tools for Software Evolution*, June 2017. URL: <http://scg.unibe.ch/archive/papers/Milo17c.pdf>.
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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: Member of Central Library Commission (until 2/17)
- 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 (until 9/16)
President of library commission Exakte Wissenschaften Plus (until 2/17)
- Th. Studer: Member of the Strategy Board

Institute:

- T. Braun : Deputy Director of INF (as of 1/17)
- P. Favaro: Director of Studies
- O. Nierstrasz: Managing Director of INF, Member of Hauskommission
Engelhalde
- Th. Strahm: Member of Library Committee Exakte Wissenschaften
- Th. Studer: Member of Hauskommission Exakte Wissenschaften
- M. Zwicker: Deputy Director of INF (until 12/16)