

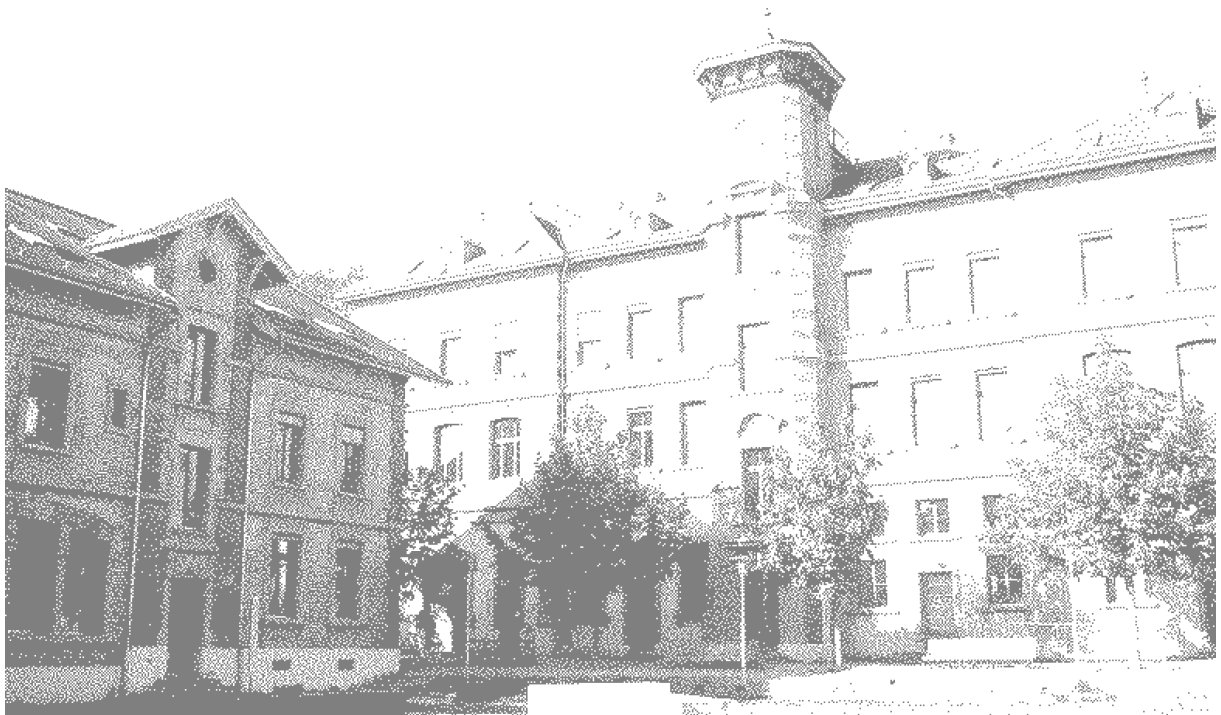
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**UNIVERSITÄT
BERN**

Institut für Informatik
Universität Bern

www.inf.unibe.ch

INF Annual Report 2018/2019



INF Annual Report
Academic Year 2018/2019

August 10, 2019

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1 Institute of Computer Science (INF)

1.1 Address

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

1.2 Personnel

Members

Florence Aellen, Orestis Charilaos Alpos, Ignacio Amores Sesar, Mohammadreza Hazhirpasand Barkadehi, Adam Bielski, Prof. David Bommers, Dr. Peppo Brambilla, Prof. Torsten Braun, Nathalie Brugger, Sabine Brunner, Prof. Christian Cachin, José Luis Carrera Villacrés, Bettina Choffat, Janik Endtner, Dragana Esser, Prof. Paolo Favaro, Pascal Gadiant, Nicolas Gallego Oriz, Mikael Gasparyan, Carole Gauch, Dr. Thiago Genez, Dr. Mohammad Ghafari, Francesca Giardina, Roman Gruber, Martin Heistermann, Simon Jenni, Simon Kafader, Eirini Kalogeiton, Mostafa Karimzadeh, Rebeca Kehl, Angela Keller, Alex Kräuchi, Eveline Lehmann, Labdelhak Lemkhenter, Manuel Leuenberger, Heng Liu, Corina Masanti, Oscar Meier, Givi Meishvili, Steve Mürset, Dr. Oliver Neumann, Prof. Oscar Nierstrasz, Patkar Nitish, Pooja Rani, Nenad Savic, Dr. Eryk Schiller, Daniela S. Schroth, Dominic Schweizer, Jonas Schwery, Dr. Ronny Standtke, Prof. Thomas Strahm, Prof. Thomas Studer, Dr. Matthias Stürmer, Noe Leon Thalheim, Prof. Athina Tzovara, Josué Page Vizcaino, Adrian Wälchli, Jan Walker, Xiaochen Wang, Stefanie Weilenmann, Tobias Welz, Luca Zanolini, Dr. Zhongliang Zhao

Administration

Bettina Choffat; Dragana Esser; Daniela Schroth

Technical staff

Dr. Peppo Brambilla; Tiziano Portenier (until 31.3.19); Adrian Wälchli (starting 1.4.19)

2 Teaching Activities

2.1 Courses for Major and Minor in Computer Science

Autumn Semester 2018

- 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 (D. Bommers, 5 ECTS)

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

Machine Learning (P. Favaro, 5 ECTS)

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

- Master Courses

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

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

Justification Logic (T. Studer, 5 ECTS)

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)

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

- Service Courses

Anwendungssoftware (J. Walker, 3 ECTS)

Spring Semester 2019

- Bachelor 2nd Semester

Datenbanken (T. Studer, 5 ECTS)

Datenstrukturen und Algorithmen (D. Bommers, 5 ECTS)

Computer Architecture (P. Favaro, 5 ECTS)

Programmierung 2 (O. Nierstrasz, 5 ECTS)

- Bachelor 4th Semester

Algorithmen, Wahrscheinlichkeit und Information (C. Cachin, 5 ECTS)

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

Betriebssysteme (T. Braun, 5 ECTS)

Berechenbarkeit und Komplexität (T. Strahm, 5 ECTS)

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

- Master Courses
 - Compiler Construction (O. Nierstrasz, 5 ECTS)
 - Internet of Things (T. Braun, 5 ECTS)
 - Advanced Topics in Machine Learning (P. Favaro, 5 ECTS)
 - Software Skills (M. Ghafari, 5 ECTS)
 - Seminar: Software Composition (O. Nierstrasz, 5 ECTS)
 - Seminar: Communication and Distributed Systems (T. Braun, 5 ECTS)
 - Seminar: Distributed Trust and Blockchains (C. Cachin, 5 ECTS)
 - Seminar: Computer Vision (P. Favaro, 5 ECTS)
 - Seminar: Logic and Theoretical Computer Science (T. Studer, 5 ECTS)
 - Seminar: Computer Graphics (D. Bommers, 5 ECTS)

- Service Courses
 - Anwendungssoftware (J. Walker, 3 ECTS)

2.2 Students

- Major Subject Students: AS 2018: 257, SS 2019: 235
- Minor Subject Students: AS 2018: 172, SS 2019: 155
- Ph.D. Candidates: AS 2018: 33, SS 2019: 32

2.3 Degrees and Examinations

- PhD: 7
- Master: 27
- Bachelor: 26

- Completion of Minor Studies: 21 (90E:0, 60E:5, 30E:11, 15E:15, 855 ECTS)
- Semester Examinations AS 2018: 893 (3331 ECTS)
- Bachelor's/Master's Theses AS 2018: 29 (590 ECTS)
- Semester Examinations FS 2019: 538 (2202 ECTS)
- Bachelor's/Masters Theses FS 2019: 16 (340 ECTS)

2.4 Activities

- Contribution to "Studienwoche, Fascinating Informatics, Schweizer Jugend Forscht", Bern, September 9-15, 2018
- Swiss Olympiad in Informatics, May 24 and 25, 2019
- Contribution to the "National Future Day for Girls and Boys", Bern, November 8, 2018
- Contribution to the "Bachelor Infotage", December 4+5, 2018
- Contribution to the "Master Infotage", March 6, 2019
- Taster course for female students, Bern, March 21, 2019
- Visitor Program, Gymnasium Thun, Bern, July 3, 2019

2.5 Awards

- Faculty Prize (INF, Masterarbeit) for "SDN Wisebed: A Software-Defined Wireless Sensor Network Testbed" by Jakob Schärer
- Alumni Award PhD INF for "Motion Deblurring from a Single Image", by Meiguang Jin
- Alumni Award Master INF for "Reproducible moldable interactions", by Mario Kaufmann
- Alumni Award Bachelor INF for "Capturing Complex Behavior of Mobile Users for Predicting Next Trajectories", by Florian Gerber

3 Cognitive Computational Neuroscience Group

3.1 Personnel

Head:	Prof. Dr. A. Tzovara	Tel.: +41 31 511 7636 email: athina.tzovara@inf.unibe.ch
Scientific Staff:	F.M. Aellen	+41 31 511 7636 email: florence.aellen@inf.unibe.ch (since 01.04.2019)
Interns:	C.A. Donnay	+41 31 511 7636 email: CDonnay3811@scrippscollege.edu (since 01.07.2019)

3.2 Overview

Prof. Tzovara joined the Institute of Computer Science in a part-time capacity in March 2019 and full-time in June 2019. The newly formed Cognitive Computational Neuroscience group conducts research in the areas of neuroscience, machine learning and computational modeling. We use invasive and non-invasive electrophysiological recordings (scalp and intracranial electroencephalography and single-unit recordings), in combination with computational techniques (machine learning and modeling of physiological signals and learning processes), to study human cognition. We have started our endeavours by focusing in two main areas: (a) studying the neural processes that underlie learning rules from our environment and (b) developing novel computational techniques for analysing electrophysiological signals.

3.3 Research Projects

Neural and computational mechanisms underlying the detection of environmental rules

The world around us is full of rich sensory experiences, which often follow repetitive rules. Thanks to these rules, we are able to learn patterns from our environment and form predictions about future events before these occur. The brain continuously operates as a predictive machine, relying on

internal models that generate automatic predictions about the most plausible states of the environment given prior information, not only when these are relevant to our actions, but also when conscious access to incoming sensory stimuli can be excluded, such as during sleep or coma. In this project, our goal is to assess the neural and computational mechanisms of learning environmental rules as a function of consciousness. To this aim, we are using experimental paradigms in which environmental rules are built by repeating regular series of sounds, and are occasionally violated by replacing regular sounds with deviant ones. This manipulation induces neural responses that correspond to prediction error signals, which are elicited every time that received sensory information does not match predictions of an environmental model. To assess cortical and subcortical components of prediction errors at a fine temporal resolution, we are using intracranial electroencephalography (EEG) recordings in patients with epilepsy undergoing pre-surgical monitoring. Moreover, we are designing novel experimental paradigms to study how prediction errors are altered by the loss of consciousness during sleep.

Research staff: Corinne Alison Donnay, Athina Tzovara

Financial support: Interfaculty Research Cooperation Decoding Sleep: From Neurons to Health “Mind” of the University of Bern and The Scripps College Internship Grant Program to C.A.D.

Machine learning techniques for analyzing EEG data

To study neural responses to environmental stimuli via EEG recordings, typically hundreds or thousands of single-trial responses are averaged and contrasted at single electrode locations. Machine Learning (ML) techniques have been developed in the past to model the distribution of single-trial EEG responses on the scalp, and detect patterns of topographic activity in a data-driven way. However, most of the available ML techniques assume that neural responses are time-locked across trial repetitions, which very often is not the case. For example, when learning new information, or when making decisions, trial-by-trial responses are highly variable in time and space. Moreover, existing approaches are mainly able to extract patterns of EEG activity at the single-participant level, and their generalization over large groups of patients or participants is limited. Here, we are developing novel machine learning techniques for decoding stimulus-related information from EEG data, that have the flexibility to (a) learn from

large populations of participants, and (b) disentangle time-unlocked neural processes, for example related to learning, on a trial-by-trial level. To this aim, we are using tools from computer vision such as convolutional neural networks, to discriminate EEG responses to environmental stimuli, and extract features from various representations of time-unlocked EEG activity.

Research staff: Florence Marcelle Aellen, Athina Tzovara

Financial support: Interfaculty Research Cooperation Decoding Sleep: From Neurons to Health Mind“ of the University of Bern

Open resources for algorithmic decision-making in neuroscience

As the amount and complexity of data collected in neuroscience increases, advanced algorithmic techniques have become imperative for analysing them. Algorithmic decisions, often reached through ML techniques, have the potential to majorly improve the lives of patients suffering from neurological disorders, for example through neural implants that automatically detect and stop epileptic seizures before they occur, or by enabling communication in individuals who cannot control their bodies. While the use of ML in neuroscience has an enormous potential for bringing positive change, this comes with a high cost, as ML algorithms are often treated as a black box. In interdisciplinary areas such as neuroscience, there is often a gap in expertise, as researchers come from very diverse fields like psychology vs. computer science. As a result, researchers from less computational fields might be using algorithms without fully understanding their assumptions, while researchers who are developing algorithms may not be fully aware of the social and ethical implications of their use. In this project, we aim at raising awareness about the use of algorithmic decision-making in the field of neuroscience by building an open resource on ML and signal-processing techniques for analysing neuroscientific data, starting with the specific case of EEG data. Our goal is to enhance the accessibility of computational techniques to all academic and citizen scientists, and increase transparency in algorithmic practices.

Research staff: Athina Tzovara

Financial support: Mozilla, Open Science Mini-Grant

3.4 Further Activities

Conference Committees

Athina Tzovara

- Organization for Human Brain Mapping (OHBM), chair of Diversity and Gender Committee

Reviewing Activities

Athina Tzovara

- IEEE Journal of Biomedical and Health Informatics
- Nature Human Behaviour
- Neuroimage
- Neuroimage Clinical

3.5 Publications

Journal Publications

- Tzovara A., Meyer S. S., Bonaiuto J.J., Abivardi A., Dolan R.J., Barnes R.G., Bach D.R. High-precision magnetoencephalography for reconstructing amygdalar and hippocampal oscillations during prediction of safety and threat. *Human Brain Mapping*, 1-16, 2019.
-
- Greshake Tzovaras B., Angrist M, Arvai K., Dulaney M., Estrada-Galinanes V., Gunderson B., Head T., Lewis D., Nov O., Shaer O., Tzovara A., Bobe J., Price Ball M. Open Humans: A platform for participant-centered research and personal data exploration. *Giga-Science*, 8(6), 2019.

Book Chapters

- Greshake Tzovaras B., Tzovara A. The personal data is political. *Book: The Ethics of Medical Data Donation*. Springer, 133-140, 2019.

Scientific Disseminations

- Tzovara A., De Lucia M. Can the brain of a patient in a coma react to sounds? *Frontiers for Young Minds*, 7-19, 2019.

4 Communication and Distributed Systems Group

4.1 Personnel

Head:	Prof. Dr. T. Braun	Tel.: +41 31 511 2631 email: torsten.braun@inf.unibe.ch
Office Manager:	D. Schroth	Tel.: +41 31 511 2630 email: daniela.schroth@inf.unibe.ch
Scientific Staff:		
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	M. Gasparyan	Tel.: +41 31 511 7645 email: mikael.gasparyan@inf.unibe.ch
	Dr. T.A. Lopes Genez*	Tel.: +41 31 511 2639 email: thiago.genez@inf.unibe.ch (Until 31.12.2018)
	E. Kalogeiton*	Tel.: +41 31 511 2638 email: eirini.kalogeiton@inf.unibe.ch
	M. Karimzadeh	Tel.: +41 31 511 7645 email: mostafa.karimzadeh@inf.unibe.ch
	A. Marandi	Tel.: +41 31 511 2634 email: ali.marandi@inf.unibe.ch (Until 30.04.2019)
	Dr. E. Schiller*	Tel.: +41 31 511 2633 email: eryk.schiller@inf.unibe.ch (Until 31.05.2019)
	A. Mariano de Souza	Tel.: +41 31 511 7631 email: allan.souza@inf.unibe.ch (Until 30.06.2019)
	Dr. Z. Zhao*	Tel.: +41 31 511 2639 email: zhongliang.zhao@inf.unibe.ch
External Ph.D. Students:		
	L. Luceri	email: luceri@inf.unibe.ch
	G. Manzo	email: gaetano.manzo@hevs.ch
	J. Schärer	email: jakob.schaerer@abilium.com

* with financial support from a third party

4.2 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), as well as the Internet of Things (IoTs). We are also working on mobility and trajectory prediction of mobile users and vehicles using advanced machine learning mechanisms.

4.3 Research Projects

FOG2

The Fog Computing for Fog Harvesting and Environmental Monitoring (FOG2) project aims to setup a platform to design, implement, and test a wireless network infrastructure and a fog computing-based system to monitor environments. The testbed consists of a water catcher system, what is called Warka water tower, deployed in the mountain areas in Quito, Ecuador, to collect and harvest potable water from the air, as well as a river water level monitoring station deployed in Para, Brazil, to deliver early hazard warnings. A wireless sensor network will be deployed to interconnect all the Warka water tower sensor data, as well as the river flow sensors, and store them in the cloud server deployed at the University of Bern. A fog computing system will be deployed next to the environmental monitoring nodes to store all the collected sensor measurements in a local copy and conduct data pre-processing for further analysis. The pre-processed data will be used by the edge server to find relationships between the collected data and the flow rate using advanced machine learning algorithms. The insights will then be transmitted in real-time by the flow conditions in case of an atypical precipitation to make predictions of flooding probabilities, etc. The CDS group leads the sub-project of the design and implementation of wireless sensor networks and machine learning-driven network applications. Therefore, CDS is mainly responsible for setting up the fog environmental monitoring testbed in Ecuador. This includes building the monitoring node as well as the gateway node that transfers the collected information to cloud servers.

On December 19th, 2018, CDS group members attended the research

slam organized by University of St. Gallen, the "Leading house for the Latin American Region. The FOG2 project was introduced to public, including both its technical innovations and possible social impacts.

On January 28th in 2019, the CDS group held the project kick-off meeting in Bern, where all the project partners participated and discussed the possible solutions to meet the application requirements. A system architecture was proposed and a detailed deployment plan was made. The consortium decided to make the deployment in Quito, Ecuador in July, 2019. From February until July 2019, all the partners made their own progresses to guarantee that all the required software and hardware components are running fine for the testbed deployment.

From July 24th until July 30th, three CDS group members joined the testbed deployment activities in Quito, Ecuador. During the deployment, the CDS group members installed two LoRa nodes with environmental sensors, where node one is next to the Warka tower deployed on top of the mountain Andres and node two is at the bottom of the mountain Andres. The monitoring node includes environmental sensors, such as humidity sensor, air pressure sensor, wind speed sensor, tank water level sensor, fog sensor, as well as the communication sensors. In our deployment, we use the LoRa technology as the data transmission technology between the monitoring station and LoRa gateway, as LoRa is a technology suitable to support low-power, long-distance wireless data transmissions. The LoRa gateway was installed in a house of the Ecuador partner, where an Internet connection is available to connect the LoRa gateway with both the TTN server (commercial LoRa solution provider) as well as the cloud server running at the OpenStack infrastructure available at the CDS group, University of Bern. The LoRa gateway is responsible for managing the data collection from all the monitoring nodes, and it also provides short-term data storage to save the raw data in a local storage for short-term data analysis. The cloud server is storing all raw data collected by the LoRa gateway, which enables it to perform long-term historical data analysis. The collected data (such as the amount of water collected by the Warka water tower, humidity level, fog visibility level, etc) will be analysed by using the mathematical model developed by the project partner to help understanding the correlation between the Warka water level with weather conditions. The testbed deployment activity was covered by local media, where the co-PI of the Ecuador partner was interviewed to explain the technical details and social impacts of the project.

The deployment activities in Quito were reported in the local TV news:
<https://bit.ly/2yNub5w>

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

Financial support: State Secretariat for Education, Research and Innovation, Bilateral Research Cooperation with the Latin American Region, Seed Money Grant, project number SMG1803

Context Awareness Engine

The Context Awareness Engine project funded by Orange focuses on exploring network context awareness to discover, reason, and predict 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), and Phase 2 includes implementation architecture definition (WP3) and software development and demonstration (WP4).

By November 2018, the CDS group has successfully delivered all project deliverables defined for Phase 1, which includes the concrete system functional architecture of the proposed CAE system. This deliverable focuses on analyzing key issues of the proposed Context Awareness Engine architecture. An CAE functional architecture is defined with solutions to the discussed key issues. For each key issue, this deliverable also identifies the relevant requirements, and proposes possible solutions. The proposed CAE system architecture includes its internal components, their connections, and the interfaces with external modules. This deliverable was successfully accepted by Orange. Therefore, Orange approved all the submitted deliverables by end of Phase 1, and decided to continue the project with Phase 2.

By the end of July 2019, the CDS group has successfully delivered the third deliverable, which provides the detailed explanations and performance evaluation of the proposed algorithms for relevant use cases that were defined in previous deliverables. This deliverable includes an individual user mobility prediction algorithm using the Long-Short Term Memory (LSTM) networks as well as some optimization using the reinforcement learning technique. It also includes an algorithm to identify mobility similarity and clustering, and to predict group trajectories of

user group. Experiment results show that the new algorithms outperform our previous works of Markov chain-based mobility prediction algorithms [Karimzadeh et al., 2019a].

As for the future works, the CDS group has helped Orange to identify relevant data that are important to optimize network performance. A data sample has been shared with CDS to validate its importance to conduct the planned use case analysis and experiments. In June 2019, Orange has officially triggered the data collection, and the collected data will be shared with CDS to enable the evaluation of the CDS's in-house prediction algorithm on the real-world dataset. By end of 2019, CDS should deliver the final deliverable, which includes the evaluation of its prediction algorithms working with the Orange dataset.

Research staff: Z. Zhao, M. Karimzadeh, T. Braun, E. Schiller.

Financial support: Orange Research Contract Number H09194

Wireless Indoor Positioning

In the research topic of indoor positioning, we focus on providing accurate, reliable, and stable indoor localization and tracking for wireless mobile devices. Our contributions are presented in [Carrera et al., 2019a] and [Carrera et al., 2019b].

In [Carrera et al., 2019a] we investigated how to improve the resampling process to assure a particle distribution over areas where the desired distribution is large. We proposed a particle filter-based reinforcement learning (PFRL) approach for autonomous robust wireless indoor positioning. A reinforcement learning method is applied on top of the proposed particle filter to improve the system robustness against localization failures. Moreover, the reinforcement learning method makes the localization system converge much faster than other particle-based localization methods. The execution time complexity of the reinforcement learning method grows linearly regarding the number of states and number of actions. Thus, the execution time complexity of the reinforcement learning method does not increase the overall time complexity of the localization system, which grows exponentially regarding the number of extracted features, number of training samples, number of particles, and number of ANs used in the localization process.

PFRL was implemented on a distributed machine learning-based network architecture. To validate environmental independence of the PFRL method, we evaluated PFRL in two complex real-world indoor scenarios.

Moreover, we compared the PFRL localization performance to a client-based PFRL approach. Results have shown that the localization performance of PFRL overcomes the localization performance of the client-based approach. This demonstrated the negative influence produced by limited processing resources of mobile devices when increasing the processing time complexity of the localization algorithms. We evaluated our localization approach in complex office and classroom-like environments along five different moving paths. Our proposed tracking approach can achieve 0.97 meters for mean localization error and recovery time latency of 1.5 seconds, which is more accurate and stable than terminal-based localization methods.

In [Carrera et al., 2019b], we proposed a MEC-based system architecture to provide indoor localization for mobile wireless devices. We provided a probabilistic method to integrate machine learning zone prediction results to radio frequency and environmental information for accurate indoor localization. Since, the computational complexity is offloaded to a MEC server, the localization algorithms are not constrained by the limited computational resources of mobile devices. We discussed the computational complexity of the proposed localization system. When fusing in a particle filter zone prediction results and radio ranging information, the time complexity of the localization system grows exponentially regarding the number of extracted features, number of training samples, number of particles, and number of ANs used in the localization process. Additionally, we tested the localization performance of the MEC-based localization system in complex office-like scenarios. Experiments results show that our approach can achieve an average tracking error of $0.44m$ and 90% accuracy is $0.6m$. It outperforms some commercial products and terminal-based tracking systems.

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

Analysis of Online Social Network Risks

The rise of OSNs has dramatically transformed our society by revolutionizing the way we communicate, socialize, make business, and politics. However, online platforms hide pitfalls still largely unknown to the final users, which may seriously impact their life and our entire society. Examples of OSN risks are related to the privacy of users' personal information and to the manipulation of public opinion. In both these issues, social relationship and interplay among users play a relevant role. The interaction with other individuals may affect users' behavior, decisions, and actions. This social phenomenon is referred to as social influence.

The understanding of how users influence each other can be used for various application. In [Luceri et al., 2019a], we aim to investigate whether it is possible to predict users future activity, which may represent a private information, by modeling social influence among subjects. To this end, we introduce Social Influence Deep Learning (SIDL), an approach based on Deep Neural Networks (DNNs), which learns influence strength in dyadic social connections and, accordingly, predict user future behavior in real-life activities [Luceri et al., 2019a]. Although SIDL can be generalized to every kind of human activity (both online and offline), we focus on real-world (offline) activities, such as attending an event or visiting a location. Results validate our approach and pose further concerns for the privacy of users' information in OSNs.

As OSNs have been proven as effective tools to influence individuals' behavior, they have been maliciously used to manipulate the public opinion. Manipulation campaigns are carried out by malicious actors (e.g., fake accounts and foreign agents), which interact with OSN users with the objective of deceiving the mass and affecting people behavior. In the political context, the 2016 U.S. Presidential election represents a recent remarkable example of OSN manipulation. Since then, OSN service providers have been increasing their efforts to suspend malicious actors and maintain a healthy conversation on OSNs. However, nefarious activity has not entirely stopped.

In [Luceri et al., 2019c], we propose to explore the activity of fake software-controlled accounts, referred to as bots, which are designed to impersonate and possibly alter human behavior. To this end, we study the behavior of increasingly sophisticated bot accounts that continuously evolve to escape detection. In [Luceri et al., 2019c], we analyze the partisan behavior of bots during the midterm election (2018) to identify and measure the effectiveness of their strategy for engaging with humans. Our findings show the multifaceted behavior of social bots, their effectiveness, and mutable nature over time. These facts raise further concerns and pose novel challenges in the fight against OSN manipulation.

Research staff: L. Luceri, T. Braun.

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 focuses on SCN requirements such as load-balancing and session support. We have extended the existing SCN session support mechanism with fault-tolerance capabilities. We have designed and evaluated three fault-tolerance mechanisms [Gasparyan et al., 2019a] in ndnSIM. The first mechanism is based upon propagating session identifiers within the network using Bloom filters, the second design is based upon the propagation of service provider identifiers, and the third design uses piggybacking for the propagation of service provider identifiers. The Bloom filter forwarding strategy does not rely on provider identifiers, which is an advantage if one does not want to depend on address-based forwarding. However, it displays the highest message overhead among the three mechanisms. The second strategy introduces provider identifier broadcast and has the best results in terms of successful forwarding. The third strategy relies on piggybacking; it does not have any message overhead, but it suffers from a high number of lost messages compared to the provider identifier broadcast mechanism. L-SCN (layered SCN) is a layered routing architecture for SCN. L-SCN uses a two-layer forwarding scheme combined of super-nodes and Bloom filters. L-SCN aims to minimize protocol overhead and maximize the shared information about services and resources available in the network with a consumer-driven strategy. We have extended L-SCN with two new service provider information propagation mechanisms. The two mechanisms are named provider-driven and event-driven. The provider-driven approach propagates service provider information periodically. The event-driven approach propagates service provider information in case of an event. The newly introduced mechanisms improve the service processing time and lower the protocol overhead.

Research staff: M. Gasparyan, T. Braun.

Bloom Filter for Information- and Service-Centric Networking

We proposed L-SCN as a layered architecture for intra and inter-domain routing of service requests (SR) in Service-Centric Networks (SCN). L-SCN assumes that the network is divided to different domains, where each domain is managed by a SuperNode (SN). Nevertheless, L-SCN

does not propose any clustering algorithms to divide the network topology into different domains and to appoint the SNs. During this period, we found Dominating Set (DS) and Connected Dominating Set (CDS) constructions as proper ways of clustering the network topology and appointing the SNs. Thus, we have designed and proposed DS and CDS construction algorithms for topology clustering. Further, we implemented Bloom filter-based intra and inter-domain routing protocols and evaluated their performance based on required bandwidth overhead for our clustering and routing algorithms. We also compared our routing algorithms with NDN multicast strategy in terms of average round-trip delays. To observe the impact of topology size on the performance of our DS-based and CDS-based routing protocols, we measured the results using various topologies with different sizes. We observed that DS-based routing performs better using small topologies, while CDS-based routing significantly performs better when large topologies are used.

Previously, we proposed pull-based BFR [Marandi et al., 2019] as a routing protocol for ICN when the number of available content objects is large. Pull-based BFR [Marandi et al., 2019] avoids advertising all the content object names, but rather only advertises the requested content object names. Before content advertisements, pull-based BFR requires a phase called *pulling content advertisements* to inform the servers about the available requests. During this period, we have focused on developing a complete framework that encompasses both content discovery and retrieval and leverages the pull BFs, from the pull-based BFR protocol, to select multi-source network codes. The resulting network coding protocol is able to mix multiple sessions and manages the multi-source rank by enforcing a rank capacity constraint on nodes. Our NC-based protocol is cooperative in the sense that nodes help each other to decode. We are evaluating our NC-based protocol based on the required bandwidth for operation and the average round-trip delay.

Research staff: A. Marandi, T. Braun.

Vehicular Ad Hoc Networks (VANETs)

Vehicular Ad Hoc Networks (VANETs) include vehicles travelling the road with random speed, direction and particular destinations. The native mobile nature and high mobility of VANETs leads to path breaks between vehicles, meaning that the connectivity between nodes is not stable and changes constantly. This intermittent connectivity between vehicles makes

difficult the satisfaction of Quality of Service (QoS) requirements of applications in VANETs, since the path between source and destination changes in an unexpected way. In our project named CONtext and Content Aware CommunicaTions for QoS support in VANETs (CONTACT), we combine three different architectures: Named Data Networking (NDN), Floating Content (FC) and Software Defined Networking (SDN). Our goal is to achieve the QoS requirements of applications in VANETs by using one or more combined paradigms.

NDN is an Internet architecture that addresses content by name instead of location of hosts. Since NDN does not rely on host identification, it is a suitable candidate for networks with intermittent connectivity, such as VANETs. Considering that VANET services and applications usually concern their surrounding area, we enable NDN in VANETs by using only Vehicle-to-Vehicle (V2V) communication. We develop a routing protocol, named enhanced Geographical aware Routing Protocol (eGaRP), using V2V communication for efficient content retrieval. A vehicle request content by sending a message in the network including its MAC addresses and geographical coordinates. Vehicles are equipped with directional antennas to send messages to particular directions. Therefore, vehicles that are outside of the spreading area of a message will not have increased unnecessary communication traffic and will be able to perform other tasks. Moreover, we make each vehicle responsible to satisfy expired requests by re-transmitting the requests after a particular time period.

[Manzo et al., 2019a] models Floating Content in the urban scenario of several European cities. [Manzo et al., 2019a] parametrizes FC in the vehicular environment, through a variation of the random waypoint mobility model, without requiring the specific geometry of the road grid. Numerical evaluations show the good accordance between the model in [Manzo et al., 2019a] and simulations driven by realistic measurement-based mobility parameters. To overcome the limitation of an analytical approach such as vehicles density uniform distributed, we design a deep learning system, which minimizes the overall use of bandwidth, user storage space, and infrastructure support over time [Manzo et al., 2019b].

Research staff: E.Kalogeiton, G. Manzo, T. Braun.

Financial support: Swiss National Science Foundation Project No. 146376

Intelligent Transportations Systems (ITS)

ITSs 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 mobility and public safety.

To improve 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 the fastest route to each vehicle. We study data dissemination protocols and networking approaches to report the traffic information properly [Souza et al., 2018a], and routing algorithms in graphs to improve the vehicular traffic mobility [Souza et al., 2018b]. 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 alternatives routes to avoid dangerous neighborhoods and risky areas while dealing with mobility issues. We use machine learning techniques such as recurrent neural networks (RNN) and reinforcement learning techniques for estimating and forecasting risky areas, and optimization techniques for multi-objective routing algorithms. Forecasting future safety dynamics enables a safer and more reliable route recommendation since it provides knowledge about dangerous areas in advance to the re-routing algorithm.

Recent results have shown substantial improvements concerning traffic mobility and public safety compared to State-of-The-Art approaches. Moreover, the prediction results have shown that RNN is suitable for predicting criminal density since it outperformed the predictions provided by other literature approaches.

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

Software Defined Networking for Wireless Sensor Networks

Recent developments in electronics led to a higher functional diversity between Wireless Sensor Nodes. While some sensors focus on increasing performance, others focus on reducing power consumption. The latter can be identified as a trend towards battery less sensor nodes. The integration of such sensors into a WSN network, to guarantee their interoperability and security are challenging tasks and SDN is a promising approach to solve it. In order to be able to do research in this field, we have integrated

the SDN-Wise framework into our IoT testbed and built SDN Wisebed a Wireless Sensor Network Testbed. This SDN-based WSN consists of a controller (in a VM), a border router and 40 TelosB sensor nodes, which enables rapid prototyping of SDN based WSN applications.

We have built DTARP: A Dynamic Traffic Aware Routing Protocol for Wireless Sensor Networks on top of this SDN based WSN [Schärer et al., 2018]. DTARP uses the traffic statistics that are collected by the SDN-Controller to distribute the traffic through the sensor network and therefore, prolong the overall network lifetime of battery driven nodes. Furthermore, we have integrated SDN-Wise Anti-Attack, a Security Framework that uses SDN information gathered by the controller in combination with unsupervised machine learning to detect and prevent attacks in the WSN.

Research staff: J. Schärer, Z. Zhao, T. Braun.

Scheduling Scientific Workflows on Clouds under a Task Replication Approach

By renting pay-as-you-go cloud resources (e.g., virtual machines) to do science, the data transfers required during the execution of data-intensive scientific workflows may be remarkably costly not only regarding the workflow execution time (makespan) but also regarding money (to lease the VMs). As such transfers are prone to delays, they may jeopardise the makespan, stretch the period of resource rentals and, as a result, compromise budgets. To tackle this issue, we explore the possibility of trading some communication time for computation time during the scheduling production, aiming to schedule a workflow by replication some computation of its tasks on which other dependent-tasks critically depend upon to lessen communication among them. This work explored this premise by enhancing the Heterogeneous Earliest Finish Time (HEFT) algorithm and the Lookahead variant of HEFT. The proposed replication approach is evaluated using simulation and synthetic data from four real-world scientific workflow applications. Our proposal [Genev et al., 2018], which is based on task replication, can effectively reduce the size of data transfers, which, in turn, contributes to shortening the rental duration of the resources, in addition to minimising network traffic within the network of the cloud provider. This work is an outcome of the researcher's PhD thesis that was carried during the researcher's postdoctoral at CDS under the Swiss Government Excellence Scholarship for Foreign Scholars and Artists for the 2017-18 Academic Year.

Research staff: T. A. Lopes Genez, T. Braun

Financial support: Swiss Government Excellence Scholarship
(#2017.0681)

Testbeds

The CDS group possesses and operates a cloud infrastructure based on Dell Power Edge Servers. Currently on the institute we own four DELL machines: R320, R520 and two R530. These support 164 parallel threads (82 cores) and 640 GB RAM. Furthermore, we operate two external Dell PowerVault md3800i that provide us 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. Together with the Lightweight Directory Access Protocol (LDAP) of the institute our infrastructure provides in the members of the CDS group the following services:

- Mirantis OpenStack 8.0 (IaaS research cloud)
- OwnCloud (shared storage between the CDS members)
- Wiki (information dissemination for the Institute and the CDS group)
- Etherpad (collaborative real-time editor)
- SVN (collaborative version management system)

For administrator purposes we use

- Teampass as a password management system

Finally for monitoring our infrastructure we use

- Nagios

The CDS group has its own IoT testbed that consists of:

- 40 MEMSIC Telsob by Crossbow (now Willow) sensors consisting of:
 - 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 consisting of:
 - Texas Instruments 16 bit microprocessor (TI MSP 430)
 - CC1020 radio interface
 - Temperature, humidity and acceleration sensor
 - SD memory interface

Hence, the CDS group built and operates a CDS testbed that consists of 47 nodes. These nodes are placed across the 4 floors of one building of the Institute of Computer Science of the University of Bern. The 7 MSB430 sensor nodes are placed indoors and one node is an outdoor node placed on a top window sill.

4.4 Master's Theses

- Severin Zumbrunn "SDN-Wise Anti-Attack - an SDN Framework for Securing IoT Networks using Machine Learning", January, 2019. URL: <http://tiny.cc/qi20az>

4.5 Bachelor's Theses

- Stefan Serena "Cloud-Based Indoor Positioning – ESP32 Client", September, 2018. URL: <http://tiny.cc/e040az>
- Lucien Madl "Attitude Heading Reference System and Step Recognition for Cloud-Based Indoor Positioning – Android Client", September, 2018. URL: <http://tiny.cc/l040az>
- Gerber Florian "Capturing Complex Behavior of Mobile Users for Predicting Next Trajectories", November, 2018. URL: <http://tiny.cc/m740az>
- Patrick Hodel "Cloud-based indoor Positioning – Bluetooth client and particle Filter", January, 2019. URL: <http://tiny.cc/q440az>
- Mischa Wenger "Indoor positioning using Raspberry Pi with UWB", January, 2019. URL: <http://tiny.cc/6440az>
- Antonio Tuor "Filtering and Smoothing Techniques for Compensating Public Transport GPS tracks", January, 2019. URL: <http://tiny.cc/q540az>

- Domenico Iapello "A geographical aware Routing Protocol in NDN-VANET", July, 2019. URL: <http://tiny.cc/6540az>

4.6 Awards

- GI-KuVS Award Bachelorarbeiten for "Video Delivery with Multi-Access Edge Computing", by Remo Roethlisberger

4.7 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

- General chair, IEEE Wireless On-demand Network Systems and Services Conference, Wengen, Switzerland. January 22-24, 2019
- ICC Workshop on 5G and Cooperative Autonomous Driving, Shanghai, China, May 20-24, 2019
- Wired/Wireless Internet Communications 2019, Steering committee, Bologna, Italy, June 17-18, 2019
- Summer School, Hasliberg, Switzerland, August 15-17, 2018

Public events organization

- **Study Week on Fascinating Informatics:** At this event, Jakob Schärer and Zhongliang Zhao taught three high school students how to program in Arduino embedded systems and they implemented an indoor localization application. Further details are available at: <https://sjf.ch/review-studienwoche-fascinating-informatics/>

Conference Program Committees

Torsten Braun

- 1st International Workshop on Urban Computing(UrbCom 2019), Santorini Island, Greece. May 29, 2019.
- 18th International Conference on Next Generation Wired/Wireless Advanced Networks and Systems (NEW2AN 2018), St. Petersburg, Russia, August 29-31, 2018.

- 10th ICT Innovations Conference 2018, Ohrid, Macedonia, September 17-19, 2018.
- 43rd IEEE Local Computer Networks Conference (LCN 2018), Chicago, October 1-4, 2018.
- 15th IEEE International Conference on Mobile Ad Hoc and Sensor Systems (MASS 2018), October 9-12, Chengdu, China.
- 10th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT 2018), Moscow, Russia, November 14, 2018.
- 21st ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2018), Montreal, Canada, October 28 - November 2, 2018.
- IEEE Global Communications Conference (GLOBECOM 2018), Abu Dhabi, December 9-13, 2018.
- 16th IEEE Consumer Communications and Networking Conference (CCNC 2019), Las Vegas, USA, January 11-14, 2019.
- IEEE/ACM International Symposium on Quality of Service (IWQoS 2019), Phoenix, Arizona, USA, June 22-28, 2018.
- 9th International Workshop on Wireless Networking and Control for Unmanned Autonomous Vehicles (Wi-UAV 2018), Abu Dhabi United Arab Emirates, December 9, 2018
- The Conference on Networked Systems (NetSys 2019), Munich, Germany, March 18-21, 2019.
- 11th IFIP Wireless and Mobile Networking Conference (WMNC 2018), Prague, Czech Republic, September 3-5, 2018.
- 2nd Workshop on Advances in Slicing for Softwarized Infrastructures (S4SI), Paris, France, June 22-24, 2019.
- International Workshop on the Recursive InterNetwork Architecture (RINA 2019), Paris, France, February 18-21, 2019.
- IEEE WoWMoM Workshop on the Internet of Things: Smart Objects and Services, Washington DC, USA, June 10, 2019.

- IEEE/ACM International Conference on Utility and Cloud Computing, Zurich, Switzerland, December 17-20, 2018.
- AdHoc-Now 2018, Saint Malo, France, September 5-7, 2018.

Project and Person Reviewing Activities

Torsten Braun

- Research Council of Norway
- Agency for Innovation and Entrepreneurship, Belgium
- European Science Foundation
- Swiss National Science Foundation
- Universität Magdeburg
- Christian Doppler Forschungsgesellschaft
- Deutsche Forschungsgemeinschaft
- Italian Ministry for Education, University and Research
- Australian Research Council

Journal Article Reviewing Activities

Torsten Braun

- Springer Informatik Spektrum
- Elsevier Computer Communications
- Elsevier Future Generation Computer Systems
- Elsevier Computer Networks
- IEEE Access
- IEEE Intelligent Transport Systems
- Wiley Transactions on Emerging Telecommunications Technologies
- IEEE Transactions on Network and Service Management

Talks and Tutorials

Torsten Braun

- Keynote talk: "Softwarization Issues for 5G", ICUMT 2018, Moscow, Russia, November 5, 2018.
- Keynote talk: "Title: Autonomic Communications in Software-Driven Networks", 10th Latin America Networking Conference, Sao Paulo, Brazil, October 3, 2018.
- Keynote talk: "Mobile Edge Computing in IoT and Mobile Network Scenarios", SWITCH Network and Security Working Group Meeting, Morschach, June 5, 2019.
- Panel talk: "Mobile Edge Computing in Vehicular Networks", ICC 2019 2nd International Workshop on 5G and Cooperative Autonomous Driving, Shanghai, China, May 24, 2019.
- Invited talk: "Caching and Computing in Mobile Edge Networks", Jilin University, Changchun, China, October 25, 2018.
- Invited talk: "Mobile Edge Computing and Caching", Universidade de Coimbra, Portugal, March 15, 2019.

PhD Committee Memberships

Torsten Braun

- Eng Aly Maher (PhD Jury), German University of Cairo, June 23, 2019

4.8 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

- Souza, A.M. and Maia, Guilherme and Braun, Torsten and Villas, Leandro A. (2018a). VIVO: An Interest-Based Approach for Reducing Network Contentions in Vehicular Transportation Systems. *Sensors*. DOI:10.3390/s19102325, May 2019.
- Carrera, J.L. and Zhao, Z. and Braun, T. and Li, Z. (2019a). *A Particle Filter-based Reinforcement Learning Approach for Reliable Wireless Indoor Positioning (Accepted for publication)*. IEEE JSAC Issue on Machine Learning in Wireless Communications, June 2019.
- Manzo, G. and Otalora, J.S. and Marsan, M.A. and Rizzo, G. (2019b). *A Deep Learning Strategy for Vehicular Floating Content Management*. ACM SIGMETRICS Performance Evaluation Review, December 2018.
- Manzo, G. and Marsan, M.A. and Rizzo, G. (2019a). *Analytical Models of Floating Content in a Vehicular Urban Environment*. Ad Hoc Networks, May 2019.
- Luceri, L., Braun, T., Giordano, S. (2019a). Analyzing and Inferring Human Real-life Behavior Through Online Social Networks with Social Influence Deep Learning. *Applied Network Science*, vol. 4, no. 34. DOI: doi.org/10.1007/s41109-019-0134-3, June 2019.
- Shao, W., Luo, H., Zhao, F., Ma, Y., Zhao, Z. (2019). Indoor Positioning Based on Fingerprint-Image and Deep Learning. *IEEE Access*. DOI:10.1109/ACCESS.2018.2884193, November 2018.
- Li, Z., Zhao, X., Hu, F., Zhao, Z., Carrera, J., Braun, T. (2019). SoICP: A Seamless Outdoor-Indoor Crowdsensing Positioning System. *IEEE Internet of Things Journal*. DOI:10.1109/JIOT.2019.2921561, June 2019.
- Zhao, Z., Carrera, J., Braun, T., Pan, Z. (2019). Conditional Probability-based Ensemble Learning for Indoor Landmark Localization. *Elsevier Journal of Computer Communications*. DOI:10.1016/j.comcom.2019.07.007, June 2019.
- Duarte, J.M. and Braun, T. and Villas, L.A. (2019). Mo-biVNDN: A Distributed Framework to Support Mobility in Vehicular Named-Data Networking. *Elsevier Journal of Ad hoc Networks*. DOI:10.1016/j.adhoc.2018.08.008, January 2019.

Conference Papers

- Souza, A.M., Braun, T., Villas, L.A. (2018b). 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.
- Carrera, J.L., Zhao, Z., Wenger, M., Braun, T. (2019b). *Mec-based UWB Indoor Tracking System.*, IEEE/IFIP Wireless On-demand Network systems and Services Conference (WONS 2019), Wengen, Switzerland, January 22-24 2019.
- Gasparyan, M., Marandi, A., Schiller, E., Braun, T. (2019a). *Fault-Tolerant Session Support for Service-Centric Networking*, 2019 IFIP/IEEE Symposium on Integrated Network and Service Management (IM), Washington DC, USA, April 8-12 2019.
- Karimzadeh, M., Gerber, F., Zhao, Z., Braun, T. (2019a). *Pedestrians Trajectory Prediction in Urban Environments*, 2019 International Conference on Networked Systems (NetSys), Munich, Germany, March 18-21 2019.
- Genez, T.A., Sakellariou, R., Bittencourt, L. F., Madeira, E. R., Braun, T. (2018). *Scheduling Scientific Workflows on Clouds Using a Task Duplication Approach*, IEEE/ACM 11th International Conference on Utility and Cloud Computing (UCC), December 17-20 2018.
- Schärer, J., Zhao, Z., Braun, T. (2018). *DTARP: A Dynamic Traffic Aware Routing Protocol for Wireless Sensor Networks*, Proceedings of the 7th International Workshop on Real-World Embedded Wireless Systems and Networks (RealWSN), Shenzhen, China, November 4th 2018.
- Luceri, L., Deb, A., Badawy, A., Ferrara, E. (2019c). Red Bots Do It Better: Comparative Analysis of Social Bot Partisan Behavior. In *WWW '19 Companion Proceedings of The 2019 World Wide Web Conference*, an Francisco, USA, May 13-17 2019.
- 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.

- Li, Z., Zhao, X., Zhao, Z., Hu, F., Liang, H., Braun, T. (2018b). Crowd-sensing Indoor Walking Paths with Massive Noisy Crowdsourcing User Traces. In *IEEE Global Communications Conference (GLOBECOM)*, Abu Dhabi, UAE, December 9-13 2018.
- Souza, A.M., Braun, T., Villas, L.A. (2018b). 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.
- Karimzadeh, M., Zhao, Z., Gerber, F., Braun, T. (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, October 15-17 2018.
- 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, October 1-4 2018.
- 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, October 1-4, 2018.
- 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.
- 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.
- Schiller, E., Röthlisberger, R., Braun, T., Karimzadeh, M. (2019a). Improving Video Delivery with Fourier Analysis of Traffic in Multi-Access Edge Computing. In *17th International Conference on*

Wired/Wireless Internet Communications (WWIC), Bologna, Italy, June 17-19 2019.

- Deb, A., Luceri, L., Badawy, A., Ferrara, E. (2019a). Perils and Challenges of Social Media and Election Manipulation Analysis: The 2018 US Midterms. In *WWW '19 Companion. Proceedings of The 2019 World Wide Web Conference*, New York, USA, May 17 2019.

5 Computer Graphics Group

5.1 Personnel

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5.2 Overview

The research activities of the Computer Graphics Group are mainly located in the area of *geometry processing*, which is one of the central topics of *computer graphics*. Geometry processing is concerned with the development of concepts and algorithms to represent, generate, analyze, and modify the shape of objects. Resulting from the physical space we live in, omnipresent classes of shapes include curves, surfaces and volumetric bodies embedded in 3D, or 4D for time-varying shapes. Nowadays, such geometric objects are fundamental in numerous disciplines, inducing a strong scientific impact of geometry processing far beyond computer graphics. Applications as for instance numerical simulation in engineering or computational geology, anomaly detection or surgery planning in medicine, shape matching in computational biology, or the design of smart materials in additive manufacturing (e.g. 3D printing) only become feasible if accurate geometric representations of the involved shapes are available.

Currently, the group focuses on the generation of discrete geometry representations in the form of semi-structured meshes with quadrilateral elements for surfaces and hexahedral elements for volumetric objects. Such meshes combine the advantages of unstructured simplicial meshes and fully structured Cartesian grids. In contrast to previous methods, e.g. based on local operations, we focus on (global) variational formulations

that enable a superior structure of the resulting meshes. There is empirical evidence that following this approach, for the first time algorithms are able to generate meshes that are comparable to manually designed ones. The variational formulation leads to involved nonlinear mixed-integer optimization problems. Hence, one goal of our research is the design of better formulations and parametrizations of the problem that pave the way for efficient solution strategies. In general, our research is driven by the idea of successively addressing the fundamental research questions that are critical from the practitioners perspective, and eventually come up with practically relevant meshing solutions.

5.3 Research Projects

Hexahedral Meshing for Computational Engineering Science

Hexahedral meshing has been a hot research topic in the past decades due to its wide use in computational applications. It is well known that hexahedral meshes have great advantages over tetrahedral meshes in simulation, e.g. better efficiency and higher precision. Despite high practical demand and superior properties, algorithmic hexahedral meshing with guarantees on robustness and quality remains unsolved. A promising direction follows the idea of integer-grid maps, which pull back the Cartesian hexahedral grid formed by integer iso-planes from a parametric domain to a surface-conforming hexahedral mesh of the input object. Since directly optimizing for a high-quality integer-grid map is mathematically challenging, the construction is usually split into two steps: (1) generation of a surface-aligned octahedral field and (2) generation of an integer-grid map that best aligns to the octahedral field. The main robustness issue stems from the fact that smooth octahedral fields generated with the state-of-the-art methods frequently exhibit singularity graphs that are not appropriate for hexahedral meshing that induce heavily degenerate integer-grid maps. The problem boils down to singularity graph correction of initial octahedral field and reconstruction of the hex-meshable octahedral field with prescribed singularity graph. Currently, we have analyzed all local configurations that exist in hexahedral meshes with bounded edge valence, leading to necessary conditions for the hex-meshability of an octahedral field in terms of its singularity graph. Moreover, we have developed a novel algorithm to generate smooth octahedral field with fixed topology, which efficiently

solves a large non-linear mixed-integer algebraic system. Next, we will focus on fundamental research on the global configurations of singularity graph that admits to a hex-meshable octahedral field. With sufficient conditions, we will propose an automatic algorithm to correct the singularity graph of the initial octahedral field. At the end of the Ph.D. project, we target a robust high-quality hexahedral mesh generation pipeline with both theoretical guarantee and practical implementation.

Research staff: Heng Liu, David Bommes

Scale-aware Geometric Feature Curve Networks

A *feature curve network* (FCN) for a surface is a set of salient points and curves tracing the surface's shape. FCNs can be seen as an abstraction of complex geometric shapes to a simplified representation that only keeps information about the most prominent ridges, valleys and corners. FCNs have applications in many areas, such as segmentation, feature-preserving decimation and smoothing, non-photorealistic rendering, or patch layout generation. Most of these tasks require the FCN detection on early stage raw data that might contain noise, outliers or even unclear topology. Moreover it should be noted that the definition of a FCN is inherently scale dependent. A part that appears to be a sharp crease when viewed from far away might turn out to be very smooth when zoomed in. On the contrary, the sampling of a smooth surface might contain a very complex FCN on the finest scale due to high-frequency noise. In this sense, a single model usually has many different FCNs depending on the investigated scale.

Motivated by these two observations, our primary goal is to develop a feature curve network detection algorithm that is

1. scale aware
2. robust to all kind of defects in raw data (noise, outliers, inconsistent topology etc.)
3. able to operate on various types of raw data (point clouds, triangle soups, polygonal meshes, etc.)
4. provides user-control on desired structure (simplicity, number of branch points, user constraints, etc.)

The overall problem can be naturally split into two main stages: (i) A local analysis that estimates the feature probability of each surface point based on a neighborhood of the intended scale and (ii) a global consolidation of the FCN that is able to correct inconsistencies caused by defects in the raw data.

The local analysis has been intensively investigated throughout the Master thesis project of Martin Heistermann.

The goal of this project is to further extend the state of the art in FCN analysis. This involves the development of global consolidation methods to complement the aforementioned local analysis algorithm as well the investigation of broader problem definitions, such as multi-scale analysis, approximation optimal reconstruction and generalizations to different data sources.

Research staff: Martin Heistermann, David Bommes

Quad Mesh Generation for Computer Graphics and Simulation

Quad meshes are discrete surface representations with attractive properties for computer graphics and simulation applications, such as curvature alignment and subdivision surfaces. Quad meshes can be modeled as graphs with its vertices representing geometrical positions as points on the surface, edges representing local connectivity, linking neighboring points and faces being the smallest cycles formed by edges being exclusively quadrilaterals. Every regular vertex has four adjacent vertices and faces. Because of topological reasons, to quadrangulate an arbitrary domain, one needs to have irregular vertices, that have more or less than four incident faces, such points are called singularities. The quadrangulation problem is a mathematically challenging problem, for which there is no unique solution in general. Along the problem of choosing how many singular vertices are needed and where to place them boils to a mixed-integer optimization problem of large dimensionality that has been tackled in previous works with greedy-algorithms. Triangle meshes, on the other hand, are easier to generate and work with, but lack of the tensor product property that makes quad meshes attractive for many applications. Often the inputs for quad meshing algorithms are high-quality triangle-meshes. This project focuses on the following step: converting a triangle mesh into a

high-quality quad mesh. We aim at providing end-users with robust methods that are fast, scalable, and deliver good quality meshes according to the application requirements.

Producing an as isotropic as possible quadrangulation is a well-understood problem by now, while there are many open questions on how to optimize with constraints on anisotropy, and the non-orthogonal intersection of feature curves, as it is often the case in the design of mechanical parts. Also, certain applications would benefit from some control on the number of singular vertices and its positions, an issue still not addressed sufficiently by the state of the art.

Our focus of this project is the design of integrable frame fields that are meshable with low alignment error. We have decided to work on the frame-field based approach because it allows the most flexible setting to consider user constraints. One of the missing components of this approach is optimization for integrability of the frame-fields, such that there is a parameterization with iso-lines aligned to the field and a quad mesh whose edges will align closely to the design frame field everywhere. In this project, we develop formulations to optimize for such criteria and have achieved a good understanding of the state of the art methods and its limitations.

Research staff: Nicolas Gallego-Ortiz, David Bommes

5.4 Further Activities

Invited Talks

David Bommes

- “Integer-Grid Maps for Hexahedral Mesh Generation”. FRAMES 2019, Universite Catholique de Louvain, Belgium, July 2019.
- “Quadrilateral and Hexahedral Mesh Generation”. Colloquium, EPFL Lausanne, Switzerland, April 2019.
- “Quadrilateral and Hexahedral Mesh Generation”. Colloquium, Institute of Mathematical Statistics and Actuarial Science, University of Bern, Switzerland, March 2019.
- “Quadrilateral and Hexahedral Mesh Generation”. Mathematics Colloquium, University of Bern, Switzerland, November 2018.

Editorial Boards

David Bommes

- Computer Graphics Forum (CGF) Journal, Associate Editor
- Graphical Models (GMOD) Journal, Associate Editor
- Computers & Graphics, Associate Editor

Conference Organization

David Bommes

- Eurographics Symposium on Geometry Processing (SGP) 2019, Program Co-Chair, July 6 – 10, 2015, Milan, Italy

Conference Program Committees

David Bommes

- ACM SIGGRAPH, July 28 – August 1, Los Angeles, USA
- EUROGRAPHICS (EG), May 6–10, Genova, Italy
- Graphics Interface (GI), May 28–31, Kingston, Canada
- Geometric Modeling and Processing (GMP), June 19–21, Vancouver, Canada
- Vision, Modeling and Visualization (VMV), September 30 – October 2, Rostock, Germany
- CAD/Graphics, May 5–6, Qingdao, China

Reviewing Activities

David Bommes

- ACM Transactions on Graphics
- Computers & Graphics, An International Journal of Systems & Applications in Computer Graphics, Elsevier
- ACM SIGGRAPH Asia conference
- International Meshing Roundtable conference

5.5 Publications

Journal Publications

- Max Lyon, Marcel Campen, David Bommes, Leif Kobbelt: Parametrization quantization with free boundaries for trimmed quad meshing, *ACM Transactions on Graphics*, Volume 38(4), (Proc. ACM SIGGRAPH), 2019.
- Gianmarco Cherchi, Pierre Alliez, Riccardo Scateni, Max Lyon, David Bommes: Selective Padding for Polycube-Based Hexahedral Meshing, *Computer Graphics Forum*, Volume 38(1), (Presented at EUROGRAPHICS), 2019.
- Heng Liu, Paul Zhang, Edward Chien, Justin Solomon, David Bommes: Singularity-Constrained Octahedral Fields for Hexahedral Meshing, *ACM Transactions on Graphics*, Volume 37(4), (Presented at ACM SIGGRAPH), 2018.

6 Computer Vision Group

6.1 Personnel

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6.2 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 quan-

tities 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?

6.3 Research Projects

Learning to Extract Flawless Slow Motion from Blurry Videos

We introduce the task of generating a sharp slow-motion video given a low frame rate blurry video. We propose a data-driven approach, where the training data is captured with a high frame rate camera and blurry images are simulated through an averaging process. While it is possible to train

a neural network to recover the sharp frames from their average, there is no guarantee of the temporal smoothness for the formed video, as the frames are estimated independently. To address the temporal smoothness requirement we propose a system with two networks: One, DeblurNet, to predict sharp keyframes and the second, InterpNet, to predict intermediate frames between the generated keyframes. A smooth transition is ensured by interpolating between consecutive keyframes using InterpNet. Moreover, the proposed scheme enables further increase in frame rate without retraining the network, by applying InterpNet recursively between pairs of sharp frames. We evaluate the proposed method on several datasets, including a novel dataset captured with a Sony RX V camera. We also demonstrate its performance of increasing the frame rate up to 20 times on real blurry videos.

Research staff: Meiguang Jin, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 153324

Video Prediction from a Single Frame and Motion Stroke

We present a method to generate a video sequence given a single image. Because items in an image can be animated in arbitrarily many different ways, we introduce as control signal a motion stroke. Such control signal can be provided by a user as a 2D sketch superimposed to the input image, but can also be automatically transferred from other videos (eg. via bounding box tracking). The motion stroke provides the *directions* to the character in the input image and we aim to train a network to generate an animation following such directions. To address this task we design a novel recurrent architecture, which can be trained easily and effectively thanks to an explicit separation of past, future and current states. As we demonstrate in the experiments our proposed architecture is capable, for the first time, of generating an arbitrary number of frames from a single image and a motion stroke. Important ingredients in our architecture are an autoencoding constraint to ensure that images are consistent with the past and a generative adversarial scheme to ensure that images look realistic and are temporally smooth. We demonstrate the effectiveness of our approach on the MNIST, KTH, Human 3.6M and Weizmann datasets.

Research staff: Qiyang Hu, Adrian Wälchli, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 156253

Unsupervised 3D shape learning

We studied monocular 3D reconstruction. The goal was to train a neural network that reproduced the 3D shape and viewpoint of an object from a single image in an unsupervised way. During the training no additional notations (key-points, segmentation mask, stereo etc.) were exploited. This is the first time this problem has been solved for real images. We trained a generative model that produces plausible 3D shapes and an autoencoder that estimates the inputs to the generative model. We formally proved that our approach solves the unsupervised 3D shape learning task under mild assumptions.

Research staff: Attila Szabó, 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

Face Super-Resolution

We developed a novel method to perform extreme (16x) face super-resolution by exploiting audio. Super-resolution is the task of recovering

a high-resolution image from a low-resolution one. When the resolution of the input image is too low (e.g., 8x8 pixels), the loss of information is so dire that the details of the original identity have been lost. However, when the low-resolution image is extracted from a video, the audio track is also available. Because the audio carries information about the face identity, we propose to exploit it in the face reconstruction process. Towards this goal, we propose a model and a training procedure to extract information about the identity of a person from her audio track and to combine it with the information extracted from the low-resolution input image, which relates more to pose and colors of the face. We demonstrate that the combination of these two inputs yields high-resolution images that better capture the correct identity of the face. In particular, we show that audio can assist in recovering attributes such as the gender and the identity, and thus improve the correctness of the image reconstruction process. Our procedure does not make use of human annotation and thus can be easily trained with existing video datasets. Moreover, we show that our model allows one to mix low-resolution images and audio from different videos and to generate realistic faces with semantically meaningful combinations.

Research staff: Givi Meishvili, Simon Jenni, Paolo Favaro

Financial support: Swiss National Science Foundation Project No. 165845

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

Unsupervised 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. The most fundamental pretext task is the task of autoencoding data, i.e., data x is encoded via some encoder E and then decoded via a decoder D . The task is then to faithfully reconstruct the training data. To prevent the trivial identity solution and to learn useful features in the encoder some constraints have to be introduced on the encoding $E(x)$. We explore novel types of constraints on the encoding space. Our proposed autoencoder architecture generates representations $E(x)$ that by design encode image features at different scales. This encourages a disentanglement of factors of variation into more global attributes (e.g., shape and viewpoint) and more local attributes (e.g., shading and textures). To further encourage such disentanglement, we propose to mix features of two images at randomly selected scales during training. The realism of reconstructions from mixed features is achieved through adversarial training. Preliminary results show that such autoencoders learn features with competitive performance when transferred to the task of image classification.

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

Self-supervised Learning of Optical Flow

Optical Flow, the problem of recovering a vector field that describes the motion in every pixel from one image to the next, as for example in a video, is one of the oldest problems in Computer Vision. Applications of Optical Flow can be found in almost any system that deals with motion, e.g., in video compression, video frame interpolation (high frame rate), motion segmentation, 3D reconstruction and more. To this date researchers are trying to develop methods that estimate Optical Flow faster, with greater accuracy or with more robustness to ambiguities. One major challenge that the prior work tries to address is the estimation of Optical Flow in regions with ambiguity, e.g., regions that are being occluded, disoccluded or have little to no texture. We believe that with a data-driven approach we can overcome the limitations of prior works and learn to handle the aforementioned challenges. Since Optical Flow does not naturally emerge as annotation from real datasets, and synthetically generated videos/flows

limit the generalization to real data, we must strive towards an unsupervised approach, i.e., we do not rely on labelled data. In this project, we investigate several possible generalizations of Optical Flow that naturally handle occlusions and have subpixel accuracy. The approach is self-supervised, hence the only training data are frames from high frame rate video recordings and no other annotation is needed.

Research staff: Adrian Wälchli, Paolo Favaro

iEEG Analysis

The goal of this research project is to develop a new framework for online analysis of iEEG recordings by leveraging the recent advances in deep learning. The project focuses on two main axis: brain activity staging and generative model of brain activity. Over the last few years, deep learning based algorithms have become the state of the art in various pattern recognition tasks such as image classification and object detection. By training these models to detect various brain states (e.g. seizure onset, sleep stages, etc), we can automate the data labeling process. In an offline setting, this would allow to scale up data-driven analysis of various brain states by using automatic pseudo-labels instead of expensive manual annotations. Furthermore, accurate detection algorithms are the cornerstone of any closed-loop modulation system where the goal is to phase-lock the triggering of an external stimulus to a specific brain activity pattern in order to study its effects. The aim is also to achieve a better understanding of brain dynamics by defining brain states through a more data driven approach. We also aim to leverage the recent advances in deep generative models such as Generative Adversarial Networks and Auto Regressive models like Wavenet. Scaling up the number of patients in a medical study can be very expensive in terms of resources and work hours or almost impossible for rare diseases for example, so by building a generative model for brain activity, we can scale the size of considered datasets by incorporating synthetic recordings. These generative models could also be extended to model the full closed-loop system by simulating both the brain activity and the effect of various external stimuli. For instance, in order to build a controller model that predicts when to apply the stimulus in order to obtain the most beneficial effect, we would need an exhaustive experimental study that is in most cases not feasible due to the prohibitive cost and/or ethical considerations. Instead, given a simulation of the closed-loop system, it is possible to train a controller model such as the one described

previously in a data efficient manner.

Research staff: Abdelhak Lemkhenter, Paolo Favaro

Financial support: Computational Platform Project No. 38-817. This research is supported by the Interfaculty Research Cooperation “Decoding Sleep from Neurons to Health & Mind” of the University of Bern.

Unsupervised image segmentation

We introduce a novel framework to build a model that can learn how to segment objects from a collection of images without any human annotation. Our method builds on the observation that the location of object segments can be perturbed locally relative to a given background without affecting the realism of a scene. Our approach is to first train a generative model of a layered scene. The layered representation consists of a background image, a foreground image and the mask of the foreground. A composite image is then obtained by overlaying the masked foreground image onto the background. The generative model is trained in an adversarial fashion against a discriminator, which forces the generative model to produce realistic composite images. To force the generator to learn a representation where the foreground layer corresponds to an object, we perturb the output of the generative model by introducing a random shift of both the foreground image and mask relative to the background. Because the generator is unaware of the shift before computing its output, it must produce layered representations that are realistic for any such random perturbation. Finally, we learn to segment an image by defining an autoencoder consisting of an encoder, which we train, and the pre-trained generator as the decoder, which we freeze. The encoder maps an image to a feature vector, which is fed as input to the generator to give a composite image matching the original input image. Because the generator outputs an explicit layered representation of the scene, the encoder learns to detect and segment objects. We demonstrate this framework on real images of several object categories.

Research staff: Adam Bielski, Paolo Favaro

6.4 Ph.D. Theses

- Attila Szabó, “Learning Interpretable Representations of Images”, June 2019.
- Qiyang Hu, “Learning Controllable Representations for Image Synthesis”, June 2019.
- Mehdi Noroozi, “Beyond Supervised Representation Learning”, January 2019.
- Meiguang Jin, “Motion Deblurring from a Single Image”, December 2018.

6.5 Master’s Theses

- Lukas Zbinden, “Learning Object Representations by Mixing Scenes”, May 2019.
- Markus Roth, “Representation Learning using Semantic Distances”, May 2019.
- Hamed Hemati, “Zero-Shot Learning using Generative Adversarial Networks”, December 2018.
- Ioannis Glampedakis, “Dimensionality Reduction via CNNs - Learning the Distance between Images”, September 2018.
- Thomas Steinmann, “Learning to Play Othello using Deep Reinforcement Learning and Self Play”, September 2018.

6.6 Bachelor’s Theses

- Alvaro Lahiguera, “Motion deblurring in the wild replication and improvements”, January 2019.
- Stefan Jonas, “Coma Outcome Prediction with Convolutional Neural Networks”, October 2018.
- Sven Kellenberger, “Automatic Correction of Self-Introduced Errors in Source Code”, August 2018.

6.7 Further Activities

Ph.D. Thesis Examiner

Paolo Favaro

- “Visual Recognition From Weakly Structured Supervision”, Rodrigo Fonseca Santa Cruz Oliveira, Australian National University, 2019.
- “Self-Supervised Learning Using Motion and Visualizing Convolutional Neural Networks”, Aravindh Mahendran, University of Oxford, 2018.

Invited Talks

Paolo Favaro

- “Blind Deconvolution From Model-Based to Deep Learning”, NTIRE Workshop, CVPR 2019, Long Beach, California, USA, June 2019.
- “Towards Unsupervised Learning”, Department of Information Technology and Electrical Engineering, ETH-Zurich, May 2019.
- “An Introduction to Computational Models for Temporal Data”, BENESCO-Lecture Series, University of Bern, April 2019.
- “Computational Models for Light Field Imaging, Depth estimation and Super-resolution”, RealVision Workshop in Erlangen, Fraunhofer Institute, Germany, February 22, 2019.
- “Machine Learning and Deep Learning”, PlanetS Workshop on ML, Observatoire de Geneve, February 2019.
- “Blind Deconvolution: From Model-Based to Deep Learning”, International BASP Frontiers workshop, Villars-sur-Ollon, February 2019.
- “Towards Unsupervised Learning”, Department of Engineering Science, University of Oxford, November 23, 2018.
- “Representation Learning for Prediction and Data Generation”, IRC Symposium, Berner Schlaf-Wach-Tage, University of Bern, October 18, 2018.
- “Beyond Supervised Learning”, Department of Computer Science, University of Padova, September 28, 2018.

- “Computer Vision and Machine Learning”, FDN retreat, Bern, August 13, 2018.
- “Beyond Supervised Learning”, The Rank Prize Funds, Symposium on Geometry and Uncertainty in Deep Learning for Computer Vision, Grasmere, UK, August 2018.

Simon Jenni

- “Wie Computer sehen lernen”, Woche des Gehirns Bern, March 11, 2019.

Event Organization

Paolo Favaro

- International Conference on Machine Vision Applications, Tokyo, Japan, May 27th - 31st, 2019. (Program Chair)
- CUSO Winter School on Deep Learning, Lenk, Switzerland, January 21st - 25th, 2019.

Conference Program Committees

Paolo Favaro

- BMVC 2019
- GCPR 2019

Journal Committees

Paolo Favaro

- Associate Editor for IEEE Transactions on Pattern Analysis and Machine Intelligence 2019

Reviewing Activities

Paolo Favaro

- NeurIPS 2019
- ICCP 2019

Simon Jenni

- CVPR 2019
- ICCV 2019

6.8 Publications

Journal Publications

- G. G. Chrysos, P. Favaro and S. Zafeiriou, “Motion Deblurring of Faces”, *International Journal of Computer Vision*, 2018.

Refereed Conference Proceedings

- S. Jonas, A. Rossetti, M. Oddo, S. Jenni, P. Favaro and F. Zubler, “EEG-based Outcome Prediction after Cardiac Arrest with Convolutional Neural Networks: Performance and Visualization of Discriminative Features”, *Human Brain Mapping*, 2019.
- M. Jin, Z. Hu and P. Favaro, “Learning to Extract Flawless Slow Motion from Blurry Videos”, *IEEE International Conference on Computer Vision and Pattern Recognition (CVPR)*, 2019.
- S. Jenni and P. Favaro, “On Stabilizing Generative Adversarial Training with Noise”, *IEEE International Conference on Computer Vision and Pattern Recognition (CVPR)*, 2019.
- 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.

Technical Reports

- A. Bielski and P. Favaro, “Emergence of Object Segmentation in Perturbed Generative Models”, Under Review, NeurIPS 2019.
- G. Meishvili, S. Jenni and P. Favaro, “Learning to Have an Ear for Face Super-Resolution”, Under Review, NeurIPS 2019.
- Q. Hu, A. Wälchli, T. Portenier, M. Zwicker and P. Favaro, “Video Synthesis from a Single Image and Motion Stroke”, arXiv:1812.01874, Technical Report, 2018.
- A. Szabó and P. Favaro, “Unsupervised 3D Shape Learning from Image Collections in the Wild”, arXiv:1811.10519, Technical Report, 2018.

7 Cryptology and Data Security Group

7.1 Personnel

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7.2 Overview

The Cryptology and Data Security Group has been established in 2019 by Christian Cachin at the University of Bern. We broadly investigate security and privacy in a digital world. Our research addresses cryptographic protocols, distributed consistency, consensus, and cloud-computing security, with applications to blockchains, distributed ledger technology, cryptocurrencies, and their economics.

Security and privacy are at stake in the information society, threatened by the enormous developments in networks, cloud, and mobile. Information technology has already revolutionized many aspects today's life. Finding a balance between the practical convenience of being "always online", current business practices, the changing demands of society, and the privacy and security concerns of individual people represents one of the great open questions of our time. Cryptography and data security provide techniques to answer this question.

7.3 Research Projects

Blockchain and consensus protocols

A blockchain is a public ledger, maintained by many nodes without central authority using a distributed cryptographic protocol, for recording transactions. The nodes validate the information to be appended to the blockchain. A distributed consensus protocol tolerating faults and adversarial attacks ensures that the nodes agree on a unique order in which entries are appended. Cryptographic tools play an important role for consistency and privacy.

Based on earlier work on Byzantine-fault tolerant (BFT) consensus for distributing trust on the Internet, we are exploring consensus protocols and security mechanisms, and apply them to blockchain systems.

In particular, we are investigating protocols with *asymmetric trust*. This builds on the abstraction of quorum systems, which are a key abstraction in distributed fault-tolerant computing for capturing trust assumptions. They can be found at the core of many algorithms for implementing reliable broadcasts, shared memory, consensus and other problems. In this project, we formulate asymmetric Byzantine quorum systems that model subjective trust. Every process is free to choose which combinations of other processes it trusts and which ones it considers faulty. Asymmetric quorum systems strictly generalize standard Byzantine quorum systems, which have only one global trust assumption for all processes. This model paves the way for realizing more elaborate algorithms with asymmetric trust.

Distributed cryptography

The design of threshold cryptosystems and proactively secure protocols has received renewed attention in recent years thanks to the rise of cloud services, blockchain, and cryptocurrency technologies. The current focus is on solutions that work in real-world environments, in particular over realistic *asynchronous* networks. However, many of the works in the area of threshold cryptography assume synchronous networks with broadcast, thereby enabling solutions that can withstand up to half of the parties being corrupted. This is in contrast to the asynchronous setting, where one can only tolerate up to a third of the parties being corrupted. Our goal in this work is to develop protocols that work in a realistic asynchronous setting while at the same time enjoy some of the better resilience properties of synchronous schemes with broadcast.

In joint work with colleagues at IBM Research and Algorand Foundation, we have developed a new tunable asynchronous model for threshold and proactive security that separates between the liveness and security thresholds of a system. In particular, we allow for such thresholds to be tuned so that the threshold for correctness and security and privacy can be increased up to half, while possibly decreasing the liveness threshold.

We have developed solutions in this model for crucial functionalities in threshold cryptography, including asynchronous verifiable secret sharing (AVSS), distributed key generation (for discrete-logarithm based public-key cryptography), proactive refreshing of shares, and share recovery.

7.4 Further Activities

Invited Talks

Christian Cachin

- “Distributed trust – From Byzantine consensus to blockchain.” Cyber Security Summer School, Tartu, Estonia, July 2019.
- “Asymmetric distributed trust.” Crypto Valley Blockchain Conference, Zug, Switzerland, June 2019.
- “Asymmetric distributed trust.” Theory and Practice of Blockchains (TPBC19), Aarhus, Denmark, June 2019.
- “From Byzantine consensus to blockchain.” Colloquium, Institute of Mathematical Statistics and Actuarial Science, University of Bern, Switzerland, Apr. 2019.
- “Distributing trust with blockchains.” Cyber-Defence Campus Seminar, Armasuisse, Thun, Switzerland, Apr. 2019.
- “Distributing trust with blockchains.” Mathematics Colloquium, University of Bern, Switzerland, Apr. 2019.

Editorial Boards

Christian Cachin

- Associate editor for Distributed Computing, 2015–, Springer.

Societies and Steering Committees

Christian Cachin

- Member of Steering Committee for ACM Conference on Advances in Financial Technologies (AFT), 2019–.
- Member of Steering Committee for ACM Symposium on Principles of Distributed Computing (PODC), 2019–2022.
- President of the International Association for Cryptologic Research (IACR); 2014–2019.

Conference Organization

Christian Cachin

- Organizer of Swiss Crypto Day 2019, University of Bern, Bern, Switzerland.
- Tutorial Chair for 1st ACM Conference on Advances in Financial Technologies (AFT), Zurich, Switzerland.

Conference Program Committees

Christian Cachin

- Member of Program Committee for 26th ACM Conference on Computer and Communications Security (CCS 2019), London, UK.
- Member of Program Committee for 24th European Symposium on Research in Computer Security (ESORICS 2019), Luxembourg.
- Organizer of Swiss Crypto Day 2019, University of Bern, Bern, Switzerland.
- Member of Program Committee for 49th Intl. Conference on Dependable Systems and Networks (DSN 2019), Portland (OR), USA.
- Member of Program Committee for 14th European Conference on Computer Systems (EuroSys 2019), Dresden, Germany.

7.5 Publications

Preprints and Other Publications

- C. Cachin and B. Tackmann, “Asymmetric distributed trust.” e-print, arXiv:1906.09314 [cs.DC], 2019.
- C. Cachin, D. Collins, T. Crain, and V. Gramoli, “Byzantine fault tolerant vector consensus with anonymous proposals.” e-print, arXiv:1902.10010 [cs.DC], 2019.

8 Logic and Theory Group

8.1 Personnel

Head:	Prof. Dr. G. Jäger	Tel.: +41 (0)31 631 85 60 email: gerhard.jaeger@inf.unibe.ch (until January 2019)
	Prof. Dr. T. Strahm	Tel.: +41 (0)31 631 49 98 email: thomas.strahm@inf.unibe.ch
	Prof. Dr. T. Studer	Tel.: +41 (0)31 631 39 84 email: thomas.studer@inf.unibe.ch
Office Manager:	B. Choffat	Tel.: +41 (0)31 631 84 26 email: bettina.choffat@inf.unibe.ch
Scientific Staff:	M. Bärtschi*	Tel.: +41 (0)31 511 76 16 email: michael.baertschi@inf.unibe.ch (until May 2019)
	L. Jaun	Tel.: +41 (0)31 511 76 10 email: lukas.jaun@inf.unibe.ch (until January 2019)
	E. Lehmann*	Tel.: +41 (0)31 511 76 09 email: eveline.lehmann@inf.unibe.ch
	Dr. K. Sato*	Tel.: +41 (0)31 511 76 21 email: sato@inf.unibe.ch (until October 2018)
	N. Savić*	Tel.: +41 (0)31 511 76 08 email: nenad.savic@inf.unibe.ch
	Dr. S. Steila	Tel.: +41 (0)31 511 76 17 email: steila@inf.unibe.ch (until September 2018)
	J. Walker*	Tel.: +41 (0)31 511 76 32 email: walker@inf.unibe.ch

Guests:	M. Rathjen	University of Leeds December 2018
	K. Fujimoto	University of Bristol November 2018
	W. Pohlers	University of Münster November 2018
	H. Mohammadi	Isfahan University of Technology June - November 2018

* with financial support from a third party

8.2 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.

8.3 Research Projects

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)

Logic and Computation

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

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

Research staff: All members of the research group

8.4 Ph.D. Theses

- T. Rosebrock: Some Models and Semi-decidability Notions of Applicative Theories
- L. Jaun: Category Theory in Explicit Mathematics
- J. Walker: Finitist Axiomatic Truth

8.5 Master's Theses

- P. Meier: On Reactive equilibrium: Modelling the process of equilibration
- N. Gass: Self-referentiality in Justification Logic

8.6 Bachelor's Theses

- N. Froidevaux: Zugriffsberechtigungen und Sicherheitsrichtlinien auf Zeilenebene in PostgreSQL
- S. Schmid: NoSQL in PostgreSQL

8.7 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

Talks

Michael Bärtschi

- Variants of ATR without set parameters, Münchenwiler Meeting Autumn 2018, Schloss Münchenwiler, October 2018
- Parameter-Free Versions of ATR_0 and Related Theories, ABM Meeting Spring 2019, LMU München, May 2019

Lukas Jaun

- Category Theory in Explicit Mathematics, Arbeitstagung Bern München, Bern, Switzerland, October 2018
- Category Theory in Explicit Mathematics, Arbeitstagung Bern München, Munich, Germany, May 2019

Gerhard Jäger

- Weyl, Feferman and Beyond, Das Kontinuum – 100 years later, University of Leeds, September 2018.
- From fixed points in weak set theories to some open problems, Research Seminar, Kurt Gödel Research Center, University of Vienna, October 2018.
- Predicative Hierarchies, Proof-Theoretic Semantics 2018: Assessment and Future Perspective, University of Tübingen, March 2019.
- From the Foundational Crisis of Mathematics to Explicit Mathematics, PhDs in Logic XI, University of Bern, April 2019.
- Predicative Hierarchies, ABM Meeting 2019, University of Munich
- The Power of Beta, Proof, Computation, Complexity 2019, Institut Mittag Leffler, Stockholm, July 2019.
- From the Foundational Crisis of Mathematics to Explicit Mathematics, Hilbert-Bernays Summer School “Logic and Computation”, University of Tübingen, July 2019.

Eveline Lehmann

- Subset models for Justification Logic and Probabilistic Evidence Logic, Swiss Logic Gathering, Bern, May, 2019.

- Subset models for Justification Logic, Workshop on Logic, Language, Information, and Computation (WoLLIC), Utrecht, July, 2019.

Kentaro Sato

- Interpretation sextet: Renovations of proof theoretic reducibility, Münchenwiler Seminar Autumn 2018, Münchenwiler, Switzerland, October 2018.

Nenad Savić

- Epistemic models, hypertheories and public announcements, Logic and Applications, Dubrovnik, September 2018.
- Public Announcements for Epistemic Models and Hypertheories, ICLA 2019, New Delhi, March, 2019.

Thomas Studer

- The proof theory of modal fixed point logics, SGSLPS Fall Meeting: Real-Valued Modal Logics, Bern, November 2018
- Subset Models for Justification Logic, ASL North America Meeting, Special Session on Proof Theory, New York, May 2019

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
- Expert for Maturitätsprüfungen Informatik

Thomas Studer

- Swiss Delegate to the International Federation for Information Processing Technical Committee 1 (Foundations of Computer Science)
- 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 Bernays Award 2018
- Expert for Maturitätsprüfungen Informatik
- Member of the PhD jury of Selena Basset, University of Neuchâtel

Jan Walker

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

Organized Events

Michael Bärtschi

- Münchenwiler Meeting Autumn 2018, Schloss Münchenwiler, 24 - 25 October 2018

Gerhard Jäger

- Münchenwiler Meeting Autumn 2018, Schloss Münchenwiler, 24 - 25 October 2018

Eveline Lehmann

- Advances in Modal Logic, Bern, 27-31 August 2018

- Logic, Algebra and Truth Degrees, Bern, 27-31 August 2018
- PhDs in Logic XI, Bern, 24-26 April 2019

Nenad Savić

- Advances in Modal Logic, Bern, 27-31 August 2018
- Logic, Algebra and Truth Degrees, Bern, 27-31 August 2018
- PhDs in Logic XI, Bern, 24-26 April 2019

Thomas Studer

- Advances in Modal Logic, Bern, 27-31 August 2018
- Logic, Algebra and Truth Degrees, Bern, 27-31 August 2018
- Logic and Application, Inter University Centre Dubrovnik, 24-28 September 2018
- Festkolloquium zur Emeritierung von Gerhard Jäger, Bern, 13-14 December 2018
- Swiss Logic Gathering, Bern, 3 May 2019

8.8 Publications

- Bahareh Afshari and Gerhard Jäger and Graham E. Leigh. An Infinitary Treatment of Full Mu-Calculus. *R. Iemhoff, M. Moortgat, R. de Queiroz (eds.), Logic, Language, Information, and Computation, LNCS 11541*. Springer, 2019.
- Guram Bezhanishvili and Giovanna D'Agostino and George Metcalfe and Thomas Studer (eds): *Advances in Modal Logic, Volume 12. College Publications*. 2018.
- Gerhard Jäger and Timotej Rosebrock and Kentaro Sato. Truncation and semi-decidability notions in applicative theories. *The Journal of Symbolic Logic*. 88(3): 967–990, September 2018.
- Roman Kuznets and Thomas Studer. *Logics of Proofs and Justifications. College Publications*. 2019.

- Eveline Lehmann and Thomas Studer. Subset models for justification logic. *Logic, Language, Information and Computation (WoLLIC)*. 433–449, 2019.
- Bojan Marinković and Paola Glavan and Zoran Ognjanović and Dragan Doder and Thomas Studer. Probabilistic Consensus of the Blockchain Protocol. In *ECSQARU 2019*. In print.
- Bojan Marinković and Paola Glavan and Zoran Ognjanović and Thomas Studer. A temporal epistemic logic with a non-rigid set of agents for analyzing the blockchain protocol. *Journal of Logic and Computation*. 2019.
- Michel Marti and Thomas Studer. The Internalized Disjunction Property for Intuitionistic Justification Logic. In *G. Bezhanishvili, G. D’Agostino, G. Metcalfe, and T. Studer, editors, Advances in Modal Logic, Volume 12*. 511–529. College Publications, 2018.
- Hamzeh Mohammadi and Thomas Studer. Bayesian Confirmation and Justifications. In *ECSQARU 2019*. In print.
- Florian Ranzi and Thomas Strahm. A flexible type system for the small Veblen ordinal. *Archive for Mathematical Logic*. 2019.
- Kentaro Sato. A note on predicative ordinal analysis I: Iterated comprehension and transfinite induction. *The Journal of Symbolic Logic*. 84(1): 226–265, 2019.
- Nenad Savić and Thomas Studer. Public Announcements for Epistemic Models and Hypertheories. In *ICLA 2019: Logic and Its Applications*. 64–75, 2019.
- Nenad Savić and Thomas Studer. Relevant Justification Logic *Journal of Applied Logics - IfCoLoG Journal of Logics and their Applications*. 397 – 412. 2019.
- Silvia Steila. "Some algebraic equivalent forms of $\mathbb{R} \subseteq L$. *Fundamenta Mathematicae*. 2018.
- Silvia Steila. A combinatorial bound for a restricted form of the Termination Theorem. *Well quasi-orders in computation, logic, language and reasoning. A unifying concept of proof theory, automata theory, formal languages and descriptive set theory*. Ed. Peter Schuster, Monika Seisenberger, Andreas Weiermann, *Trends in Logic, Springer*. 2018.

- Silvia Steila. From Mathesis Universalis to fixed points and related set-theoretic concepts. *Mathesis Universalis, Computability and Proof*, eds: P. M. Schuster, S. Centrone, D. Sarikaya, S. Negri. 2019.
- Thomas Studer. The Logic of Temporal Domination. In *RIVF 2019 Conference Proceedings*. 187–190. IEEE, 2019.
- Chao Xu and Yanjing Wang and Thomas Studer. A logic of knowing why. *Synthese*. 2019.

9 Research Center for Digital Sustainability

9.1 Personnel

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*with financial support from a third party

9.2 Overview

In January 2019 the Research Center for Digital Sustainability joined the Institute of Computer Science from the Institute of Information Systems of the Faculty of Business, Economics and Social Sciences at University of Bern. The new research group is lead by Dr. Matthias Stürmer and currently employs 20 staff members. They conduct research and teaching as well as continuing education courses and services on the topics of digital sustainability, open source software, open data and linked data, Smart City and open government, Blockchain/smart contracts, and public procurement.

In March 2019 the Research Center for Digital Sustainability received the assignment on behalf of the Faculty of Science to build up the Competence Network Digitalization (CND). The CND is a network of individuals, research groups and institutes of the Faculty of Science that deals with digitalization in research, teaching, continuing education and services. The CND was founded in April 2019 with CHF 200'000 from the strategic funds from the Faculty of Science.

On the one hand, the CND connects all interested parties within the Faculty of Science regarding digitalization topics. Also it is involved in the implementation of the planned university-wide digitalization strategy. On the other hand, the CND organizes workshops on particular topics in order to launch specific projects and useful digital services. In addition, the CND provides visibility for the faculty in digitalization issues and increases networking within the University of Berne and with business and government agencies.

10 Software Composition Group

10.1 Personnel

Head:	Prof. Dr. O. Nierstrasz	Tel: +41 31 631 46 18 email: oscar@inf.unibe.ch
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*with financial support from a third party

10.2 Overview

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

10.3 Research Projects

Agile Software Analysis

Research staff: All members of the research group.

Duration: Jan 1, 2016 – Jan. 31, 2019

Financial support: SNSF project #200020-162352

In this project we explored new ways to enable developers to efficiently answer detailed questions about a software system under development. The project was organized into four orthogonal tracks. We briefly summarize the results obtained in each track over the course of the project.

- **Agile Model Extraction.** In this track we explored techniques to rapidly extract software models from unknown source code. The key result was the development of *bounded seas*, an approach to parsing that allows one to incrementally refine a parser that recognizes elements of interest within source code while ignoring others.

More recently we have started to explore how to exploit executable domain models as part of the software system under development, to keep requirements and implementation in sync.

- **Context-Aware Tooling.**

In this track we explored ways to close the abstraction gap between code and application domains in IDEs.

We explored the potential for *moldable tools*: software development tools that are designed to be easily tailored to specific application domains. Many of these tools have been adopted in the Pharo¹ development environment, and others are part of the Glamorous Toolkit.²

We have also studied how to support software developers in selecting suitable visualizations to present and explore the results of software analyses. We have developed tools to help developers explore and select suitable visualizations as well as dedicated tools to visualize and explore collaboration networks.

- **Ecosystem Mining.**

¹<https://pharo.org>

²<https://gtoolkit.com>

Here we explored how information mined from the broader ecosystems of related software can be exploited to support analysis of a given software system under development.

The *Ecosystem Monitoring Framework* is a proof-of-concept infrastructure that can automate a variety of different kinds of analyses on a given corpus of software projects. The *Object Repository* is an experimental ecosystem analysis tool that extracts code snippets from the ecosystem to create objects that can then be used as input for other analyses, such as determining potential dynamic types.

We have investigated the effectiveness of numerous lightweight heuristics to infer types for dynamically-typed programming languages and we have also explored the use of data extracted from the inline caches of virtual machines to rank the inferred types. We have also mined software ecosystems to infer the likelihood of the most common type of errors in Java code, namely “null pointer exceptions”, which arise when an attempt is made to use an uninitialized variable.

- **Evolutionary Monitoring.**

This track was concerned with monitoring of technical debt over the lifetime of a software project.

We have carried out various empirical studies to track the evolution of exception usage in Java projects. We have extensively explored the use of machine learning techniques for bug prediction, and found that feature selection and hyperparameter tuning have a significant impact on the quality and efficiency of the results.

We have explored ways to improve feedback to developers of software quality issues by reporting such issues “just in time”. The resulting tool, called QualityAssistant, is now a standard feature of the Pharo IDE.

Finally, we have studied the effectiveness of “code smell” detection rules to expose security concerns in the development of mobile apps. The results of this work will be integrated into the Android Studio IDE.

All publications resulting from this project are available electronically from the project home page: <http://scg.unibe.ch/asa2>

Agile Software Assistance

Research staff: All members of the research group.

Duration: Feb 1, 2019 – Apr. 30, 2022

Financial support: SNSF project #200020-181973

- **Speculative software analysis.**

During software development, developers encounter complex scenarios that require information to be collected from multiple sources. Although considerable research has been performed to understand the information needs of software developers, little is known about methods and measures to collect these information needs. We investigated this by conducting a systematic literature review. Furthermore, we investigated tools and techniques used to extract knowledge from social media platforms and found that due to lack of tools, it is difficult to analyze information needs over multiple sources. We are currently developing a tool to address this need, and plan to assess it by replicating an existing study and performing a case study.

We also studied the information developers write in code comments. As code comments play a substantial role in program comprehension and maintenance tasks, identifying and leveraging comment information can help developers to increase their productivity and write better documentation. We conducted an empirical study in Pharo to analyze evolutionary patterns and practices developers follow while writing class comments.

- **Executable domain models.**

To actively involve project stakeholders in modeling activities, the first step is to gather and understand the requirements for a specific software model. We explored state-of-art innovative requirements gathering approaches such as using mobile devices or apps to encourage multiple stakeholders participation. We conducted an empirical study of available requirements elicitation methods for mobile apps or those which involve using mobile devices.

Furthermore, we conducted an exploratory study to understand challenges in requirements gathering for mobile apps in practice. Currently we are building a tool in the Glamorous Toolkit to model business scenarios, and we intend to compare our results with GEMOC

Studio.³

- **Domain-specific software quality.**

In previous research, we investigated the prevalence of *Security Code Smells* in Android mobile applications, *i.e.*, in Android's Java API as well as the Inter-Component Communication (ICC) framework in particular. We found that the majority of available apps suffers from issues that could lead to privacy leaks, or even worse, compromised handsets for millions of users. We are carrying out additional research to provide developers quick and guided fixes within the IDE for major smells. In addition, we plan to assess the developers' perception with respect to tool support, ultimately, improving measures against these problems.

Since many of the discovered *Security Code Smells* relate to web communication, we specifically investigated the configuration, the implementation, and use of such interfaces; focusing on the interaction between apps and their web services. Our preliminary results show that the use of web communication is largely based on two building blocks, the *i.e.*, HTTP(S) transmission protocol and JSON data structures. We consequently screened thousands of apps and their corresponding API endpoints for the use of HTTP and JSON functionality, and we gathered a strong evidence that existing protective measures are not adequate; some of them could easily be bypassed. In other words, we revealed conceptional flaws in current HTTPS API implementations and proposed solutions that should be deployed in the short term to protect billions of end users from potential attackers.

To understand whether developer experience has an impact on their performance, we conducted research on how developers use Java Cryptography Architecture (JCA) APIs. We analyzed 2324 Java projects whose codes had used JCA APIs. We identified four influential factors in developer experience, namely the number of committed days, the number of JCA-related commits, the number of used JCA APIs, and the number of contributed JCA projects. We analyzed two of the aforementioned determinants which were highly correlated with their performance, *i.e.*, the number of JCA-related commits and the number of used JCA APIs by a developer. Finally, we did not find any correlation between the two highly correlated factors and the performance of developers.

³<http://gemoc.org/>

We also developed a web-based tool, named CryptoExplorer, based on our dataset of APIs wrong/correct uses. CryptoExplorer enables developers to find examples of different JCA APIs and also provides a short description regarding each example to guide developers to understand why examples are marked as misuse.

We also conducted a survey with developers who had good and bad performance in using JCA APIs. Currently, we are analyzing the survey results and we intend to conduct in-depth interviews with those who provided their email address to draw a more confident conclusion.

Furthermore, we also examined the permission API of HTML5 and how browsers obtain users' permit. The Permission API presents the uniform way for web applications to ask for permission for sensitive resources or features that demand user consent, such as notifications or geolocation. In an experiment with 120 participants, we found that by asking users to click as fast as possible, the likelihood of being tricked to permit sensitive permission, such as camera access, is almost 90%.

- **API client migration.**

Albeit open-source projects have been co-evolving since years, upgrading a library can still be a tedious task for developers. As APIs of a library change over time, breaking changes require precious developer time to adapt the code of an API client. Current IDEs lack the necessary tooling to support the API client migration process, as they treat a project in isolation from its ecosystem. IDEs neither provide feedback on the impact of an API change onto its clients, nor do they provide an approachable tool to systematically transform code of an API client. As a consequence, library developers resort to providing migration guides alongside their releases, which highlight breaking changes and describe a migration path mostly informally. We aim at bridging this gap by embracing co-evolution of an API and its clients as a first-class citizen of the IDE, integrating API client migration as an inspectable and executable process.

We developed a prototype for live feedback on the compatibility of API changes. Whenever an API is changed, the change is replayed on previously selected API clients. Examples in the API client project are then executed, revealing breaking changes in the API. This feedback can be obtained within seconds, allowing an API developer to quickly assess the impact of a change.

To support developers of API clients, we explored how examples provided by API can be used to craft code transformation rules. In our experiment we migrated examples of the Mondrian visualization engine from using a Roassal backend to using the alternative GToolkit backend. While the underlying ideas of the two APIs are very similar, the API interfaces are different and impose different usage protocols. The migration was expressed in code transformation rules, which were hand-written in a migration workbench. This migration workbench leverages API usage examples and interactive transformations to migrate code from one API to the other.

For further details, please consult:

<http://scg.unibe.ch/asa3>

10.4 Master's Theses

- Marc-Andrea Tarnutzer. Web communication analysis of Android applications. Masters thesis, University of Bern, May 2019. URL: <http://scg.unibe.ch/archive/masters/Tarn19a.pdf>.

10.5 Bachelor's Theses and Computer Science Projects

- Markus Eggimann. Software testing in industry — assessing unit testing in an industrial software project. Bachelor's thesis, University of Bern, September 2018. URL: <http://scg.unibe.ch/archive/projects/Eggi18a.pdf>.
- Manuela Eschler. Search interface implementation for a learning management system. Bachelor's thesis, University of Bern, February 2019. URL: <http://scg.unibe.ch/archive/projects/Esch19a.pdf>.
- Mario Hess. Pervasive visualization in immersive augmented reality for software performance monitoring. Bachelor's thesis, University of Bern, February 2019. URL: <http://scg.unibe.ch/archive/projects/Hess19a.pdf>.
- Patrick Indermühle. Modular exceptions — a system for handling exceptions in a modular way. Bachelor's thesis, University of Bern,

September 2018. URL: <http://scg.unibe.ch/archive/projects/Inde18a.pdf>.

- Marcel I. Chavez Panduro. Archiving in small and medium enterprises. Bachelor's thesis, University of Bern, January 2019. URL: <http://scg.unibe.ch/archive/projects/Chav19a.pdf>.
- Jonas Richner. Software developers' information needs. Bachelor's thesis, University of Bern, February 2019. URL: <http://scg.unibe.ch/archive/projects/Rich19a.pdf>.
- Timo Spring. Benchmarking Android data leak detection tools. Bachelor's thesis, University of Bern, August 2018. URL: <http://scg.unibe.ch/archive/projects/Spri18a.pdf>.
- Astrid Ytrehorn. Smelly APIs in Android ICC analysis of source code and relevant metadata. Bachelor's thesis, University of Bern, September 2018. URL: <http://scg.unibe.ch/archive/projects/Ytre18a.pdf>.

10.6 Awards

- VISSOFT 2018 Distinguished Paper Award for *Overcoming Issues of 3D Software Visualization through Immersive Augmented Reality* by Leonel Merino, Alexandre Bergel and Oscar Nierstrasz
- Joint Computer Science Alumni Association Award for Mario Kaufmann's MSc thesis, *Reproducible moldable interactions*

10.7 Further Activities

Invited Talks

Mohammad Ghafari

- Invited Speaker at the University of Auckland: "Why Johnny cannot develop secure apps" – Auckland, New Zealand, 31 Oct 2018.
- Invited Speaker at Victoria University of Wellington: "Let's help Johnny to develop secure apps" Wellington, New Zealand, 29 Oct 2018.

- Invited Speaker at Karlstad University: “Building secure software systems” – Karlstad , Sweden, 20 Sep 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)
- SATToSE – Seminar Series on Advanced Techniques & Tools for Software Evolution (Steering Committee Member)
- SNF — Swiss National Science Foundation (Member of the Research Council)

Program Committees

Oscar Nierstrasz

- PC Member of SANER 2019 (International Conference on Software Analysis, Evolution, and Reengineering ? Hangzhou, People?s Republic of China, February 24-27, 2019) 2018
- PC Member of SCAM 2018 (18th IEEE International Working Conference on Source Code Analysis and Manipulation ? Madrid, Spain, Sept. 23-24, 2018)

Mohammad Ghafari

- PC member of SEAD 19 (2nd International Workshop on Software Security from Design to Deployment – California, United States, November , 2019)
- PC member of VISSOFT 19 (7th IEEE Working Conference on Software Visualization – Ohio, USA, September 2019)

Reviewing Activities

Oscar Nierstrasz

- IEEE Transactions on Software Engineering
- IEEE VR 2018
- The Art, Science, and Engineering of Programming 2019
- Deutsche Forschungsgemeinschaft

Mohammad Ghafari

- IEEE Transactions on Software Engineering (TSE)
- SEAD 19
- VISSOFT 19
- SANER 19

Pascal Gadiant

- SANER 2019

Manuel Leuenberger

- SANER 2019
- VISSOFT 2019 Artifact Evaluation

Pooja Rani

- SANER 2019

10.8 Publications

Journal Papers

- Pascal Gadiant, Mohammad Ghafari, Patrick Frischknecht, and Oscar Nierstrasz. Security code smells in Android ICC. *Empirical Software Engineering*, 2018. URL: <http://scg.unibe.ch/archive/papers/Gadi18a.pdf>, doi:10.1007/s10664-018-9673-y.

Conference Papers

- Leonel Merino, Alexandre Bergel, and Oscar Nierstrasz. Overcoming issues of 3d software visualization through immersive augmented reality. In *VISSOFT'18: Proceedings of the 6th IEEE Working Conference on Software Visualization*, pages 54–64. IEEE, 2018. URL: <http://scg.unibe.ch/archive/papers/Meri18c.pdf>, doi:10.1109/VISSOFT.2018.00014.
- Leonel Merino, Mario Hess, Alexandre Bergel, Oscar Nierstrasz, and Daniel Weiskopf. PerfVis: Pervasive visualization in immersive augmented reality for performance awareness. In *Companion of the 2019 ACM/SPEC International Conference on Performance Engineering, ICPE '19*, pages 13–16, New York, NY, USA, 2019. ACM. URL: <http://scg.unibe.ch/archive/papers/Meri19a-perfvis.pdf>, doi:10.1145/3302541.3313104.
- Nitish Patkar, Pascal Gadiant, Mohammad Ghafari, and Oscar Nierstrasz. Towards a catalogue of mobile elicitation techniques. In *25th International Conference on Requirements Engineering: Foundation for Software Quality (REFSQ)*, 2019. URL: <http://scg.unibe.ch/archive/papers/Patk19a.pdf>, doi:10.1007/978-3-030-15538-4_20.
- Sten Vercammen, Mohammad Ghafari, Serge Demeyer, and Markus Borg. Goal-oriented mutation testing with focal methods. In *Proceedings of the 9th ACM SIGSOFT International Workshop on Automating TEST Case Design, Selection, and Evaluation, A-TEST 2018*, pages 23–30, New York, NY, USA, 2018. ACM. URL: <https://arxiv.org/abs/1807.10953>, doi:10.1145/3278186.3278190.

11 Administration

University:

- T. Braun: Member of the Committee for Computing Services (Kommission für Informatikdienste)
Representative of University of Bern in SWITCH
Stiftungsrat
- G. Jaeger: Member of *Kantonale Maturitätskommission (to January 19)*
- O. Nierstrasz: Deputy Faculty delegate
Faculty contact person for digitalization

Faculty:

- T. Braun: Faculty Board
- P. Favaro: Member of the Board of Studies
Joint Master in Computer Science of the Universities of Bern, Fribourg and Neuchâtel: Member of the Branch Committee
Faculty delegate
- O. Nierstrasz: Member Faculty Strategy Committee
Member Digitalisation Strategy Working Group
Member Precision Medicine Working Group
- Th. Studer: Member of the Strategy Board

Institute:

- Ch. Cachin: Member of Library Committee on behalf of INF
Representative to CUSO Doctoral School in Computer Science
- O. Nierstrasz: Managing Director of INF
Member of Hauskommission Engehalde
President CUSO Doctoral School in Computer Science (to December 18)
- T. Braun: Deputy Director of INF
- P. Favaro: Director of Studies

Th. Studer: Member of Hauskommission Exakte Wissenschaften