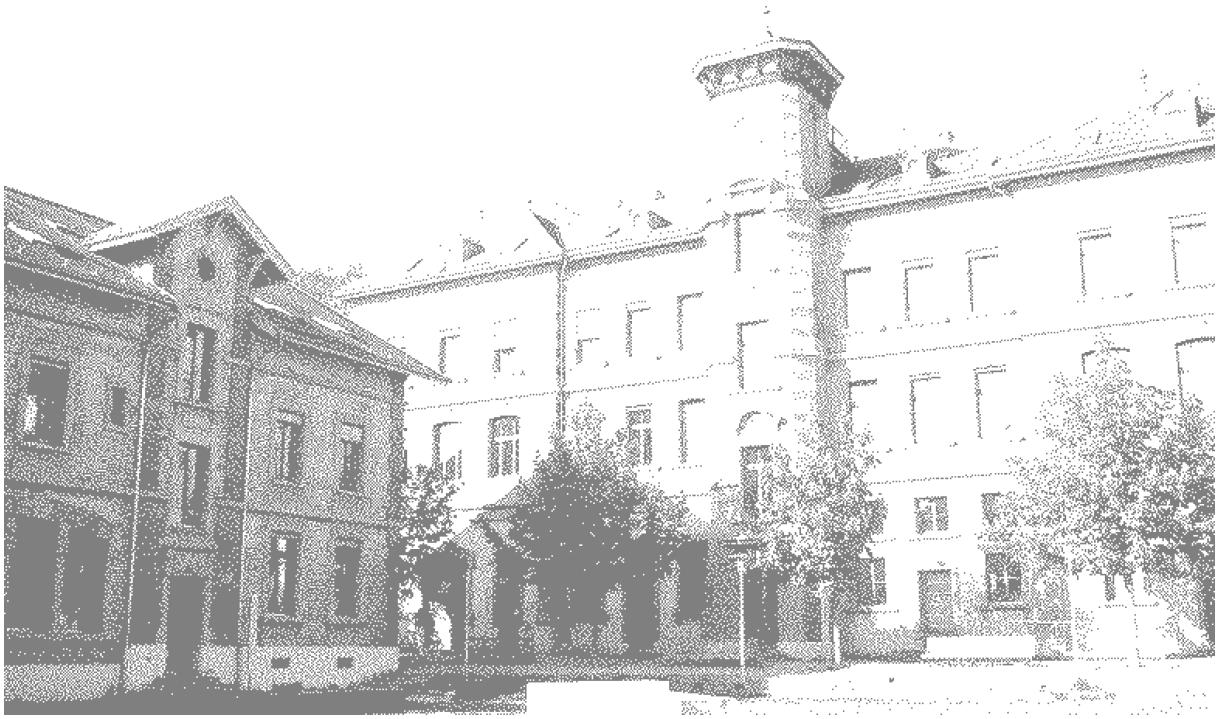
UNIVERSITÄT
BERN

Institut für Informatik
Universität Bern

www.inf.unibe.ch

# INF Annual Report 2017/2018



# INF Annual Report

# Academic Year 2017/2018

September, 2018

# Contents

# 1 Institute of Computer Science (INF)

## 1.1 Address

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

## 1.2 Personnel

### Members

S. Arjoumand Bigdeli; M. Bärtschi; P. Bertholet; Dr. P. Brambilla; Prof. Dr. T. Braun; J.L. Carrera; B. Choffat; C. Corrodi; D. Esser; Prof. Dr. P. Favaro; P. Gadient; M. Gasparyan; Dr. T. Genez; Dr. M. Ghafari; M. Hazhirpasand Barkadehi; Q. Hu; Prof. Dr. G. Jäger; L. Jaun; S. Jenni; M. Jin; E. Kalogeiton; M. Karimzadeh; E. Lehmann; M. Leuenberger; A. Marandi; Dr. M. Marti; G. Meishvili; L. Merino del Campo; Dr. N. Lazarević; Prof. Dr. O. Nierstrasz; M. Noroozi; H. Osman; N. Patkar; T. Portenier; P. Rani; T. Rosebrock; J. Saltarin; Dr. K. Sato; N. Savić; Dr. E. Schiller; D. S. Schroth; A. Souza; Dr. S. Steila; Prof. Dr. Th. Strahm; Prof. Dr. Th. Studer; Y. Tymchuk; J. Walker; X. Wang; S. Wu; Dr. Z. Zhao

### Board of directors

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

### Managing director

Prof. Dr. Oscar Nierstrasz

### Director of studies

Prof. Dr. Paolo Favaro

## Administration

Bettina Choffat; Dragana Esser; Daniela Schroth

## Technical staff

Dr. Peppo Brambilla; Tiziano Portenier

# 2 Teaching Activities

## 2.1 Courses for Major and Minor in Computer Science

### Autumn Semester 2017

- Bachelor 1st Semester

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

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

  Programmierung 1 (T. Studer, 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 (P. Berholet, 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

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

  Internet of Things (T. Braun, 5 ECTS)

  Description Logic (T. Studer, 5 ECTS)

Structural Pattern Recognition (K. Riesen, 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: Communication and Distributed Systems (T. Braun, 5 ECTS)

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

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

Seminar: Algebra und Logik (G. Jäger, G. Metcalfe, T. Studer)

Graduate Seminar Logik und Information (G. Jäger, G. Metcalfe, K. Stoffel, U. Ultes-Nitsche)

- Service Courses

  Anwendungssoftware (M. Marti, 3 ECTS)

## Spring Semester 2018

- Bachelor 2nd Semester

  Datenbanken (S. Bucheli, 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. Staub, 5 ECTS)

  Betriebssysteme (T. Braun, 5 ECTS)

  Berechenbarkeit und Komplexität (J. Walker, 5 ECTS)

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

- Bachelor 6th Semester

  Anleitung zu wissenschaftlichen Arbeiten (5 ECTS)

- Master Courses

  Programming Languages (O. Nierstrasz, 5 ECTS)

  Mobile Communications (T. Braun, 5 ECTS)

  Advanced Topics in Machine Learning (P. Favaro, 5 ECTS)

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

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

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

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

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

  Graduate Seminar Logik und Information (G. Jäger, G. Metcalfe, K. Stoffel, U. Ultes-Nitsche)

- Service Courses

  Anwendungssoftware (J. Walker, 3 ECTS)

## 2.2 Students

- Major Subject Students: AS 2017: 226, SS 2018: 214
- Minor Subject Students: AS 2017: 160, SS 2018: 153
- Ph.D. Candidates: AS 2017: 30, SS 2018: 32

## 2.3 Degrees and Examinations

- PhD: 8
- Master: 18
- Bachelor: 18

- Completion of Minor Studies: 24 (90E:0, 60E:4, 30E:9, 15E:11, 675 ECTS)
- Semester Examinations AS 2017: 724 (2554 ECTS)
- Bachelor's/Master's Theses AS 2017: 18 (360 ECTS)
- Semester Examinations SS 2018: 462 (1755 ECTS)
- Bachelor's/Masters Theses SS 2018: 24 (440 ECTS)

## 2.4 Activities

- Contribution to "Schweizer Jugend Forscht", Bern, September 10-16, 2017
- Contribution to the "National Future Day for Girls", Bern, November 9, 2017
- Contribution to the "Bachelor Infotage", December 6 and 7, 2017
- Contribution to the "Master Infotage", March 7, 2018
- Taster course for female students, Bern, March 22, 2018
- Visitor Program, Gymnasium Thun, Bern, July 4, 2018

## 2.5 Awards

- Alumni Award PhD INF for "Contributions to Intuitionistic Epistemic Logic", by Michel Marti
- Alumni Award Master INF for "From Cartoons to Real Images – An Approach to Unsupervised Visual Representation Learning", by Simon Jenni
- Alumni Award Bachelor INF for "Machine Learning for Indoor Positioning", by Joel Niklaus
- Faculty Prize (INF, Masterarbeit) for "Nullable Method Detection — Inferring Method Nullability From API Usage" by Manuel Leuenberger

# 3 Communication and Distributed Systems Group

## 3.1 Personnel

| | | |
|---|---|---|
| **Head:** | Prof. Dr. T. Braun | Tel.: +41 31 511 2631<br>email: braun@inf.unibe.ch |
| **Office Manager:** | D. Schroth | Tel.: +41 31 511 2630<br>email: schroth@inf.unibe.ch |
| **Scientific Staff:** | | |
| | J. Carrera* | Tel.: +41 31 511 2637<br>email: carrera@inf.unibe.ch |
| | M. Gasparyan | Tel.: +41 31 511 7645<br>email: gasparyan@inf.unibe.ch |
| | Dr. T..A. Lopes Genez | Tel: +41 31 511 26 39<br>Email: genez@inf.unibe.ch<br>(As of 1.1.18) |
| | E. Kalogeiton* | Tel.: +41 31 511 2638<br>email: kalogeiton@inf.unibe.ch |
| | M. Karimzadeh | Tel.: +41 31 511 7645<br>email: karimzadeh@inf.unibe.ch |
| | A. Marandi | Tel.: +41 31 511 2634<br>email: marandi@inf.unibe.ch |
| | J. Saltarin* | email: saltarin@inf.unibe.ch<br>(until 30.9.17) |
| | Dr. E. Schiller* | Tel.: +41 31 511 2633<br>email: schiller@inf.unibe.ch |
| | A. Mariano de Souza | Tel.: +41 31 511 7631<br>email: souza@inf.unibe.ch<br>(As of 1.1.18) |
| | Dr. Z. Zhao* | Tel.: +41 31 511 2639<br>email: zhao@inf.unibe.ch |

**External Ph.D. Students:**

| | |
|---|---|
| L. Luceri | email: luceri@inf.unibe.ch |
| G. Manzo | email: gaetano.manzo@hevs.ch |

**Guests:**

| | |
|---|---|
| Prof. Dr. Hyoung-Gook Kim | Email: hkim@kw.ac.kr<br>(01.06.-31.07.18)<br>Kwangwoon University,<br>Multimedia Signal Processing Lab,<br>Seoul, South Korea |

* 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 (ICN). We are also working on mobility and trajectory prediction of mobile users and vehicles using advanced machine learning mechanisms.

## 3.3 Research Projects

### SwissSenseSynergy

The SwissSenseSynergy project established a synergistic platform that 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 a machine learning-driven real-time localization and mobility prediction engine for producing insights. By end of March 2018, the SwissSenseSynergy project concluded successfully with all the proposed ideas and system components implemented and validated. Research activities have been conducted in four sub-projects, and integration efforts were made to combine all the sub-projects into one integrated, secure and privacy-preserving synergistic crowd-sensing framework.
The CDS group was leading the sub-project of “mobility, localization and tracking”, in which our tasks are indoor localization/tracking, and mobility

prediction. We first apply individual and ensemble machine learning algorithms to derive the correlation between smartphones' received sensor values and their indoor locations. Our real-world experiment results show that the Voting ensemble predictor outperforms individual predictors and it achieves the best indoor room recognition accuracy of 94% in office-like indoor environments [Zhao et al., 2018e]. We further developed an efficient ensemble learning method to provide room level localization in smart buildings. Our proposed method achieves high room-level localization accuracy by combining Hidden Markov Models with simple discriminative learning methods. Experimental results show that our system can overcome traditional individual machine learning and ensemble learning approaches [Carrera et al., 2018b]. Thanks to the accurate room recognitions, we use the detected room to further improve our indoor positioning system. We then integrate room detection and an enhanced ranging model to achieve high and stable indoor positioning performance. Experiment results in an office-like indoor environment show that our system outperforms traditional localization approaches considering stability and accuracy. The localization method can achieve performance with an average localization error of 1.26 m [Carrera et al., 2018a]. Moreover, we have designed a positioning system using narrowband signals, particularly ZigBee signals, based on an enhanced fingerprinting algorithm by fusing received signal strength (RSS) and time information. We designed a feature-based fusion approach to fuse and standardize time and RSS fingerprints, and adopt a random forest regression model to design an enhanced pattern matching algorithm for fingerprinting. Experimental results show that the system achieves a mean positioning accuracy of 1.61 m, which represents a 36.1% improvement over traditional RSS-based fingerprinting [Li et al., 2018a].

In the task of mobility prediction, our goal is to predict the future locations and trajectories of mobile users or vehicles based on the their historical and current context, such as GPS locations, frequency and duration of visiting a place, and smart-phone system information, such as WLAN connections, movement acceleration, running applications, etc. In [Zhao et al., 2018b], we modelled the location and trajectory prediction problem as a supervised learning task and proposed to use ensemble learning methods with hybrid features to solve it. We characterized the properties of users' visited locations and movement patterns and then extracted feature types (temporal, spatial, and system) to quantify the correlation between locations and features. Finally, we applied ensemble methods to predict users' future locations with extracted features. Moreover, we designed an adaptive Markov Chain model to predict users' trajectories

between two locations. We used a real-life dataset from the Nokia Mobile Data Challenge to validate the system performance, and experimental results unveil interesting findings: (1) For individual predictors, Bayes Networks outperform all others when data quality is good, while J48 delivers the best results when data quality is bad; (2) Ensemble predictors outperform individual predictors in general under all conditions; and (3) Ensemble predictor performance depends on the user movement patterns. To further validate the effectiveness of our mobility prediction approach, we applied our prediction algorithm to vehicle location prediction scenarios by collaborating with another partner. We designed a multi-tier caching mechanism with an over-the-top (OTT) content popularity estimation scheme to forecast the content request distribution. We implemented a learning-based algorithm to proactively prefetch the user content to VANET edge caching at RSUs. We implemented a prototype using Raspberry Pi emulating RSU nodes to prove the system functionality. Extensive experiment results prove that the system can bring benefits for both end users and OTT service providers, which help them to optimize network resource utilization and reduce bandwidth consumption [Zhao et al., 2018a]. To further make our system resistant to traces with different qualities, we proposed a hybrid Markov model that constantly adapts to available user trace quality to select either the first order or the second order Markov chain. Compared to existing solutions, our model is adaptive to discrete gaps in data trace. In addition, we implemented a proper mechanism to predict congestion in city areas. To help us understanding complex user behaviors, we have also proposed a technique benefiting from both temporal and spatial parameters to extract Zone of Interests (ZOIs). Intuitively, a ZOI is a city area that a user visits frequently and the user spends considerable time in this region. Evaluation results show that the system can achieve a satisfactory user future location prediction accuracy of 70-84% and area congestion prediction accuracy of 65-73% for the vehicles [Karimzadeh et al., 2018b]. In addition to our own individual research progress, the CDS group has collaborated with other project partners. In [Luceri et al., 2018a], we have successfully integrated our indoor positioning system with the works of the other project partners and developed a secure, privacy-preserving and real-time crowd-sensing framework for the Internet of Things applications.

Social influence is recognized as a key factor that governs human behavior. It indicates the attitude of certain individuals to be affected by other subjects' actions and decisions. The understanding of how influence propagates among subjects in a social network opens the way to a growing number of applications. Many efforts have been made to quantitatively

measure the influence probability between pairs of subjects. Existing approaches have two main drawbacks: 1) they assume that the influence probabilities are independent of each other, 2) they do not consider the actions not performed by the subject (but performed by her/his friends) to learn these probabilities.
We proposed to address these limitations by employing a deep learning approach [Luceri et al., 2018b]. We introduced a Deep Neural Network (DNN) framework that has the capability for both modeling social influence and for predicting human behavior. To empirically validate the proposed framework, we conducted experiments on real-life datasets from event-based and location-based social networks. Results indicate that our approach outperforms existing solutions, by efficiently resolving the limitations previously described. Moreover, we investigated the trade-off between performance and scalability of the proposed framework. In particular, we introduced three approaches by considering different network structures at varying granularity: ego networks, communities, and the entire social network. We showed that the whole social network achieves better performance but it needs more computational effort if compared to the ego networks approach, which in turn achieves lower performance. Finally, communities approach closely approach the performance of the entire social network scenario while requiring less computational effort.
To extend and validate our approach on different scenarios, we consider to collect data from a large number of individuals' portable sensing devices, such as smartphones. However, collecting such crowd-sensed data for research is not simple; contributors need to be actively enrolled in a campaign, and thus issues related to device heterogeneity, security, and privacy need to be considered. To this aim, we implemented VIVO [Luceri et al., 2018a], an open framework for crowd-sensed big data gathering, where security and privacy are managed within the framework at the client side. VIVO allows to collect social, physical, and environmental information, and thus, opens the way to multiple application scenarios.

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

**Financial support:** Swiss National Science Foundation Sinergia project number 154458

## Context Awareness Engine

The Context Awareness Engine project funded by Orange focuses on exploring network context awareness in order to discover, reason, and pre-

dict situations (context sensing) by appropriate computation and information modelling based on collected network data in nearly real-time from various data sources (network nodes, devices, applications). The purpose is to propose recommendations or request actions (context awareness) using advanced machine learning algorithms. We aim to find insights from observed phenomena and infer the root causes, such that future situation prediction can be achieved and further exploited to optimize network performance. The project is broken into 2 phases: Phase 1 includes use case definition (WP1) and functional architecture definition (WP2). Phase 2 includes implementation architecture definition (WP3) and software development and demonstration (WP4).
By the end of July 2018, the CDS group has successfully delivered the first project deliverable. The goal of the first deliverable is to find insights from observed phenomena and infer the Root Causes (RCs) so that the future situation prediction can be achieved and exploited using input provided by relevant customers (internal Orange Core Networks (CNs), operations-administration-management, applications, external platforms, etc.). This will allow us to guide network behaviours and optimize the network performance. The purpose of the first deliverable is to define and provide a Proof of Concept (PoC) related to the Context Sensing and Awareness Engine (CSAE). The first deliverable provides the results of the architecture design and use cases definition that have been proposed within project proposal (WP1). A general 5G-compatible architecture has been proposed, and concrete use cases have been defined. Currently, the CDS group is working closely with Orange to define the functional architecture of the project to analyze key issues of context sensing and awareness engine. We have proposed concrete system components and machine learning algorithms that might be used for the project implementation.

**Research staff:** Z. Zhao, E. Schiller, T. Braun.

**Financial support:** Orange Research Contract Number H09194

## Testbeds

The CDS group possesses a cloud infrastructure based on Dell Power Edge Servers. We have four machines R320, R520, and 2xR530 supporting 164 parallel threads (82 cores) and 640 GB RAM. Moreover, two external storage Dell PowerVault md3800i provides disk space of 20.6 TB in Raid 5 and Raid 6. The network backbone is based on Dell N4032 switches with 48x10 GbE-T ports and 80 Gb/s backbone connection. The

infrastructure supports the following services perfectly integrated with the Lightweight Directory Access Protocol (LDAP) of the institute.

- Mirantis OpenStack 8.0 (IaaS research cloud)
- OwnCloud (shared storage)
- Wiki (information dissemination)
- Etherpad (collaborative real-time editor)
- SVN (collaborative version management system)

For collaborative administration and monitoring, we use:

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

CDS owns an IoT testbed of 40 MEMSIC Telsob nodes deployed in the building of the Institute of Computer Science of the University of Bern. We have extended the IoT testbed with SDN functions to evaluate various types of SDN-based WSN applications and to enhance their performance. The testbed consists of the following sensor nodes:

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

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

## Popularity-based Caching for Network Coding enabled Named Data Networking

PopNetCod (Popularity-based caching policy for Network Coding enabled Named Data Networking) [Saltarin et al., 2018] is a distributed caching policy, in which each router measures the local popularity of the content objects by analyzing the Interests that it receives. It then uses this information to decide which Data packets to cache or evict from its content store [Saltarin et al., 2018]. Since network coding is used, partial caching of content objects is supported, which facilitates the management of the content store. The routers decide the Data packets that they cache or evict when they receive Interests for Data packets. Since the first routers to take a decision are the ones closer to the clients, the most popular Data packets are cached at the network edges. The evaluation of PopNetCod shows an improved cache-hit rate compared to the widely used Leave Copy Everywhere placement policy and the Least Recently Used eviction policy. The improved cache-hit rate helps the clients to achieve higher goodput, while it also reduces the load on the source servers. In future work, PopNetCod could be extended to improve video streaming, by considering features related to adaptive video streaming, like popular video representations and the adaptation policies used by the video streaming clients [Saltarin et al., 2018].

**Research staff:** J. Saltarin, T. Braun.

**Financial support:** Swiss National Science Foundation project number 149225

## Bloom Filter-based Content Discovery for Information-Centric Networks

During the considered period of this report, we aimed at comparing the performance of our previously proposed BFR routing protocol with other Bloom Filter (BF)-based routing protocols for Information-Centric Networks (ICNs). Further, we studied BF-based routing with large content universes and we proposed pull-based BFR as a new routing protocol for ICN with large content universe.

To comparatively analyze BFR with other BF-based routing protocols, we compared the performance of BFR with COntent-driven, Bloom filter-based intra-domain Routing Algorithm (COBRA). We described that BFR is a proactive routing protocol that works based on BF-based

content advertisements, while COBRA is a reactive routing protocol that uses Stable Bloom Filters (SBFs) to store the route traces left from already retrieved content objects for routing. We showed that COBRA requires significantly more memory space for storing route traces in SBFs compared to BFR that stores content advertisements in BFs. Therefore, BFR is a more appropriate routing protocol for IoT scenarios that use devices with constrained capacity. We also showed that BFR outperforms COBRA in terms of average round-trip delay, normalized communication overhead, total Interest communication overhead, and mean hit distance [Marandi et al., 2018].

To study BF-based routing with large content universes, we showed that the required communication and storage overhead for propagating and storing BFR content advertisements linearly grows with content universe size, i.e., the number of provided file names, because BFR advertises all the provided file names. To deal with this problem, we proposed pull-based BFR that permits servers to only advertise the requested file names rather than all the file names. We used BFs to inform the servers about the available requests in the network and we proposed BF aggregation strategies to further decrease the required communication overhead for propagating content advertisements. We conducted experiments in the ndnSIM environment and we showed that pull-based BFR outperforms BFR in terms of average roundtrip delay, the required communication overhead for content advertisements, the required memory space for storing content advertisements, and the impact of false positive errors on routing. We also compared pull-based BFR with a flooding-assisted routing prortocol and we showed that pull-based BFR performs better in terms of average round-trip delay, in particular when the bandwidth resources is scarce [Marandi et al., 2019].

**Research staff:** A. Marandi, T. Braun.

**Financial support:** Swiss National Science Foundation project number 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 architecture. Service-Centric Networking (SCN) is a future Internet architecture paradigm derived from ICN. SCN extends the ICN approach by integrating service support. Our research focusses on SCN requirements such as load-balancing and session support. Based on Named Data Link State Routing Protocol (NLSR), we have designed and evaluated an SCN intra-domain routing architecture named laDRA-SCN [Gasparyan et al., 2018]. NLSR is a link-state routing protocol for ICN. We have extended ICN and NLSR with the ability to support services. We have extended our designed SCN session support mechanism with fault-tolerance capabilities. We have designed and evaluated three distinct strategies to recover from node and link failures. The first mechanism uses Bloom filters for session identifier propagation, the second mechanism is based on service provider identifier propagation, and the third mechanism uses a piggybacking technique for provider identifier propagation.
We built the L-SCN (Layered-SCN) architecture to support services over CCN. L-SCN uses a two-layer forwarding scheme combined of nodes and Bloom filters. L-SCN aims to minimize protocol overhead and maximize the shared information about services and resources available in the network. We have extended the existing NDN implementation in ndnSIM with new data structures and forwarding techniques. The default CCN routing mechanism was not changed. Therefore, traditional CCN traffic can be forwarded as usual. We have implemented and evaluated our design in ndnSIM by comparing its processing time performance against available forwarding strategies in ndnSIM. The results show that our architecture outperforms the three existing strategies in ndnSIM, which are the Best Route, Multicast, and Random forwarding strategies.

**Research staff:** M. Gasparyan, T. Braun.

**Financial support:** Swiss National Science Foundation Project No. 146376

## Vehicular Ad Hoc Networks (VANETs)

VANET characteristics include unpredictable vehicle location and high mobility. This leads to intermittent connectivity between nodes, since the path between source and destination nodes changes in an unexpected way. VANETs applications should meet their Quality of Service (QoS) requirements to be deployed in vehicles. Thus, in the CONtext and conTent Aware

CommunicaTions for QoS support in VANETs (CONTACT) project, we investigate how to achieve the QoS requirements in VANETs applications by combining three paradigms: Named Data Networking (NDN), Floating Content (FC) and Software Defined Networking (SDN).
To make opportunistic communication between vehicles available, we enable the Vehicle to Vehicle (V2V) communication by addressing content via name, and exploit different changing routes that are established between vehicles. To define paths for content retrieval we either let the vehicles decide for themselves where the request for content should be sent, or we use available infrastructure that exists in the road. By using V2V and/or Vehicle to Infrastructure (V2I) communication we develop paths between source and destination in a VANET. We study the delay that each path provides and establish three different techniques for path selection. Moreover, we develop three different content retrieval techniques based on the infrastructure available in the area. First, we use V2V communication to retrieve messages and we develop iMMM-VNDN (improved Multihop Multipath and Multichannel NDN for VANETs routing protocol) [Kalogeiton et al., 2018a]. Then we use infrastructure, i.e. Road Side Units (RSUs) and we develop a centralized routing protocol to forward all traffic through the RSUs [Kalogeiton et al., 2018b]. Finally, we study a combination of V2V and V2I communication and we create a hybrid routing protocol, where we use available infrastructure as a back-up mechanism for content retrieval when a vehicle does not have any available information about the content's location [Kalogeiton et al., 2018b]. Our results indicate that the centralized protocol creates a bottleneck around the RSUs and thus is not ideal for a VANET environment. In contrast, iMMM-VNDN and the hybrid routing protocol retrieve more content faster than other state of the art and established routing protocols.
Please note that content V2V exchange is location-based (i.e., the information broadcast is interested within a limited area). In this context, of main interest is opportunistic communication model such as FC that geographically constrain vehicles content exchange. Our primary results, concerning the dimensioning of the communication area, show a significant improvement to the State-of-The-Art in terms of resource usage and content storage.

The significant node mobility together with the unreliability of wireless communications make it very challenging to achieve high communication performance in VANETs. Several problems arise in this context and shall be addressed. We investigated such problems and have proposed efficient solutions to overcome their effects including degradation of communica-

tion performance due to source mobility [Duarte et al., 2017a], and low vehicle densities [Duarte et al., 2017b], in addition to our previous works on receiver mobility. We have also integrated all our proposed solutions in a single framework [Duarte et al., 2018] to improve VANET communication performance in highly mobile, complex, and realistic traffic scenarios.

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

**Financial support:** Swiss National Science Foundation Project No. 146376

## Mobile Edge Computing

CDS-MEC [Schiller et al., 2018] is one of the first open-source Network Function Virtualization (NFV)/Software Defined Networking (SDN)-based Mobile Edge Computing (MEC) platforms. Our platform solves the Mobile Edge (ME) management issues with respect to Application (App) provisioning and traffic management. ME Apps are managed as Virtual Network Functions (VNFs) on top of the virtual environment through the Juju VNF Manager (VNFM). We developed an SDN controller to manage traffic on the ME System. Unlike other relevant architectures of ME systems, we use the control plane, i.e., S1 interface, to derive appropriate states for traffic management. We run three use-cases: ME caching, Information Centric (ICN)/Delay Tolerant (DTN) Public Safety communication (PS), and Dynamic Adaptive Streaming over HTTP (DASH)-based video streaming. The MEC caching framework displays improved user Quality of Experience, e.g., latency, in comparison to direct communication, the PS solution provides a residual mean of communication for rescue teams, when the network core (EPC) and a Public Data Network (PDN) are unavailable. The MEC-assisted video delivery improves the video qualities delivered to the mobile video consumer, e.g., representations, buffer fill level.

**Research staff:** E. Schiller, T. Braun.

**Financial support:** Context Awareness Engine Orange Research Contract No: H09194

## Intelligent Transportations Systems (ITS)

ITS integrates advanced sensing, processing and communication technologies and derive services to improve the vehicles' mobility as well as

the safety, and comfort of drivers and passengers. In this research topic, we focus on the development of services to improve the mobility and the public safety.
To improve the mobility, we extract knowledge about traffic conditions from the information provided by the vehicles using vehicular networking. Thus, based on this knowledge we can recommend fastest routes to the vehicles. We study data dissemination protocols and network approaches to provide the information about traffic mobility properly and routing algorithms in graphs to recommend better routes to each vehicle [Souza et al., 2018]. On the other hand, to improve the public safety we extract knowledge about criminal activities over the city to identify risky areas. In this way, we can also recommend alternative routes to avoid dangerous neighborhoods and risky areas, while dealing with mobility issues. We use machine learning techniques for estimating and forecasting risky areas and also optimization techniques for multi-objective routing algorithms.
Our early results have shown substantial improvements concerning traffic mobility and public safety compared to State-of-The-Art approaches.

**Research staff:** A. M. Souza, T. Braun.

## 3.4 Ph.D. Theses

- João Duarte “Mobility Support in Vehicular Named-Data Networking” (Joint-supervision doctorate), January, 2018
- Jonnahtan Saltarin “Network Coding Enabled Named Data Networking Architectures ”, November, 2017

## 3.5 Master’s Theses

- Jakob Schaerer “SDNWisebed – A Software-Defined Wireless Sensor Network Testbed”, July, 2018

## 3.6 Bachelor’s Theses

- Remo Roethlisberger “Video Delivery with Multi-Access Edge Computing”, May, 2018
- Dominic Kohler “Predicting future locations of mobile users using hybrid features”, February, 2018

- Joel Niklaus “Machine Learning for Indoor Positioning”, November, 2017

## 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 Bachelor Theses at Fachhochschule Bern
- Expert for Diploma and Matura Exams at Gymnasium Burgdorf, Hofwil, Langenthal
- 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)
- Chair of thesis award committee of GI-KuVS

## 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

- ICC Workshop on 5G and Cooperative Autonomous Driving, Program Chair, Kansas City, MO, USA, May 20-24 2018
- Wired/Wireless Internet Communications 2018, Steering committee, Boston, MA, USA, June 18-20, 2018
- Summer School, Hasliberg, Switzerland, August 15-17 2018

### Zhongliang Zhao

- Organising committee of KuVS EToL 2018: Expert Talk on Localization, Lübeck, Germany July 12-13 2018

## Public events organization

### Torsten Braun

- **Kinderuniversität:** At this event, Prof. Braun gave a lecture about *Die Welt des Internets*. In an additional workshop, our group showed multiple demos of indoor positioning, adaptive video streaming, and IoT programming to the audience. Further details are available at `http://www.kinderuni.unibe.ch/programm/archiv/`
- **Nacht der Forschung:** At this event, our group had a booth of indoor positioning at the main university building, and we showed live demos to public. Some hundreds of people visited our booth, and tried out our indoor positioning system, which covered two floors of the university main building. Further details are available at:`http://www.nachtderforschung.unibe.ch/`

- **Study Week on Fascinating Informatics:** At this event, Zhongliang Zhao and Jose Carrera taught three high school students how to program in Android and they implemented a indoor localization application. Further details are available at: `https://sjf.ch/review-studienwoche-fascinating-informatics/`

## Conference Program Committees

### Torsten Braun

- 17th International Conference on Next Generation Wired/Wireless Advanced Networks and Systems (NEW2AN 2017), St. Petersburg, Russia, August 28-30, 2017
- 9th ICT Innovations Conference 2016, Skopje, Macedonia, September 18-23, 2017
- 1st International Conference in Networking Science and Practice (ITC30 2017), Vienna, Austria, September 27, 2017
- The Communications Network Annual Conference (ComNet 2017), Miami Beach, USA, September 27-29, 2017
- 42th IEEE Local Computer Networks Conference (LCN 2017), Singapore, October 9-12, 2017
- 14th IEEE International Conference on Mobile Ad Hoc and Sensor Systems (MASS 2017), October 22-25, Orlando, Florida, USA
- 9th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT 2017), Munich, Germany, November 6-8, 2017
- Asian Internet Engineering Conference (AINTEC 2017), Bangkok Thailand, November 20 - 22 , 2017
- 20th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2017), Miami Beach, USA, November 21-25, 2017
- 13th ACM International Symposium on QoS and Security for Wireless and Mobile Network (Q2SWinet 2017), Miami Beach, USA, November 21-25, 2017

- IEEE Global Communications Conference (GLOBECOM 2017), Singapore, December 4-8, 2017
- 15th IEEE Consumer Communications and Networking Conference (CCNC 2018), Las Vegas, USA, January 12-15, 2018
- 33st ACM Symposium on Applied Computing (SAC 2018), Pau, France, April 9-13, 2018
- 2nd IEEE INFOCOM Workshop on Integrating Edge Computing, Caching, and Offloading in Next Generation Networks (IECCO 2018), Honolulu, HI, USA, April 15-19, 2018
- IEEE/IFIP Network Operations and Management Symposium (NOMS 2018), Taipei, Taiwan, April 23-27, 2018
- IFIP Networking Conference 2018 (Networking 2018), Zurich, Switzerland, May 14-16, 2018
- IEEE International Conference on Communications (ICC 2018), Kansas City, MO, USA, 20-24 May 2018
- IEEE/ACM International Symposium on Quality of Service (IWQoS 2018), Banff, Alberta, Canada, June 4-6, 2018
- 4th Smart Cloud Networks and Systems Conference (SCNS 2018), Paris, France, June 6-8, 2018
- 7th IEEE WoWMoM Workshop on the Internet of Things: Smart Objects and Services (IoT-SoS 2018), Chania, Greece, June 12, 2018
- IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM 2018), Chania, Greece, June 12-15, 2018
- IFIP International Conference on Wired and Wireless Internet Communications (WWIC 2018), Boston, MA, USA, June 18-20, 2018
- 10th IFIP Latin American Networking Conference (CLEI 2018-LANC), Sao Paulo, Brazil, October 3-4, 2018
- 9th International Workshop on Wireless Networking and Control for Unmanned Autonomous Vehicles (Wi-UAV 2018), Abu Dhabi United Arab Emirates, December 9, 2018

## Project and Person Reviewing Activities

### Torsten Braun

- Chair of Review Panel, Beyond 5G Systems, Academy of Finland
- Deutsche Forschungsgemeinschaft, DFG
- Excellence in Research for Australia, Australian Research Council

## Journal Article Reviewing Activities

### Torsten Braun

- IEEE Journal on Selected Areas in Communications (JSAC)
- Elsevier Future Generation Computer Systems
- Elsevier Computer Networks
- IEEE Communications Magazine
- IEEE Access
- IEEE Transactions on Network and Service Management

### Thiago Genez

- Springer Journal of Network and Systems Management
- Sringer Journal of Automated Software Engineering
- Wiley Journal of Software: Practice and Experience
- Elsevier Future Generation Computer Systems

### Mostafa Karimzadeh

- IEEE Transactions on Vehicular Technology

## Talks and Tutorials

### Torsten Braun

- Invited talk: “Security Threats in the Internet of Things and Cyber-Physical Systems”, Bank Cyber-Physical Security Workshop, Napoli, October 19, 2017
- Keynote talk: “Information-Centric Networking in Wireless and Mobile Networks”, International Conference on Next Generation Computing and Information Systems, Jammu, India, December 11, 2017
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, IIT Delhi, India, December 15, 2017
- Invited talk: “Information-Centric Networking in Wireless and Mobile Networks”, Universidade Federal do Amazonas, Manaus, Brazil, January 12, 2018
- Invited talk: “The Future VR/AR Network – Towards Virtual Human/Object Teleportation”, NSF Visioning Workshop on Networked Virtual and Augmented Reality Communications, Washington, DC, USA, April 23-24, 2018
- Invited talk: “Caching and Computing in Mobile Edge Networks”, Universidade Cabo Verde Info-Telecom Workshop, Praia, Cape Verde, May 17, 2018
- Invited talk: “Vehicular Networking in RINA”, 5th international RINA Workshop, Barcelona, May 22, 2018
- Keynote talk: “Caching and Computing in Mobile Edge Networks”, IEEE Symposium on Computers and Communications, June 25, 2018
- Keynote talk: “Autonomic Communications in Software-Driven Networks”, IEEE Symposium on Computers and Communications, June 26, 2018

## PhD Committee Memberships

### Torsten Braun

- Hasan Islam (Pre-examination of PhD Thesis), Aalto University, Finland

- João Duarte (PhD Jury), Unicamp, Brazil, January 2018
- Noor Abani (PhD Jury), UCLA, USA, May 2018
- Aleksandar Karadimce (Reviewer of PhD Thesis), Faculty of Computer Science and Engineering, Ss. Cyril and Methodius University in Skopje, R. Macedonia

## 3.8 Awards

Alumni Award 2017 for the Bachelor thesis “Machine Learning for Indoor Positioning”, by Joel Niklaus.

## 3.9 Publications

**Disclaimer:** The publication list only includes publications published during the academic year, but does not include submitted and not yet published papers.

### Journal Papers


- Luceri, L., Cardoso, F., Papandrea, M., Giordano, S., Buwaya, J., Kundig, S., Angelopoulos, C., Rolim, J., Zhao, Z., Carrera, J.L., Braun, T., Tossou, A.C.Y., Dimitrakakis, C., and Mitrokotsa, A. (2018a). VIVO: A secure, privacy-preserving, and real-time crowd-sensing framework for the Internet of Things. *Elsevier Pervasive and Mobile Computing, 49, 126-138*. DOI:10.1016/j.pmcj.2018.07.003
- Kurtz, W., Lapin, A., Schilling, O.S., Tang, Q., Schiller, E.J., Braun, T., Hunkeler, D., Vereecken, H., Sudicky, E., Kropf, P., Franssen, H., and Brunner, P. (2018). Integrating hydrological modelling, data assimilation and cloud computing for real-time management of water resources. *Elsevier Environmental Modelling and Software, 93, 418-435*. DOI: 10.1016/j.envsoft.2017.03.011
- Li, Z., Braun, T., Zhao, X., Zhao, Z., Hu, F., and Hui, L. (2018a). A Narrow-Band Indoor Positioning System by Fusing Time and Received Signal Strength via Ensemble Learning. *IEEE Access, 6, 9936 - 9950*. DOI: 10.1109/ACCESS.2018.2794337

- Neto, A., Zhao, Z., Rodrigues, J., Camboim, H., and Braun, T. (2018). Fog-Based Crime-Assistance in Smart IoT Transportation System. *IEEE Access, 6, 11101 - 11111*. DOI: 10.1109/ACCESS.2018.2803439

- Duarte, J., Braun, T., and Villas, L.A. (2017a). Source Mobility in Vehicular Named-Data Networking: An Overview. In *Springer Ad Hoc Networks ,223,83-93*, January 20 2018. DOI: 10.1007/978-3-319-74439-1_8

- Zhao, Z., Guardalben, L., Karimzadeh, M., Silva, J., Braun, T., and Sargento, S. (2018a). Mobility Prediction-Assisted Over-The-Top Edge Prefetching for Hierarchical VANETs. *IEEE Journal on Selected Areas in Communications*. DOI:10.1109/JSAC.2018.2844681

- Zhao, Z., Karimzadeh, M., Gerber, F., and Braun, T. (2018b). Mobile crowd location prediction with hybrid features using ensemble learning. *Elsevier Future Generation Computer Systems*. DOI:10.1016/j.future.2018.06.025

- Kalogeiton, E., Kolonko, T., and Braun, T. (2018a). A topology-oblivious routing protocol for NDN-VANETs. *Springer Annals of Telecommunications*. DOI: 10.1007/s12243-018-0661-4

- Duarte, J.M., Braun, T., and Villas, L.A. (2018). MobiVNDN: A Distributed Framework to Support Mobility in Vehicular Named-Data Networking. *Elsevier Ad Hoc Networks, 82, 77-90*. DOI:10.1016/j.adhoc.2018.08.008

- Schiller, E.J., Nikaein, N., Kalogeiton, E., Gasparyan, M., and Braun, T. (2018). CDS-MEC: NFV/SDN-based Application Management for MEC in 5G Systems. *Elsevier Computer Networks, 135, 96-107*. DOI: 10.1016/j.comnet.2018.02.013

- Nobre, J., Souza, A.M., Rosario, D., Both, C., Cerqueira, E., Villas, L.A., Braun, T., and Gerla, M. (2018). Vehicular Software-Defined Networking and Fog Computing: Integration and Design Principles. *Elsevier Ad Hoc Networks*. DOI: 10.1016/j.adhoc.2018.07.016

- Zhao, Z., Cumino,P., Souza, A., Rosario, D., Braun, T., Cerqueira, E., and Gerla, M. (2018c). Software-Defined Unmanned Aerial Vehicles Networking for Video Dissemination Services. *Elsevier Ad Hoc Networks*. DOI: 10.7892/boris.112274

## Book Chapters

- Zhao, Z., and Braun, T. (2018d). Mobile Cloud Networking: future communication architecture for mobile cloud. *IET digital library*. DOI: 10.1049/PBTE073E_ch8

## Conference Papers

- Marandi, A., Braun, T., Salamatian, K., Thomos, N. (2019). Pull-based Bloom Filter-based Routing for Information-Centric Networks. In *IEEE Consumer Communications and Networking Conference (CCNC)*, Las Vegas, USA, January 11-14 2019. DOI: 10.7892/boris.116573

- Li, Z., Zhao, X., Zhao, Z., Hu, F., Liang, H., Braun, T. (2018b). Crowdsensing Indoor Walking Paths with Massive Noisy Crowdsourcing User Traces. In *IEEE Global Communications Conference (GLOBECOM)*, Abu Dhabi, UAE, December 9-13 2018. DOI: 10.7892/boris.116244

- Souza, A.M., Braun, T., Villas, L.A. (2018). Efficient Context-aware Vehicular Traffic Re-routing based on Pareto-Optimality: A Safe-Fast Use Case. In *The 21st IEEE International Conference on Intelligent Transportation Systems (ITSC)*, Maui, Hawaii, USA, November 4-7 2018. DOI: 10.7892/boris.119177

- Carrera, J, Zhao, Z., Braun, T., Li, Z. (2018a). Pedestrians Complex Behavior Understanding and Prediction with Hybrid Markov Chain. *IEEE 14th International Conference on Wireless and Mobile Computing, Networking and Communications Workshop on Selected Topics in Wireless and Mobile computing (STWiMob-2018)*, Limassol, Cyprus,15-17 October, 2018. DOI: 10.7892/boris.118504

- Carrera, J, Zhao, Z., Braun, T., Li, Z. (2018a). Real-time Smartphone Indoor Tracking Using Particle Filter with Ensemble Learning Methods. *IEEE Conference on Local Computer Networks (LCN)*, Chicago, USA,1-4 October, 2018. DOI: 10.7892/boris.118504

- Karimzadeh, M., Zhao, Z., Gerber, F., Braun, T. (2018b). Mobile Users Location Prediction with Complex Behavior Understanding. *IEEE Conference on Local Computer Networks (LCN)*, Chicago, USA,1-4 October, 2018. DOI: 10.7892/boris.116297

- Abani, N., Braun, T., and Gerla, M. (2018a). Betweenness Centrality and Cache Privacy in Information-centric Networks. In *ACM Conference on Information-Centric Networking (ICN)*, Boston, MA, USA, September 21-23 2018. DOI: 10.7892/boris.119417

- Carrera, J., Zhao, Z., Braun, T. (2018b). Room Recognition Using Discriminative Ensemble Learning with Hidden Markov Models for Smartphones. In *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, Bologna, Italy, September 9-12 2018. DOI: 10.7892/boris.116376

- Akhtar, N., Matta, I., Raza, A., Goratti, L., Braun, T., Esposito, F. (2018). Virtual Function Placement and Traffic Steering over 5G Multi-Technology Networks. In *IEEE Conference on Network Softwarization (NetSoft)*, Montreal, Canada, June 25-29 2018. DOI:10.7892/boris.114669

- Marandi, A., Braun, T., Salamatian, K., Thomos, N. (2018). A Comparative Analysis of Bloom Filter-based Routing Protocols for Information-Centric Networks. In *IEEE Symposium on Computer Communications (ISCC)*, Natal, Brazil, June 25-28 2018. DOI: 10.7892/boris.112421

- Zhao, Z., Carrera, J., Niklaus, J., Braun, T. (2018e). Machine Learning-based Real-Time Indoor Landmark Localization. In *The 16th International Conference on Wired/Wireless Internet Communications (IFIP WWIC)*, Boston, MA, USA, June 18-20 2018. DOI: 10.7892/boris.116245

- Kalogeiton, E., and Braun, T. (2018b). Infrastructure-Assisted Communication for NDN-VANETs. In *IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, Chania, Greece, June 12-15 2018. DOI: 10.7892/boris.117388

- Braun, T., Careglio, D., and Matta, I. (2018). Vehicular Networking in the Recursive InterNetwork Architecture. In *IEEE 87th Vehicular Technology Conference (VTC Spring)*, June 3-6 2018. DOI: 10.1109/VTCSpring.2018.8417755

- Medeiros, I., Junior, W.L., Rosario, D., Cerqueira, E., Braun, T., Villas, L.A. (2018). A Comparative Analysis of Platoon-Based Driving Protocols for Video Dissemination over VANETs. In *IEEE International Conference on Communications Workshops*

*(ICC Workshops)*, Kansas City, MO, USA, May 20-24 2018. DOI: 10.1109/ICCW.2018.8403776

- Gasparyan, M., Braun, T., Schiller, E.J. (2018). IaDRA-SCN: Intra-domain routing architecture for Service-Centric Networking. In *IEEE International Conference on Communications Workshop on Information-Centric Edge Computing and Caching for Future Networks (ICECC)*, Kansas City, MO, USA, May 20-24 2018. DOI: 10.7892/boris.106975

- Saltarin, J., Braun, T., Bourtsoulatze, E., Thomos, N. (2018). PopNetCod: A Popularity-based Caching Policy for Network Coding-enabled Named Data Networking . In *IFIP Networking Conference*, Zurich, Switzerland, May 14-16 2018. DOI: 10.7892/boris.101229

- Luceri, L., Braun, T., and Giordano, S. (2018b). Social Influence (Deep) Learning for Human Behavior Prediction. In *Springer International Conference on Complex Networks and their Applications*, February 15 2018. DOI: 10.1007/978-3-319-73198-8_22

- Luceri, L., Vancheri, A., Braun, T., and Giordano, S. (2017c). On the Social Influence in Human Behavior: Physical, Homophily, and Social Communities. In *Springer International Conference on Complex Networks and their Applications*, November 27 2017. DOI: 10.1007/978-3-319-72150-7_69

- Duarte, J., Braun, T., and Villas, L. (2017b). Addressing the Effects of Low Vehicle Densities in Highly Mobile Vehicular Named-Data Networks. In *6th ACM Symposium on Development and Analysis of Intelligent Vehicular Networks and Applications*, Miami, Florida, USA, November 21-25 2017. DOI: 10.1145/3132340.3132341

- Du, P., Pang, F., Braun, T., Gerla, M., Hoffmann, C., and H. Kim, J. (2017). Traffic Optimization in Software Defined Naval Network for Satellite Communications. In *IEEE Military Communications Conference (MILCOM)*, Baltimore, MD, USA, October 23-25 2017. DOI: 10.1109/MILCOM.2017.8170766

- Zhao, Z., Kuendig,S., Carrera, J.L., Carron, B., Braun, T., and Rolim, J. (2017f). Indoor Location for Smart Environments with Wireless Sensor and Actuator Networks. In *42nd Conference on Local Computer Networks (LCN)*, Singapore, October 9-12 2017. DOI: 10.1109/LCN.2017.65

- Abani, N., Braun, T., and Gerla, M. (2017b). Proactive Caching with Mobility Prediction under Uncertainty in Information-Centric Networks. In *4th ACM Conference on Information-Centric Networking*, Berlin, Germany, September 26-28 2017. DOI: 10.1145/3125719.3125728

- Schärer, J., Zumbrunn, S.D., and Braun, T. (2017). Universal Large Scale Sensor Network. In *Springer International Conference on ICT Innovations*, September 7 2017. DOI: 10.1007/978-3-319-67597-8_8

- Manzo, G., Ajmone Marsan, M., Rizzo, G. (2017). Performance Modeling of Vehicular Floating Content in Urban Settings. In *29th International Teletraffic Congress (ITC 29)*, Genoa, Italy, September 4-8 2017. DOI: 10.23919/ITC.2017.8064344

# 4 Computer Vision Group

## 4.1 Personnel


| | | |
|---|---|---|
| **Heads:** | Prof. Dr. P. Favaro | Tel.: +41 31 631 4451<br>email: paolo.favaro@inf.unibe.ch |
| **Office Managers:** | D. Esser | Tel.: +41 31 631 4914<br>email: esser@inf.unibe.ch |
| **Scientific Staff:** | Q. Hu | Tel.: +41 31 511 76 04<br>email: hu@inf.unibe.ch |
| | S. Jenni | Tel.: +41 31 511 76 04<br>email: jenni@inf.unibe.ch |
| | M. Jin | Tel.: +41 31 511 76 04<br>email: jin@inf.unibe.ch |
| | G. Meishvili | Tel.: +41 31 511 76 04<br>email: meishvili@inf.unibe.ch |
| | M. Noroozi | Tel.: +41 31 511 76 04<br>email: noroozi@inf.unibe.ch |
| | A. Szabó | Tel.: +41 31 511 76 04<br>email: szabo@inf.unibe.ch |
| | X. Wang | Tel.: +41 31 511 76 04<br>email: wang@inf.unibe.ch |
| | A. Wälchli | Tel.: +41 31 511 76 04<br>email: waelchli@inf.unibe.ch |


## 4.2 Overview

Prof. Dr. P. Favaro joined the Institute of Computer Science and established the Computer Vision group in June 2012. The Computer Vision group conducts research on the broad areas of 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). We are also working extensively in unsupervised learning with the purpose of building useful feature representations of images. In our approaches a good representation is one that makes future learning easier. Currently, we use neural networks to solve tasks and because of their compositional architecture, a feature is naturally identified as one of many possible intermediate outputs of the trained model. The questions we focus on are then: How do we build a feature that can be used as input to a weak classifier or regressor for different unknown tasks? How do we use the least amount of annotation to build general purpose features?

## 4.3 Research Projects

### Learning to Extract a Video Sequence from a Single Motion-Blurred Image

We present a method to extract a video sequence from a single motion-blurred image. Motion-blurred images are the result of an averaging process, where instant frames are accumulated over time during the exposure of the sensor. Unfortunately, reversing this process is nontrivial. Firstly, averaging destroys the temporal ordering of the frames. Secondly, the recovery of a single frame is a blind deconvolution task, which is highly ill-posed. We present a deep learning scheme that gradually reconstructs a temporal ordering by sequentially extracting pairs of frames. Our main

contribution is to introduce loss functions invariant to the temporal order. This lets a neural network choose during training what frame to output among the possible combinations. We also address the ill-posedness of deblurring by designing a network with a large receptive field and implemented via resampling to achieve a higher computational efficiency. Our proposed method can successfully retrieve sharp image sequences from a single motion blurred image and can generalize well on synthetic and real datasets captured with different cameras.

**Research staff:** Meiguang Jin, Givi Meishvili, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 153324 and No. 165845

## Normalized Blind Deconvolution

We introduce a family of novel approaches to single-image blind deconvolution, i.e. , the problem of recovering a sharp image and a blur kernel from a single blurry input. This problem is highly ill-posed, because infinite (image, blur) pairs produce the same blurry image. Most research effort has been devoted to the design of priors for natural images and blur kernels, which can drastically prune the set of possible solutions. Unfortunately, these priors are usually not sufficient to favor the sharp solution. In this paper we address this issue by looking at a much less studied aspect: the relative scale ambiguity between the sharp image and the blur. Most prior work eliminates this ambiguity by fixing the L1 norm of the blur kernel. In principle, however, this choice is arbitrary. We show that a careful design of the blur normalization yields a blind deconvolution formulation with remarkable accuracy and robustness to noise. Specifically, we show that using the Frobenius norm to fix the scale ambiguity enables convex image priors, such as the total variation, to achieve state-of-the-art results on both synthetic and real datasets.

**Research staff:** Meiguang Jin, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 153324

## Learning to See through Reflections

Pictures of objects behind a glass are difficult to interpret and understand due to the superposition of two real images: a reflection layer and a background layer. Separation of these two layers is challenging due to the ambiguities in assigning texture patterns and the average color in the input image to one of the two layers. In this paper, we propose a novel method to reconstruct these layers given a single input image by explicitly handling the ambiguities of the reconstruction. Our approach combines the ability of neural networks to build image priors on large image regions with an image model that accounts for the brightness ambiguity and saturation. We find that our solution generalizes to real images even in the presence of strong reflections. Extensive quantitative and qualitative experimental evaluations on both real and synthetic data show the benefits of our approach over prior work. Moreover, our proposed neural network is computationally and memory efficient.

**Research staff:** Meiguang Jin, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 153324

## Learning Face Deblurring Fast and Wide

Portrait images and photos containing faces are ubiquitous on the web and the predominant subject of images shared via social media. Especially selfie images taken with lightweight smartphone cameras are susceptible to camera shake. Despite significant progress in the field of image deblurring over the last decade, the performance of state-of-the-art deblurring methods on blurry face images is still limited. In this work, we present a novel deep learning architecture that is designed to be computationally fast and exploits a very wide receptive field to return sharp face images even in challenging scenarios. Our network features an effective resampling convolution operation that ensures a wide receptive field from the very first layers, while at the same time being highly computationally efficient. We also show that batch normalization prevents networks from yielding high-quality image results and introduce instance normalization instead. We demonstrate our architecture on face deblurring as well as other more general scenes. Extensive experiments with state-of-the-art methods demonstrate the effectiveness of our proposed network, in terms

of run-time, accuracy, and robustness to ISO levels as well as gamma correction.

**Research staff:** Meiguang Jin, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 153324

## Understanding Degeneracies and Ambiguities in Attribute Transfer

We study the problem of building models that can transfer selected attributes from one image to another without affecting the other attributes. For example, we would like to transfer only the viewpoint of a car between the images of two different car models. As data we use a weakly labeled training set, where labels indicate what single factor has changed between two data samples, although the relative value of the change is unknown. This labeling is of particular interest as it is often readily available without annotation costs. Towards this goal, we develop analysis and training methodology for autoencoding models, whose encoded features aim to disentangle factors of variation. These features are explicitly split into two components: one that should represent attributes in common between pairs of images, and another that should represent attributes that change between pairs of images. We show that achieving this objective faces two main challenges: One is that the model may learn degenerate mappings, which we call shortcut problem, and the other is that the attribute representation for an image is not guaranteed to follow the same interpretation on another image, which we call reference ambiguity. To address the shortcut problem, we introduce novel constraints on image pairs and triplets and show their effectiveness both analytically and experimentally. In the case of the reference ambiguity, we formally prove that a model that guarantees an ideal feature separation cannot be built. We validate our findings on several datasets and show that, surprisingly, the trained models often do not exhibit the reference ambiguity.

**Research staff:** Qiyang Hu, Attila Szabó, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 156253

## 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 unlabelled training set. These models can discover what factors determine the images. We assume that these factors are statistically independent and we fix their number before training. We encoded the factors into features, then decoded them to images again in an autoencoder setting. The main idea is to mix the features of two different images to obtain a mixed one. This image should look realistic, which we can enforce with a generative adversarial net. Then we use the mixed image and one of the original input image to "demix" the features, and the resulting image should look like the input image. This is enforced by the L2 loss. We show this setup is not enough for disentanglement, as a shortcut can occur, when all the information is encoded in only one feature. Therefore we added a classifier that decides, which input image originates the features of the mixed image for any given feature. Experiments show the setup with the three components disentangles factors of variation on datasets like CelebA, MNIST and Sprites.

**Research staff:** Qiyang Hu, Attila Szabó, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 156253

## Deep Sketch-based Face Image Editing

We present a novel system for sketch-based face image editing, enabling users to edit images intuitively by sketching a few strokes on a region of interest. Our interface features tools to express a desired image manipulation by providing both geometry and color constraints as user-drawn strokes. As an alternative to the direct user input, our proposed system naturally supports a copy-paste mode, which allows users to edit a given image region by using parts of another exemplar image without the need of hand-drawn sketching at all. The proposed interface runs in real-time and facilitates an interactive and iterative workflow to quickly express the intended edits. Our system is based on a novel sketch domain and a convolutional neural network trained end-to-end to automatically learn to render image regions corresponding to the input strokes. To achieve high quality and semantically consistent results we train our neural network on two simultaneous tasks, namely image completion and image translation.

To the best of our knowledge, we are the first to combine these two tasks in a unified framework for interactive image editing. Our results show that the proposed sketch domain, network architecture, and training procedure generalize well to real user input and enable high quality synthesis results without additional post-processing.

**Research staff:** Tiziano Portenier, Qiyang Hu, Attila Szabó, Siavash Arjomand Bigdeli, Paolo Favaro, Matthias Zwicker

**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.

In self-supervised learning, one trains a model to solve a so-called pretext task on a dataset without the need for human annotation. The main objective, however, is to transfer this model to a target domain and task. Currently, the most effective transfer strategy is fine-tuning, which restricts one to use the same model or parts thereof for both pretext and target tasks. In this paper, we present a novel framework for self-supervised learning that overcomes limitations in designing and comparing different tasks, models, and data domains. In particular, our framework decouples the structure of the self-supervised model from the final task-specific fine-tuned model. This allows us to: 1) quantitatively assess previously incompatible models including handcrafted features; 2) show that deeper neural network models can learn better representations from the same pretext task; 3) transfer knowledge learned with a deep model to a shallower one

and thus boost its learning. We use this framework to design a novel self-supervised task, which achieves state-of-the-art performance on the common benchmarks in PASCAL VOC 2007, ILSVRC12 and Places by a significant margin. Our learned features shrink the mAP gap between models trained via self-supervised learning and supervised learning from 5.9% to 2.6% in object detection on PASCAL VOC 2007.

**Research staff:** Mehdi Noroozi, Paolo Favaro

## 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 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

## Generalization in Deep Learning

A core objective in machine learning is to build models that generalize well, i.e., that have the ability to perform well on new unseen data. However, recent work has shown that common regularization methods applied to neural networks often fail to achieve good generalization. For example, it has been shown that neural networks can learn to map data samples to arbitrary labels despite using regularization techniques such as weight decay, dropout, and data augmentation. We developed a novel regularization approach to train neural networks that enjoys better generalization and test error than standard stochastic gradient descent. Our approach is based on the principles of cross-validation, where a validation set is used to limit the

model overfitting. We formulate such principles as a bilevel optimization problem. This formulation allows us to define the optimization of a cost on the validation set subject to another optimization on the training set. The overfitting is controlled by introducing weights on each mini-batch in the training set and by choosing their values so that they minimize the error on the validation set. In practice, these weights define mini-batch learning rates in a gradient descent update equation that favor gradients with better generalization capabilities. We evaluate extensively our proposed algorithm on several neural network architectures and datasets, and find that it consistently improves the generalization of the model, especially when labels are noisy.

**Research staff:** Simon Jenni, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 169622

## Stabilizing the Training of Generative Adversarial Networks

Since the introduction of the generative adversarial network (GAN), GANs have been widely used and analyzed due to the quality of the samples that they produce, in particular when applied to the space of natural images. Unfortunately, GANs still prove difficult to train. In fact, a vanilla implementation does not converge to a high-quality sample generator and heuristics used to improve the generator often exhibit an unstable behavior. We developed a simple regularization method to stabilize generative adversarial training that results in accurate generative models. Our method is rather general and can be applied to other GAN formulations with an average improvement in generated sample quality and variety, and training stability. Since GAN training aims at matching probability density distributions, we exploit additive noise to extend the support of the densities and thus facilitate the matching through gradient descent. More importantly, we show that using multiple loss terms with different additive noise (including the no-noise case) is necessary to achieve a highly accurate match of the original data distribution. We demonstrate the proposed training method on several common datasets of real images.

**Research staff:** Simon Jenni, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 169622

## 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 tasks. These systems rely on large annotated datasets, which require expensive and time-consuming human labor. To address these issues self-supervised learning methods have been proposed. These methods learn features from images without annotated data by introducing a pretext task. As a new pretext task, we propose to learn features by classifying images into real or corrupt (with artifacts). We aim at creating image artifacts, such that a model capable of spotting them would require an accurate representation of objects and thus build features that could transfer well to tasks such as object classification, detection and segmentation.
To generate artifacts we first train an autoencoder to reproduce images. Then, we randomly drop entries from the encoded feature (at the bottleneck) so that some information about the input image is lost. We then add a repair neural network to the decoder to help it render a realistic image. The repair network inpaints the feature representations at every layer of the decoder, but its limited capacity does not allow it to fully recover the missing information. In this way we obtain an image with artifacts that cannot be detected through local analysis. We then train a discriminator to distinguish real from corrupt images. The repair network and the discriminator are then trained in an adversarial fashion. However, in contrast to other adversarial schemes, notice that our repair network is designed not to completely confuse the discriminator. Finally, we transfer features from the discriminator, since this is the model that learns an approximation of the distribution of images and achieve state of the art performance on several transfer learning evaluations (ILSVRC2012, Pascal VOC and STL-10).

**Research staff:** Simon Jenni, Paolo Favaro

**Financial support:** Swiss National Science Foundation Project No. 169622

### Learning Structure from Motion

Structure from motion (SfM) is the problem of reconstructing the 3D geometry and camera parameters given a set of photographs of a scene. State-of-the-art SfM systems assume that all observed motion in the measurements are caused by the camera's motion, and objects that move in the scene are considered noise. Handling this type of noise is indeed one of the main difficulties in SfM. Occlusions, change of lighting and specular reflections are other examples of noise that challenge the robustness of a SfM system. In our research, we consider a temporal sequence of images (video) instead of an unordered set. This makes it suitable for real-time applications where the input is a continuous video stream. We aim to build a system that incrementally outputs the estimated 3D and camera parameters as it reads the video frames one after the other, and are investigating several Deep Learning approaches to solve the aforementioned challenges for this type of sequential data. One of them are Recurrent Neural Networks (RNNs). Prior works have shown that RNNs can perform well on sequence tasks such as translation, speech recognition, speech synthesis and more. However, the higher the complexity between input and output space, the harder it is to train them on long sequences. We are investigating the suitability of RNN's for SfM and how they could be applied or extended.

**Research staff:** Adrian Wälchli , Paolo Favaro

## 4.4 Master's Theses

- Bernard Swart, "Crime location and timing prediction", 2018 (Visiting Student from University of Stellenbosch).

- Felix Meyenhofer, "ABA-J Interactive Multi-Modality Tissue Section-to-Volume Alignment: A Brain Atlasing Toolkit for ImageJ", March 2018 (University of Friburg).

- Adrian Wälchli, "Learning Visual Odometry with Recurrent Neural Networks", February 2018.

- Simon Jenni, "From Cartoons to Real Images: An Approach to Unsupervised Visual Representation Learning", February 2017.

## 4.5 Bachelor's Theses

- Till Nikolaus Schnabel, "Neural Face Transfer: Training a Deep Neural Network to Face-Swap ", July 2018.

## 4.6 Further Activities

### Ph.D. Thesis Examiner

#### Paolo Favaro

- "Eye labelling for Medical Image data", L. Lejeune, ARTORG, UniBe, 2018.
- "Longitudinal Brain Tumor Segmentation with Uncertainty Estimation using Fully-connected Conditional Random Field and Perturb-and-Maximum-Posterior-Marginal Estimation", A. Jungo, ISTB, UniBe, 2018.
- "Computational Imaging with Diffractive Optics", Y. Peng, University of British Columbia, 2018.
- "Sparse Gradient Optimization and its Applications in Image Processing', N. A. Darginis, EPFL, 2017.

### Invited Talks

#### Paolo Favaro

- "Beyond supervised learning", International Computer Vision Summer School 2018, July 13, 2018.
- "Beyond supervised learning", University of Zurich, July 2, 2018.
- "Unsupervised Learning and Knowledge Transfer", 2nd Workshop in Beyond Supervised Learning, CVPR 2018, June 22, 2018.
- "Beyond supervised learning", IEEE SPS Summer School on Light Field Data Representation, Interpretation, and Compression, May 30, 2018.
- "A Computational Model to Learn from Hallucinations", 1st Sleep Science Winter School, BENESCO, March 3, 2018.

- “Beyond Supervised Learning”, Novartis Pharma AG, March 2018.
- “Beyond supervised learning”, PAVIS Italian Institute of Technology, January 2018.
- “Beyond supervised learning”, Institute of Mathematical Statistics and Actuarial Science, UniBe, November 2017.
- “Apprendimento automatico di rappresentazioni semantiche senza supervisione”, Coscienza di sè e intelligenza artificiale, November 18, 2017.

### Conference Program Committees

**Paolo Favaro**

- Area chair of ECCV 2018 and ICCV 2017

### Journal Committees

**Paolo Favaro**

- Associate Editor for IEEE Transactions on Pattern Analysis and Machine Intelligence 2018
- Associate Editor for Computer Vision and Image Understanding 2018

### Reviewing Activities

**Paolo Favaro**

- CVPR 2018
- ICCP 2018

## 4.7 Publications

## Journal Publications

- P. Chandramouli, M. Jin, D. Perrone and P. Favaro, “Plenoptic Image Motion Deblurring”, IEEE Transactions on Image Processing, 2018.

# Refereed Conference Proceedings

- M. Jin, S. Roth and P. Favaro, “Normalized Blind Deconvolution”, European Conference on Computer Vision (ECCV), 2018.
- A. Szabó, Q. Hu, T. Portenier, M. Zwicker and P. Favaro, “Understanding Degeneracies and Ambiguities in Attribute Transfer”, European Conference on Computer Vision (ECCV), 2018.
- S. Jenni and P. Favaro, “Deep Bilevel Learning”, European Conference on Computer Vision (ECCV), 2018.
- T. Portenier, Q. Hu, A. Szabó, S. Bigdeli, P. Favaro and M. Zwicker, “FaceShop: Deep Sketch-based Image Editing”, SIGGRAPH 2018.
- M. Jin, M. Hirsch and P. Favaro, “Learning Face Deblurring Fast and Wide”, New Trends in Image Restoration and Enhancement workshop, 2018.
- M. Jin, S. Süsstrunk and P. Favaro, “Learning to See through Reflections”, International Conference on Computational Photography (ICCP), 2018.
- M. Noroozi, A. Vinjimoor, P. Favaro and H. Pirsiavash, “Boosting Self-Supervised Learning via Knowledge Transfer”, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), 2018.
- S. Jenni and P. Favaro, “Self-Supervised Feature Learning by Learning to Spot Artifacts”, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), 2018.
- M. Jin, G. Meishvili and P. Favaro, “Learning to Extract a Video Sequence from a Single Motion-Blurred Image”, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), 2018.
- Q. Hu, A. Szabó, T. Portenier, M. Zwicker and P. Favaro, “Disentangling Factors of Variation by Mixing Them”, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), 2018.
- S. A. Bigdeli, M. Jin, P. Favaro and M. Zwicker, “Deep Mean-Shift Priors for Image Restoration”, Neural Information Processing Systems (NIPS), 2017.

# Technical Reports

- A. Szabó, Q. Hu, T. Portenier, M. Zwicker and P. Favaro, “Challenges in Disentangling Independent Factors of Variation”, International Conference on Learning Representations (ICLR) workshop, 2018.

- S. Jenni and P. Favaro, “Noise-Regularized Generative Adversarial Networks”, Under Review, NIPS 2018.

# 5 Logic and Theory Group

## 5.1 Personnel

| | | |
|---|---|---|
| **Head:** | Prof. Dr. G. Jäger | Tel.: +41 (0)31 631 85 60<br>email:<br>jaeger@inf.unibe.ch |
| **Office Manager:** | B. Choffat | Tel.: +41 (0)31 631 84 26<br>email:<br>choffat@inf.unibe.ch |
| **Docents:** | Prof. Dr. T. Strahm | Tel.: +41 (0)31 631 49 98<br>email:<br>strahm@inf.unibe.ch |
| | Prof. Dr. T. Studer | Tel.: +41 (0)31 631 39 84<br>email:<br>tstuder@inf.unibe.ch |
| **Scientific Staff:** | M. Bärtschi* | Tel.: +41 (0)31 511 76 16<br>email:<br>baertsch@inf.unibe.ch |
| | L. Jaun | Tel.: +41 (0)31 511 76 10<br>email: jaun@inf.unibe.ch |
| | E. Lehmann* | Tel.: +41 (0)31 511 76 09<br>email:<br>lehmann@inf.unibe.ch |
| | Dr. M. Marti* | Tel.: +41 (0)31 511 76 12<br>email:<br>mmarti@inf.unibe.ch<br>(until February 2018) |
| | T. Rosebrock* | Tel.: +41 (0)31 511 76 33<br>email: rose@inf.unibe.ch<br>(until July 2018) |
| | Dr. K. Sato* | Tel.: +41 (0)31 511 76 21<br>email: sato@inf.unibe.ch |
| | N. Savić* | Tel.: +41 (0)31 511 76 08<br>email: savic@inf.unibe.ch |
| | Dr. S. Steila | Tel.: +41 (0)31 511 76 17<br>email:<br>steila@inf.unibe.ch |
| | J. Walker* | Tel.: +41 (0)31 511 76 32 |

email:
walker@inf.unibe.ch

| | | |
|---|---|---|
| **Guests:** | Dr. I. Petrakis | University of Munich<br>September – November 2017 |
| | Prof. Dr. H.-P. Künzi | University of Cape Town<br>November 2017 |
| | H. Mohammadi | Isfahan University of Technology<br>Since June 2018 |

* with financial support from a third party

## 5.2 Overview

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

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

**Proof Theory:** This research topic focuses on the development and analysis of formal systems of first and second order arithmetic, set theory and of what are known as logical frameworks (type and set theoretical, explicit, constructive, extensional, intentional). Our interests range from feasible subsystems of arithmetic to highly impredicative set and type theories and

deals with the interplay between constructive, recursive and operational approaches. In addition, abstract computations and computable knowledge are being investigated.

## 5.3 Research Projects

### Algebraic and Logical Aspects of Knowledge Processing

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

**Research staff:** G. Jäger, T. Rosebrock, K. Sato, S. Steila, T. Strahm

**Financial support:** Swiss National Science Foundation (No. 137678)

### 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 (No. 165549)

### 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 mathemat-

ics. Furthermore, we are interested in analyzing the close connections between the complexities of computations and proofs in suitable formalizations, ranging from propositional calculi up to abstract frameworks for computations (in higher types).

**Research staff:** All members of the research group

## 5.4 Habilitation Theses

- D. Probst: A Modular Ordinal Analysis of Metapredicative Subsystems of Second Order Arithmetic

## 5.5 Master's Theses

- R. Imhof: JassBot – Learning to Play Schieber with Reinforcement Learning
- S. Matter: Extension of the Logic of Probabilistic Evidence to Nested Evidence

## 5.6 Bachelor's Theses

- P. Allemann: Entwicklung einer mikroprozessorgesteuerten Voice Coil Schutzschaltung
- R. Beck: Beweissuche für Modallogik und linearer $\mu$-Kalkül
- L. Bosshart: Komplexität der Logic of Common Knowledge
- S. Furrer: Eine gefühlsbezogene Analyse von Rezensionen
- A. Jaha: Eine algorithmische Annäherung an das Briefträgerproblem
- K. Meister: Implementing a Finite-State Machine in Unreal Engine 4
- F. Trübner: Unreal Engine 4: Dynamische Daten im Raum

## 5.7 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

#### Thomas Studer

- Member of the Editorial Board of Springer book series on Progress in Computer Science and Applied Logic

### Invited Talks

#### Michael Bärtschi

- Uniform fixpoints and relatives in second order arithmetic, Arbeitstagung Bern-München, University of Bern, April 2018.
- Theories around $\Gamma_0$, OST18: Operations, Sets, and Types, University of Bern, March 2018.
- Uniform fixpoint variants in second order arithmetic, 1st Swiss-Italian Workshop on Proof and Computation, University of Verona, January 2018.
- Arithmetical transfinite recursion and relatives, Logic Colloquium, Stockholm University, August 2017.

#### Lukas Jaun

- Category Theory in Explicit Mathematics, OST18: Operations, Sets, and Types, University of Bern, March 2018.

- Category Theory and Universes in Explicit Mathematics, Arbeitstagung Bern-München, Ludwig-Maximilians-Universität München, December 2017.

**Gerhard Jäger**

- About fixed points of monotone $\Sigma_1$ operators in Kripke-Platek environments, Logic Colloquium, University of Gothenburg, April 2018.
- $\Delta^1_1$ transfinite recursion and its relatives, Logic Seminar, University of Munich, January 2018.
- Theories around $\Gamma_0$ – again, 1st Swiss-Italian Workshop on Proof and Computation, University of Verona, January 2018.
- Remnants from the Bookshelf, Arbeitstagung Bern-München, Ludwig-Maximilians-Universität München, December 2017.
- Axiomatic Systems: An Operational Perspective, International Conference “Axiomatic Thinking”, University of Zurich, September 2017.

**Timotej Rosebrock**

- Recursion theory in applicative theories, Arbeitstagung Bern-München, University of Bern, April 2018.

**Kentaro Sato**

- Making a detour via intuitionistic theories: Applications to SOSOA, Proof and Computation, University of Bonn, July 2018.
- Hierarchy of formula-classes in the intuitionistic second order setting, Arbeitstagung Bern-München, University of Bern, April 2018.
- Conservations of second order $\Sigma^1_1$ collection and $\Sigma^1_1$ closure, OST18: Operations, Sets, and Types, University of Bern, March 2018.
- Negative Church’s thesis and Russian constructivism, Wormshop 2017: Workshop on Proof Theory, Modal Logic and Reflection Principles, Russian Academy of Sciences, October 2017.
- Inductive dichotomy and determinacy of difference hierarchy, Logic Colloquium, Stockholm University, August 2017.

**Silvia Steila**

- SCT through the reverse mathematical looking glasses, Workshop on Ramsey Theory and Computability, University of Rome, July 2018.
- An overview over least fixed points in weak set theories, Proof and Computation, University of Bonn, July 2018.
- SCT through the reverse mathematical looking glasses, Logic Seminar, University of Leeds, May 2018.
- A first order approach to almost-fullness, Computational Approaches to the Foundations of Mathematics, Ludwig-Maximilians-Universität München, April 2018.
- Fixed point statements in the locally predicative and impredicative spotlights, OST18: Operations, Sets, and Types, University of Bern, March 2018.
- When the reals form a proper class, IIIM: Incontro Italiano Insiemi e Modelli, University of Torino, February 2018.
- SCT through the reverse mathematical looking glasses, 1st Swiss-Italian Workshop on Proof and Computation, University of Verona, January 2018.
- How large are proper classes?, Arbeitstagung Bern-München, Ludwig-Maximilians-Universität München, December 2017.
- Playing with equivalent forms of CH, XXVI incontro AILA, University of Padova, September 2017.
- On some fixed point statements over Kripke Platek, Minisymposium: Applied Proof Theory and the Computational Content of Mathematics, University of Salzburg, September 2017.
- On some fixed point statements over Kripke Platek, Logic Colloquium, Stockholm University, August 2017.

**Thomas Studer**

- The proof theory of modal fixed point logics, Chinese Mathematical Logic Conference, Duyun, May 2018.
- Common knowledge from a proof-theoretic perspective, Department of Philosophy, Tsinghua University, May 2018.

- I know that you know that I know – epistemic logic in computer science, Mini Symposium of Computer Graphics, Data Science, Logic and Security, University of Bern, February 2018.
- A Logic of Blockchain Updates, Logical Foundations of Computer Science, Deerfield Beach, Florida, January 2018.
- Justification Logic with Approximate Conditional Probabilities, LORI 2017, Hokkaido University, September 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
- Member of the Kantonale Maturitätskommission
- Expert for Maturitätsprüfungen Mathematik und Informatik

### 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
- Member of the Jury for Prix Schläfli 2018
- Expert for Maturitätsprüfungen Mathematik und Informatik

**Jan Walker**

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

### Organized Events

**Michael Bärtschi**

- Together with Gerhard Jäger and Kentaro Sato. OST18: Operations, Sets, and Types, University of Bern, March 2018.

**Gerhard Jäger**

- Workshop "Proof and Computation", Hausdorff Trimester "Types, Sets and Constructions", Hausdorff Research Institute for Mathematics, University of Bonn, July 2018.
- Together with Kentaro Sato and Michael Bärtschi. OST18: Operations, Sets, and Types, University of Bern, March 2018.

**Kentaro Sato**

- Together with Gerhard Jäger and Michael Bärtschi. OST18: Operations, Sets, and Types, University of Bern, March 2018.

**Silvia Steila**

- 11th Young Set Theory Workshop, EPFL Lausanne, June 2018.
- 1st Swiss-Italian Workshop on Proof and Computation, University of Verona, January 2018.

**Thomas Studer**

- Logic and Application, Inter University Centre Dubrovnik, September 2018.

## 5.8 Awards

- Annual Alumni Award 2017 for Michel Marti's Ph.D. thesis *Contributions to Intuitionistic Epistemic Logic*.
- Paul Bernays Award 2017 for Silvia Steila's outstanding contribution in the area of logic and philosophy of science

## 5.9 Publications

- Gerhard Jäger and Silvia Steila. About some fixed point axioms and related principles in Kripke-Platek environments. *The Journal of Symbolic Logic*, 83(2):642–668, June 2018.
- Michel Marti and George Metcalfe. Expressivity in chain-based modal logics. *Archive for Mathematical Logic*, 57(3–4):361–380, May 2018.
- Michel Marti and Thomas Studer. The Proof Theory of Common Knowledge. In Hans van Ditmarsch and Gabriel Sandu, editors, *Jaakko Hintikka on Knowledge and Game-Theoretical Semantics*, volume 12 of *Outstanding Contributions to Logic*, pages 433–455. Springer International Publishing, 2018.
- Paulo Oliva and Silvia Steila. A direct proof of Schwichtenberg's bar recursion closure theorem. *The Journal of Symbolic Logic*, 83(1):70–83, March 2018.
- Kai Brünnler and Dandolo Flumini and Thomas Studer. A logic of blockchain updates. In *LFCS 2018: Logical Foundations of Computer Science*, volume 10703 of *Lecture Notes in Computer Science*, pages 107–119. Springer International Publishing, 2018.
- Dragan Doder and Nenad Savic and Zoran Ognjanović. A decidable multi-agent logic with iterations of upper and lower probability operators. In *FoIKS 2018: Foundations of Information and Knowledge Systems*, volume 10833 of *Lecture Notes in Computer Science*, pages 170–185. Springer International Publishing, 2018.
- Silvia Ghilezan and Jelena Ivetić and Simona Kašterović and Zoran Ognjanović and Nenad Savić. Probabilistic reasoning about simply typed lambda terms. In *LFCS 2018: Logical Foundations of Computer Science*, volume 10703 of *Lecture Notes in Computer Science*, pages 170–189. Springer International Publishing, 2018.
- Nenad Savic and Dragan Doder and Zoran Ognjanović. Logics with lower and upper probability operators. *International Journal of Approximate rerasoning*, 88:148–168, September 2017.
- Zoran Ognjanović and Nenad Savic and Thomas Studer. Justification logic with approximate conditional probabilities. In *LORI 2017: Logic, Rationality, and Interaction*, volume 10455 of *Lecture Notes in*

*Computer Science*, pages 681–686. Springer International Publishing, 2017.

- Giorgio Audrito and Silvia Steila. Generic large cardinals and systems of filters. *The Journal of Symbolic Logic*, 82(3):860–892, September 2017.

- Gerhard Jäger and Wilfried Sieg (editors). *Feferman on Foundations – Logic, Mathematics, Philosophy*, volume 13 of *Outstanding Contributions to Logic*. Springer International Publishing, 2017.

- Gerhard Jäger. The operational penumbra: some ontological aspects. In Gerhard Jäger and Wilfried Sieg, editors, *Feferman on Foundations – Logic, Mathematics, Philosophy*, volume 13 of *Outstanding Contributions to Logic*, pages 253–283. Springer International Publishing, 2017.

- Thomas Strahm. Unfolding schematic systems. In Gerhard Jäger and Wilfried Sieg, editors, *Feferman on Foundations – Logic, Mathematics, Philosophy*, volume 13 of *Outstanding Contributions to Logic*, pages 187–208. Springer International Publishing, 2017.

# 6 Software Composition Group

## 6.1 Personnel


| | | | |
|---|---|---|---|
| **Head:** | Prof. Dr. O. Nierstrasz | Tel: | +41 31 631 46 18 |
| | | email: | oscar@inf.unibe.ch |
| **Office Managers:** | B. Choffat | Tel: | +41 31 631 46 92 |
| | | email: | choffat@inf.unibe.ch |
| **Scientific Staff:** | Dr. M. Ghafari* | Tel: | +41 31 511 7637 |
| | | email: | ghafari@inf.unibe.ch |
| | C. Corrodi* | Tel: | +41 31 511 7639 |
| | | email: | corrodi@inf.unibe.ch |
| | O. Flückiger | Tel: | +41 31 511 7638 |
| | | email: | o@o1o.ch |
| | P. Gadient | Tel: | +41 31 511 7644 |
| | | email: | gadient@inf.unibe.ch |
| | M. Hazhirpasand | Tel: | +41 31 511 7644 |
| | | email: | mhhazhirpasand@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 |
| | Dr. N. Lazarević (Milojković) | Tel: | +41 31 511 7639 |
| | | email: | nevena@inf.unibe.ch |
| | H. Osman | Tel: | +41 31 511 7644 |
| | | email: | osman@inf.unibe.ch |
| | N. Patkar | Tel: | +41 31 511 7644 |
| | | email: | patkar@inf.unibe.ch |
| | P. Rani | Tel: | +41 31 511 7639 |
| | | email: | pooja@inf.unibe.ch |
| | Y. Tymchuk* | Tel: | +41 31 511 7643 |
| | | email: | tymchuk@inf.unibe.ch |


*with financial support from a third party

## 6.2 Overview

Software systems that are used in practice must evolve over time to maintain their relevance, yet as systems evolve, they become more complex and harder to evolve. The Software Composition Group carries out re-

search into tools, techniques and programming language mechanisms to enable the graceful evolution of complex software systems.

## 6.3 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.**

  Modelling is an important activity in software development, as it enables all the technical and non-technical stakeholders of a project to understand and communicate underlying problems in a mutually understandable way. Hence, a model has to be communicative, understandable, and, as the Object Management Group (OMG) suggests, also transformable into executable code. Domain modelling is a special area of modelling where a model represents possible relevant aspects of the problem domain, in particular the entities involved in that domain, their structure, and their behaviour. There are various approaches people have tried for modelling, notably UML modelling which is used for general purpose modelling, Domain Specific Languages (DSLs), which are high level languages intended to be used by non-programmers, Domain specific Modelling Languages (DSMLs), which abstract further from DSLs and mostly provide domain specific visual notations, and Domain Driven Design (DDD) where the code itself is written in a systematic way that represents the underlying model. Our initial contribution in the field is a mobile tool called Vision Backlog that helps to elicit requirements in situ, and is thus more suitable for domain modelling. On modelling itself we take a different perspective, and we imagine that a model should be

part of the final running system. Our initial attempts are creating a visual scenario builder in Pharo, and automatically generating code for it. The Pharo environment itself can provide various opportunities such as executable model documentation. These initial research ideas were presented at SATToSE 2018.

- **Context-Aware Tooling.**

  To identify common problems in the evaluation of software visualizations with the goal of formulating guidelines to improve future evaluations, we conducted a systematic review of papers published in the software visualization literature. We identified several pitfalls, and elaborated on guidelines to support researchers who need to evaluate their software visualization approaches.

  We used our proposed guidelines in a recent controlled experiment and case study in which we evaluated two 3D visualization techniques that support comprehension of structure and behavior of software systems. In the experiment, we investigated how usability issues of 3D visualizations can be minimized by displaying them in an immersive augmented reality environment. We found that immersive augmented reality eases navigation and reduces occlusion. Nevertheless, selection and text readability remain issues.

  Software systems continuously evolve and present multiple challenges for performing an analysis. To deal with the expanding size and complexity of software systems, developers employ reverse engineering methods and tools to extract information. In order to analyze the software using these tools, developers need to learn the query language of the tool which poses a burden for novice developers. Furthermore, starting the analysis process is itself a challenging task for novices like what questions they shall ask and how to formulate such questions in the tool to get the correct answer.

  We constructed a corpus of common software analysis questions that can serve as examples to start the analysis process. We started to develop a tool which can take a developer's question in natural language, i.e., English. We compared different natural language processing techniques to capture the maximum information from a natural language sentence. Combining different approaches, we performed a semantic and structural analysis on the questions present in the corpus. Using this tool, we can find the composition of a question and how two questions are related to each other structurally and semantically. We aim to translate the question to the query language

of the tool. In order to do this, we are performing an extensive study on neural networks.

- **Ecosystem Mining.**

  Based on our previous finding that a missing null check of returned values from methods is one of the most prevalent bug patterns in Java systems, we had mined the usage of specific APIs to identify methods that potentially return null. We published the tool to collect usage data as well as an empirical study on the usage of Apache Lucene, which showed how this information can be harvested by hinting developers at potentially missing or unnecessary null checks. We are currently working on improving the evaluation of our empirical approach by comparing our inferred categorization of a method as nullable or non-null with their respective specification given by the API experts. As another extension, we are investigating whether the same approach can be applied to determine the expected nullness of a method parameter.

  The analysis of mobile applications can often greatly benefit from separating library from application code, for example to improve the performance of the analysis by excluding all library code. Existing approaches try to detect indexed libraries within an application, which requires the index to be continuously updated in order to avoid missing the detection of a new library. We are currently investigating whether we can work around the need for a maintained index by grouping code by their different authors, using a machine learning approach based on stylistic code features that are inherent to and distinctive between individuals and organizations.

  The lack of static type information in dynamically-typed language poses an obstacle to software analysis. The field of type inference has been heavily researched during the last several decades. However, for a type inference algorithm to be precise, it is necessary to be complex and hence not scalable. Simpler algorithms scale well, but pay the price in losing the precision. We demonstrated that the precision of a simple type inference algorithm may be ameliorated by exploiting the programming idioms of the language under analysis. More precisely, we have used type hint information hidden in method argument names to augment a type inference algorithm. We are now investigating the ways of using string similarity metrics and machine learning models to predict the type of a variable.

  In previous research, we showed that numerous security vulnerabil-

ities are prevalent in mobile applications distributed over app stores, which put the digital life of millions of users at risk. During recent years, mobile development platforms continuously tried to innovate; however, security is one major opponent of innovation as its proper assessment is very time demanding. In addition, mobile platforms receive increasing attention from self-made developers; people that lack any educational background in computer science, and thus are prone to estimate potential risks that come with a security-related decision inaccurately. A plethora of static, dynamic, and hybrid analysis tools have been proposed, but the vast majority of those tools only target some specific aspects, such as data flow analysis, or features for malware detection, and does not provide generic bad practices for the use of security-related features that could cause future threats. Hence, the available tools do not sufficiently support developers in making secure mobile apps. We perform literature reviews to compile a diverse set of security issues published in scientific work. We develop tools to assess the collected security issues in byte- and source-code. We evaluate these issues on large corpora in order to determine the common mistakes developers encounter and subsequently propose guidelines and mitigation strategies to avoid any security issues. The obtained results are promising; we were able to predict security issues on par with state of the art approaches, while still providing immediate responses and efficient system resource usage, properties that are currently not found in competing approaches.

- **Evolutionary Monitoring.**

  Recent efforts in research on static analysis of Android applications have yielded many approaches and ideas to detect security issues. In their respective works, the ideas are often evaluated by implementing a tool or prototype of the approach, and by comparing them to other similar works. To benefit from past research efforts, tools need to be made publicly available and are ideally kept up to date. However, there are several reasons why this can be difficult. For example, the Android platform and other dependencies evolve quickly over time; tools need to be updated accordingly. Furthermore, researchers may want to focus on different things once the works have been published. In our work, we investigate the state of static analysis tools for detecting data leaks in Android applications. We review the state-of-the-art and focus on prototypes and tools. We report on availability and usability in a modern, up-to-date setting. To stream-

line the analysis and run tools in a common setting, we implemented a benchmark that provides a common interface to tools and generates normalized reports from a tool's output. This makes comparisons between those tools easy and fair. Furthermore, adding new and emerging tools in the domain is straightforward. Consequently, our benchmark can be used instead of performing custom analysis to compare approaches.

By analyzing applications before they are deployed, companies can discover and fix software vulnerabilities to avoid exploitation. To achieve an acceptable level of software code security, several solutions could be used such as a Secure Software Development Life Cycle (S-SDLC), or static and dynamic analysis tools.

In SATToSE 2018, we presented initial research concerning how to design a custom Secure Software Development Life Cycle (S-SDLC) for in-house Android developers. This research is in the initial stage, and we plan to employ Pharo to design a threat-modeling tool. Moreover, we did research on how WebRTC IP leakage could impact users' privacy and how this vulnerability could be prevented. The corresponding paper was presented at ESSoS 2018. Currently, we are exploring ways in which DNS-rebinding attack can benefit from our findings in infringing users' privacy by WebRTC IP leakage. A large-scale analysis of Java projects on GitHub is also being performed to discover Java Cryptography Architecture (JCA) usage. We intend to identify developers whose projects are correctly using JCA.

**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`

## 6.4 Ph.D. Theses

- Leonel Merino. *The Medium of Visualization for Software Comprehension*. PhD thesis, University of Bern, June 2018. URL: `http://scg.unibe.ch/archive/phd/merino-phd.pdf`.

- Haidar Osman. *Empirically-Grounded Construction of Bug Prediction and Detection Tools*. PhD thesis, University of Bern, December 2017. URL: http://scg.unibe.ch/archive/phd/osman-phd.pdf.
- Yuriy Tymchuk. *Quality-Aware Tooling*. PhD thesis, University of Bern, December 2017. URL: http://scg.unibe.ch/archive/phd/tymchuk-phd.pdf.

## 6.5 Master's Theses

- Pascal Gadient. Security in Android applications. Masters thesis, University of Bern, August 2017. URL: http://scg.unibe.ch/archive/projects/Gadi17.pdf.
- Andreas Hohler. Big commit analysis — towards an infrastructure for commit analysis. Masters thesis, University of Bern, January 2018. URL: http://scg.unibe.ch/archive/masters/Hohl18a.pdf.
- Mario Kaufmann. Reproducible moldable interactions. Masters thesis, University of Bern, April 2018. URL: http://scg.unibe.ch/archive/masters/Kauf18a.pdf.

## 6.6 Bachelor's Theses and Computer Science Projects

- Sébastien O. Broggi. Bug prediction with neural nets using regression- and classification-based approaches. Bachelor's thesis, University of Bern, January 2018. URL: http://scg.unibe.ch/archive/projects/Brog18a.pdf.
- Simon Curty. Issue report assessment — assessment of issue report quality and class through natural language processing. Bachelor's thesis, University of Bern, February 2018. URL: http://scg.unibe.ch/archive/projects/Curt18a.pdf.
- Patrick Frischknecht. Security in Android ICC. Bachelor's thesis, University of Bern, June 2018. URL: http://scg.unibe.ch/archive/projects/Fris18a.pdf.
- Tanja Leigh Küry. Replication mechanisms for reference data. Bachelor's thesis, University of Bern, March 2018. URL: http://scg.unibe.ch/archive/projects/Kuer18a.pdf.

- Sara Peeters. Personalized autism infographics: A web development project with and for autistic people. Bachelor's thesis, University of Bern, April 2018. URL: http://scg.unibe.ch/archive/projects/Peet18a.pdf.

- Eve Mendoza Quiros. Visualising objects in Pharo. Bachelor's thesis, University of Bern, June 2018. URL: http://scg.unibe.ch/archive/projects/Mend18a.pdf.

- Aliaksei Syrel. The moldable editor. Bachelor's thesis, University of Bern, February 2018. URL: http://scg.unibe.ch/archive/projects/Syre18a.pdf.

- Andreas Wälchli. AppCheck — monitoring of a JavaEE server application. Bachelor's thesis, University of Bern, September 2017. URL: http://scg.unibe.ch/archive/projects/Wael17a.pdf.

- Lars Wüthrich. A shape grammar interpreter using local coordinates for subshape detection. Bachelor's thesis, University of Bern, February 2018. URL: http://scg.unibe.ch/archive/projects/Wuet18a.pdf.

## 6.7 Awards

- Faculty Prize for Manuel Leuenberger's MSc thesis, "Nullable Method Detection — Inferring Method Nullability From API Usage"

## 6.8 Further Activities

### Invited Talks

#### Oscar Nierstrasz

- Invited Speaker at Simula 50 Years: "Great Moments in the History of OOP (50 years anniversary of Simula, the first object-oriented programming language — Oslo, Norway, Sept. 27, 2017)

#### Mohammad Ghafari

- Invited Course Lecture at Brunel University: "Java Arrays" – London, UK, May 24, 2018

- Invited Speaker at Brunel University: “Towards quality software development” – London, UK, May 24, 2018

**Leonel Merino**

- Invited Speaker at University of Chile: “The Medium of Visualization for Software Comprehension” – Santiago, Chile, Dec 15, 2017
- Invited Speaker at Austral University of Chile: “The Medium of Visualization for Software Comprehension” – Valdivia, Chile, Jan 18, 2018
- Invited Speaker at German Aerospace Center (DLR): “The Medium of Visualization for Software Comprehension” – Cologne, Germany, Feb 16, 2018

## Editorial Boards and Steering Committees

**Oscar Nierstrasz**

- AITO – Association Internationale pour les Technologies Objets (Member)
- CHOOSE – Swiss Group for Object-Oriented Systems and Environments (Board member)
- 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

- Invited Speaker at Simula 50 Years: ”Great Moments in the History of OOP (50 years anniversary of Simula, the first object-oriented programming language — Oslo, Norway, Sept. 27, 2017)
- PC Member of SANER 2018 (International Conference on Software Analysis, Evolution, and Reengineering — Campobasso, Italy, March 19-23, 2018) 2017
- PC Member of BENEVOL 2017 (16th BElgian-NEtherlands software eVOLution symposium — University of Antwerp, Belgium, Dec 4-5, 2017)
- PC Member of ICSME 2017 (International Conference on Software Maintenance and Evolution — Shanghai, China, Sept. 17-23, 2017)
- PC Member of SANER 2017 (International Conference on Software Analysis, Evolution, and Reengineering — Klagenfurt, Austria, Feb. 21-24, 2017)

### Mohammad Ghafari

- PC member of ICSME 2018 (34th International Conference on Software Maintenance and Evolution – Madrid, Spain, Sep 23-29, 2018)
- PC member of MaLTeSQuE 2018 (2nd Workshop on Machine Learning Techniques for Software Quality Evaluation – Campobasso, Italy, March 20-23, 2018)
- PC member of VST 2018 (2nd Workshop on Validation, Analysis and Evolution of Software Tests – Campobasso, Italy, March 20-23, 2018)

### Leonel Merino

- PC Member of VISSOFT 2018 – Artifact Evaluation Committee (6th IEEE Working Conference on Software Visualization — Madrid, Spain, September 24-25, 2018)

### Yuriy Tymchuk

- PC Member of VISSOFT 2018 – NIER and Tool Demo Track (6th IEEE Working Conference on Software Visualization — Madrid, Spain, September 24-25, 2018)

**Nevena (Milojković) Lazarević**

- PC member of SATToSE 2018 (11th Seminar Series on Advanced Techniques & Tools for Software Evolution – Athens, Greece, July 4-6, 2018)
- PC Member of IWST 2018 – (10th International Workshop on Smalltalk Technologies – Cagliari, Italy, September 10-14, 2018)

## Reviewing Activities

**Oscar Nierstrasz**

- IEEE Transactions of Software Engineering
- Israel Science Foundation

**Mohammad Ghafari**

- Journal of Software: Evolution and Process (JSEP)
- ICSME 2018
- SCAM 2018

**Haidar Osman**

- IEEE Transactions on Software Engineering (TSE Journal)

**Leonel Merino**

- VR 2018
- SANER 2018
- VISSOFT 2018

**Claudio Corrodi**

- SATToSE 2018

**Manuel Leuenberger**

- SATToSE 2018
- SCAM 2018

**Yuriy Tymchuk**

- VISSOFT 2017

**Pooja Rani**

- SCAM 2018
- SATToSE 2018

**Nevena (Milojković) Lazarević**

- SANER 2018
- SATToSE 2018
- IWST 2018

**Pascal Gadient**

- SCAM 2018

## 6.9 Publications

### Journal Papers

- Jan Kurš, Jan Vraný, Mohammad Ghafari, Mircea Lungu, and Oscar Nierstrasz. Efficient parsing with parser combinators. *Science of Computer Programming*, 161:57.88, September 2018. URL: `http://scg.unibe.ch/archive/papers/Kurs17a.pdf`, `doi:10.1016/j.scico.2017.12.001`.
- Max Leske, Andrei Chiş, and Oscar Nierstrasz. Improving live debugging of concurrent threads through thread histories. *Science of Computer Programming*, 161:122–148, 2018. URL: `http://scg.unibe.ch/archive/papers/Lesk17a.pdf`, `doi:10.1016/j.scico.2017.10.005`.
- Leonel Merino, Mohammad Ghafari, Craig Anslow, and Oscar Nierstrasz. A systematic literature review of software visualization evaluation. *Journal of Systems and Software*, 144:165–180, October 2018. URL: `http://scg.unibe.ch/archive/papers/Meri18a.pdf`, `doi:https://doi.org/10.1016/j.jss.2018.06.027`.
- Leonel Merino, Mohammad Ghafari, and Oscar Nierstrasz. Towards actionable visualization for software developers. *Journal of Software: Evolution and Process*, 30(2):e1923–n/a, 2017. URL: `http://scg.unibe.ch/archive/papers/Meri17a.pdf`, `doi:10.1002/smr.1923`.

- Nevena Milojković, Clément Béra, Mohammad Ghafari, and Oscar Nierstrasz. Mining inline cache data to order inferred types in dynamic languages. *Science of Computer Programming, Elsevier, Special Issue on Adv. Dynamic Languages*, 161:105–121, 2018. URL: http://scg.unibe.ch/archive/papers/Milo17e.pdf, doi:10.1016/j.scico.2017.11.003.

## Conference Papers

- Claudio Corrodi, Timo Spring, Mohammad Ghafari, and Oscar Nierstrasz. Idea: Benchmarking Android data leak detection tools. In Mathias Payer, Awais Rashid, and Jose M. Such, editors, *Engineering Secure Software and Systems*, pages 116–123, Cham, 2018. Springer International Publishing. URL: http://scg.unibe.ch/archive/papers/Corr18a.pdf, doi:10.1007/978-3-319-94496-8_9.

- Mohammad Ghafari, Pascal Gadient, and Oscar Nierstrasz. Security smells in Android. In *17th IEEE International Working Conference on Source Code Analysis and Manipulation (SCAM)*, pages 121–130, September 2017. URL: http://scg.unibe.ch/archive/papers/Ghaf17c.pdf, doi:10.1109/SCAM.2017.24.

- Mohammadreza Hazhirpasand. Mheye: A hybrid android security assessment tool for ordinary users. In *SATTOSE*, SATToSE '18. SATToSE, 2018. URL: http://scg.unibe.ch/archive/papers/Hazh18b.pdf.

- Mohammadreza Hazhirpasand and Mohammad Ghafari. One leak is enough to expose them all — from a WebRTC IP leak to web-based network scanning. In *International Symposium on Engineering Secure Software and Systems (ESSoS 2018)*, 2018. To appear. URL: http://scg.unibe.ch/archive/papers/Hazh18a.pdf, doi:10.1007/978-3-319-94496-8_5.

- Manuel Leuenberger, Haidar Osman, Mohammad Ghafari, and Oscar Nierstrasz. Harvesting the wisdom of the crowd to infer method nullness in Java. In *Proceedings of the 17th International Working Conference on Source Code Analysis and Manipulation*, SCAM 2017. IEEE, 2017. URL: http://scg.unibe.ch/archive/papers/Leue17b-InferMethodNullness.pdf, doi:10.1109/SCAM.2017.22.

- Manuel Leuenberger, Haidar Osman, Mohammad Ghafari, and Oscar Nierstrasz. KOWALSKI: Collecting API clients in easy mode. In *Proceedings of the 33rd International Conference on Software Maintenance and Evolution*, ICSME 2017. IEEE, 2017. URL: http://scg.unibe.ch/archive/papers/Leue17c-KowalskiCollectingApi.pdf, doi:10.1109/ICSME.2017.78.

- Leonel Merino, Johannes Fuchs, Michael Blumenschein, Craig Anslow, Mohammad Ghafari, Oscar Nierstrasz, Michael Behrisch, and Daniel Keim. On the impact of the medium in the effectiveness of 3D software visualization. In *VISSOFT'17: Proceedings of the 5th IEEE Working Conference on Software Visualization*, pages 11–21. IEEE, 2017. URL: http://scg.unibe.ch/archive/papers/Meri17b.pdf, doi:10.1109/VISSOFT.2017.17.

- Leonel Merino, Mohammad Ghafari, Craig Anslow, and Oscar Nierstrasz. CityVR: Gameful software visualization. In *ICSME'17: Proceedings of the 33rd IEEE International Conference on Software Maintenance and Evolution (TD Track)*, pages 633–637. IEEE, 2017. URL: http://scg.unibe.ch/archive/papers/Meri17c.pdf, doi:10.1109/ICSME.2017.70.

- Haidar Osman, Mohammad Ghafari, Oscar Nierstrasz, and Mircea Lungu. An extensive analysis of efficient bug prediction configurations. In *Proceedings of the 13th International Conference on Predictive Models and Data Analytics in Software Engineering*, PROMISE, pages 107–116, New York, NY, USA, 2017. ACM. URL: http://doi.acm.org/10.1145/3127005.3127017, doi:10.1145/3127005.3127017.

- Nitish Patkar. Towards executable domain models. In *SATTOSE*, SATToSE '18. SATToSE, 2018. URL: http://scg.unibe.ch/archive/papers/Patk18a.pdf.

- Yuriy Tymchuk, Mohammad Ghafari, and Oscar Nierstrasz. JIT feedback — what experienced developers like about static analysis. In *26th IEEE International Conference on Program Comprehension (ICPC 2018)*, 2018. To appear. URL: http://scg.unibe.ch/archive/papers/Tymc18a.pdf, doi:10.1145/3196321.3196327.

## Book Chapters


- Andrei Chiş, Tudor Gîrba, Juraj Kubelka, Oscar Nierstrasz, Stefan Reichhart, and Aliaksei Syrel. Moldable tools for object-oriented development. In Bertrand Meyer Manuel Mazzara, editor, *PAUSE: Present And Ulterior Software Engineering*, pages 77–101. Springer, Cham, 2017. URL: `http://scg.unibe.ch/archive/papers/Chis17a-MoldableToolsPAUSE.pdf`, `doi:10.1007/978-3-319-67425-4_6`.

# 7 Administration

**University:**

| | |
|---|---|
| T. Braun: | Member of the Committee for Computing Services (Kommission für Informatikdienste)<br>Representative of University of Bern in SWITCH Stiftungsrat |
| G. Jaeger: | Member of *Kantonale Maturitätskommission* |

**Faculty:**

| | |
|---|---|
| T. Braun: | Faculty Board Natural Sciences |
| G. Jaeger: | Member Faculty Strategy Committee (until December 2017) |
| P. Favaro: | Member of the Board of Studies<br>Joint Master in Computer Science of the Universities of Bern, Fribourg and Neuchâtel: Member of the Branch Committee<br>Faculty delegate |
| O. Nierstrasz: | Chair, Teaching Evaluation Committee, Faculty of Natural Sciences<br>Joint Master in Computer Science of the Universities of Bern, Fribourg and Neuchâtel: Member of the Branch Committee<br>Member Faculty Strategy Committee (as of January 2018)<br>Member Digitalisation Strategy Working Group<br>Member Precision Medicine Working Group |
| Th. Studer: | Member of the Strategy Board |

**Institute:**

| | |
|---|---|
| O. Nierstrasz: | Managing Director of INF<br>Member of Hauskommission Engehalde<br>President CUSO Doctoral School in Computer Science |
| T. Braun: | Deputy Director of INF |

| | |
|---|---|
| P. Favaro: | Director of Studies |
| N. Lazarević: | Member of Library Committee Exakte Wissenschaften |
| Th. Studer: | Member of Hauskommission Exakte Wissenschaften |