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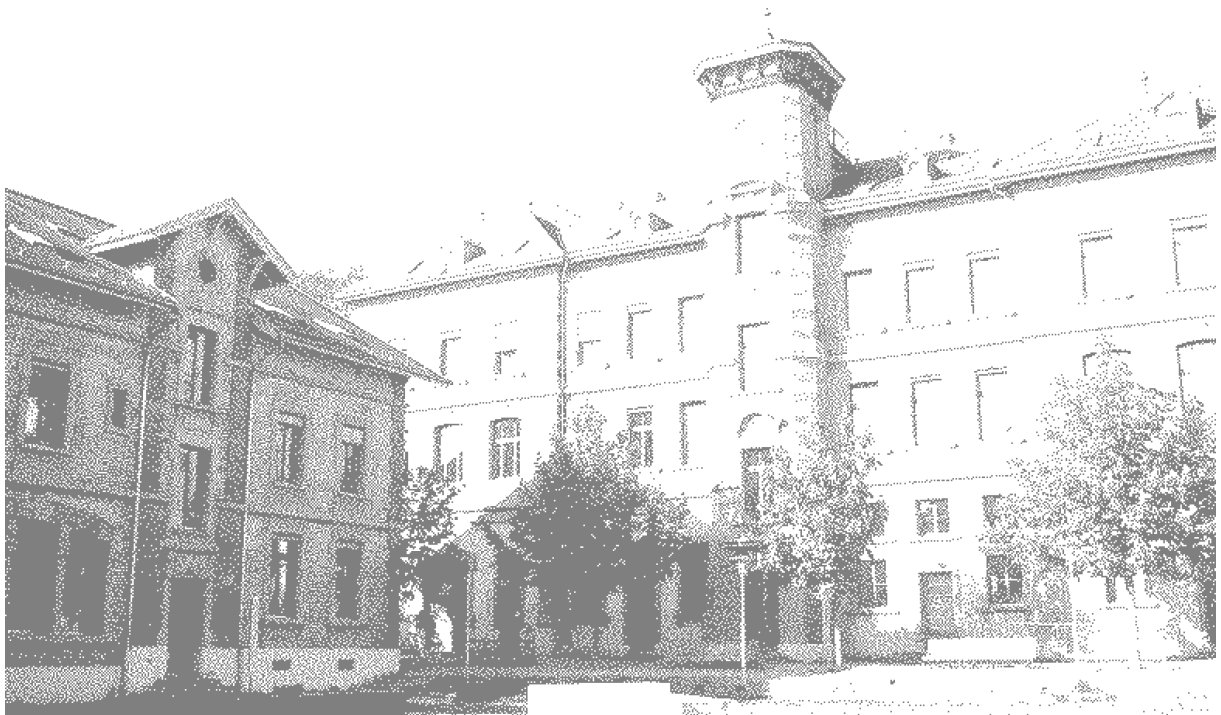
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**UNIVERSITÄT  
BERN**

Institut für Informatik  
Universität Bern

[www.inf.unibe.ch](http://www.inf.unibe.ch)

# INF Annual Report 2019/2020





**INF Annual Report**  
**Academic Year 2019/2020**

September 18, 2020

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# 1 Institute of Computer Science (INF)

## 1.1 Address

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<http://www.inf.unibe.ch>

## 1.2 Personnel

### Members

Florence Aellen, Sigurd Alnes, Orestis Charilaos Alpos, Ignacio Amores Sesar, Mohammadreza Hazhirpasand Barkadehi Michael Baur, Marcel Behn, Lara Biehl, Adam Bielski, Prof. David Bommers, Prof. Torsten Braun, Nathalie Brugger, Sabine Brunner, Patrick Brunner, Prof. Christian Cachin, José Luis Carrera Villacrés, Bettina Choffat, Dr. Nhu Ngoc Dao, Negar Emami, Janik Endtner, Dragana Esser, Maria Fanger, Prof. Paolo Favaro, Nathalie Froidevaux, Mathias Fuchs, Pascal Gadiant, Nicolas Gallego-Ortiz, Mikael Gasparyan, Dr. Mohammad Ghafari, Francesca Giardina, Pinar Göktepe, Roman Gruber, Martin Heistermann, Johanna Jaeger, Simon Jenni, Simon Kafader, Eirini Kalogeiton, Mostafa Karimzadeh, Rebecca Kehl-Sanchez, Angela Keller, Alex Kräuchi, Eveline Lehmann, Abdelhak Lemkhenter, Manuel Leuenberger, Heng Liu, Dr. Giorgia Marson, Alisson Patrick Medeiros do Lima, Oscar Meier, Givi Meishvili, Hugo Leonardo Melo dos Santos, Jovana Micic, Dusan Mihajlov, Steve Mürset, Alejandro Nardo, Oliver Neumann, Prof. Oscar Nierstrasz, Valentin Nigolian, Joël Niklaus, Patkar Nitish, Dr. Jasmin Nussbaumer, Diego Oliveira Rodrigues, Géraldine Oppliger, Anna Parker, Alex Pellegrini, Pooja Rani, Simone Raimondi, Atefeh Rohani, PD Dr. Kaspar Riesen, Nenad Savic, Daniela S. Schroth, Alec Schürmann, Dominic Schweizer, Jonas Schwery, Siddhartha Singh, Nathalie Sinz, Dr. Ronny Standke, Prof. Thomas Strahm, Prof. Thomas Studer, Dr. Nataliia Stulova, Prof. Matthias Stürmer, Noe Leon Thalheim, Ruxandra Tivada, Prof. Athina Tzovara, Adrian Wälchli, Xiaochen Wang, Jethro Warnett, Stefanie Weilenmann, Tobias Welz, Roland Widmer, Dimitrios Xenakis, Luca Zanolini, Dr. Zhongliang Zhao, Alena Zwahlen

**Administration**

Nathalie Brugger, Bettina Choffat, Dragana Esser, Daniela Schroth

**Technical staff**

Dr. Peppo Brambilla, Martin Heistermann, Adrian Wälchli

## 2 Teaching Activities

### 2.1 Courses for Major and Minor in Computer Science

#### Autumn Semester 2019

- Bachelor 1st Semester

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

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

Programmierung 1 (T. Strahm, 5 ECTS)

- Bachelor 3rd Semester

Diskrete Mathematik (C. Cachin, 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

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

Mobile Communications (T. Braun, 5 ECTS)

Modal Logic (T. Studer, 5 ECTS)

Computer Vision (P. Favaro, 5 ECTS)

Applied Optimization (D. Bommès, 5 ECTS)

Cryptography (C. Cachin, 5 ECTS)

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

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

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

Seminar: Machine Learning and Artificial Intelligence (P. Favaro, 5 ECTS)

Seminar: Computer Graphics (D. Bommès, 5 ECTS)

Seminar: Secure Computation (C. Cachin, 5 ECTS)

- Service Courses

Anwendungssoftware (T. Studer, 3 ECTS)

## Spring Semester 2020

- Bachelor 2nd Semester

Datenbanken (T. Studer, 5 ECTS)

Datenstrukturen und Algorithmen (D. Bommès, 5 ECTS)

Computer Architecture (P. Favaro, 5 ECTS)

Programmierung 2 (A. Chiş, 5 ECTS)

- Bachelor 4th Semester

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

Betriebssysteme (T. Braun, 5 ECTS)

Berechenbarkeit und Komplexität (T. Strahm, 5 ECTS)

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

- Bachelor 6th Semester

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

- Master Courses

Network Security (T. Braun, 5 ECTS)

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

3D Geometry Processing (D. Bommès, 5 ECTS)

Distributed Algorithms (C. Cachin, 5 ECTS)

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

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

Seminar: Machine Learning and Artificial Intelligence (P. Favaro, 5 ECTS)

Seminar: Computer Graphics (D. Bommès, 5 ECTS)

Seminar: Distributed Trust and Blockchains (C. Cachin, 5 ECTS)

- Service Courses

Anwendungssoftware (K. Riesen, 3 ECTS)

## 2.2 Colloquium in Computer Science

- 01.10.2019 (CGG) Valentin Nigolian (PhD student) - University of Bern  
INVANER: INteractive VAscular Network Editing and Repair
- 21.02.2020 (CGG) Max Lyon - RWTH Aachen University, Germany  
Parametrization Quantization with Free Boundaries for  
Trimmed Quad Meshing
- 04.03.2020 (CGG) Maxance Reberol - Université Catholique de Louvain, Belgium  
3D Frame Fields and Block Decomposition of CAD models
- 04.03.2020 (CGG) Pierre A. Beaufort - Université Catholique de Louvain, Belgium  
Crossfields from the Renormalized Energy
- 23.01.2020 (CVG) Siavash Arjomand Bigdeli - EPFL Lausanne  
Learning Generative Models using Denoising Density  
Estimators
- 26.09.2019 (CVG) Luigi Fiorillo - University Lugano  
An interactive automatic sleep scoring system using raw  
single-channel EEG
- 28.08.2019 (CVG) Antonino Furnari - Gast-postdoc CVG  
Situational awareness in First-Person (Egocentric) Vision

## 2.3 Students

- Major Subject Students: HS 2019: 270, FS 2020: 245
- Minor Subject Students: HS 2019: 186, FS 2020: 154
- Ph.D. Candidates: HS 2019: 37, FS 2020: 39

## 2.4 Degrees and Examinations

- PhD: 4
- Master: 18
- Bachelor: 22
- Completion of Minor Studies: 27 (90E:0, 60E:10, 30E:12, 15E:5, 1035 ECTS)
- Semester Examinations HS 2019: 877 (3177 ECTS)
- Bachelor's/Master's Theses HS 2019: 16 (280 ECTS)

- Semester Examinations FS 2020: 716 (2544 ECTS)
- Bachelor's/Masters Theses FS 2020: 19 (310 ECTS)

## 2.5 Activities

- Contribution to the “National Future Day for Girls and Boys”, Bern, November 14, 2019
- Contribution to the “Bachelor Infotage“, December 3+4, 2019
- Contribution to the “Master Infotage“, March 10, 2020
- Taster course for female students, Bern, March 26, 2020 (cancelled due to Corona)

## 2.6 Awards

- Faculty prize for José Carrera's PhD thesis, *Indoor Positioning and Tracking Methods for Mobile Wireless Devices*
- Joint Computer Science Alumni Association Award for Mehdi Noroozi's PhD thesis, *Beyond Supervised Representation Learning*
- Joint Computer Science Alumni Association Award for Marc-Andrea Tarnutzer's MSc thesis, *Web Communication Analysis of Android Applications*
- Joint Computer Science Alumni Association Award for Mario Hess's BSc thesis, *Pervasive Visualization in Immersive Augmented Reality for Software Performance Monitoring*

## 3 Cognitive Computational Neuroscience Group

### 3.1 Personnel

<b>Head:</b>	Prof. Dr. A. Tzovara	Tel.: +41 31 511 7636 email: athina.tzovara@inf.unibe.ch
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	S.A. Alnes	+41 31 511 7636 email: sigurd.ernes@inf.unibe.ch
	P. Göktepe	+41 31 511 7636 email: pinar.goektepe@students.unibe.ch
	R.I. Tivadar	+41 31 511 7636 email: ruxandra.tivadar@inf.unibe.ch

### 3.2 Overview

The 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 machine learning techniques to study neural functions of the human brain. We are focusing in two main areas: (a) studying the neural processes that underlie learning rules from our environment and (b) developing novel techniques for analysing electrophysiological signals.

### 3.3 Research Projects

#### Neural correlates of sensory predictions

In our daily lives we are immersed in streams of sensory events, like sounds or images, which very often follow repetitive rules and patterns. These these rules allow us to learn regularities from the environment and anticipate future events before these occur. The brain operates as a predictive machine, relying on internal models of the environment which generate predictions about the most plausible future states given prior information. Every time that incoming sensory information does not match the



predictions of an environmental model, it is updated via prediction error signals, which represent the difference between anticipated and received information. Predictions of an internal model are generated not only when paying attention to incoming information, but also when conscious perception can be excluded, such as during sleep or coma. In this project we are investigating the neural and computational correlates of sensory predictions, in order to dissociate attentive from automatic predictive processes in the brain.

To this aim, we are developing experimental paradigms in which sensory patterns are constructed in the auditory modality, by repeating series of regular sounds which form a predictive sequence. Occasionally the sequence is broken, eliciting a prediction error signal in the brain. To measure the neural manifestation of prediction error signals, we are using electroencephalography (EEG) and magnetoencephalography (MEG) recordings in healthy participants, in combination with signal processing and machine learning techniques.

**Research staff:** Ruxandra Tivadar, Pinar Göktepe, Athina Tzovara

**Financial support:** Swiss National Science Foundation (320030\_188737)

## **Electrophysiological markers of implicit sensory processing**

Humans spend on average one third of their lives sleeping. During sleep, conscious perception of the environment fades away: we are majorly unaware of our surroundings, and unresponsive to most external stimuli. Nevertheless, despite a temporary loss of consciousness, the human brain still processes sensory information from the environment. Sounds can reach the main sensory areas of the brain and are processed during sleep without our overt awareness. Processing of sensory information in the absence of consciousness has also been observed in pathological conditions, such as during coma, or in patients with disorders of consciousness. In these cases, the integrity of sensory processing is an indicator of residual levels of consciousness, of the depth of anesthesia, or a predictor of the patients' chances of awakening from a coma. Despite its clinical relevance, the neural circuit underlying sensory processing in the absence of consciousness remains under-explored.

One main tool for assessing neural functions non-invasively is electroencephalography (EEG). EEG measures electric activity of the brain through electrodes on the scalp, providing an excellent temporal resolution, at the millisecond range. Our goal with this project is to use EEG recordings in healthy and pathological conditions, and develop markers of (un)conscious processing of sensory information. Our first efforts focus on EEG recordings from patients in a coma following a cardiac arrest. We are using signal processing techniques to quantify the structure of EEG responses of comatose patients and healthy controls in space (across electrodes on the scalp) and in time (over the time-course of EEG signals). Our long-term goal is to develop biomarkers of patients' outcome that are automated and can be easily integrated in the clinical routine.

**Research staff:** Sigurd Alnes, Athina Tzovara

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

## **Machine learning techniques for analyzing EEG data**

Machine learning is increasingly used in the field of EEG research to extract in a data-driven way patterns of EEG activity that are relevant to an experimental manipulation. Multivariate decoding techniques (MVPA) have been developed in the past to detect EEG features that differ most between experimental conditions of interest (for example EEG responses to different types of stimuli), and to classify EEG signals. Most 'traditional' machine learning techniques consist of training and testing multiple classifiers over single time points of EEG responses, assuming that the response of interest will always appear at the same latency and electrodes across trials or across a group of participants. In reality, this assumption may be often violated, for example when new information is being learned, or when decisions are made, where trial-by-trial EEG responses are highly variable.

In the past few years, the field of computer vision has gained a tremendous momentum with the introduction of deep learning algorithms. Deep neural networks that rely on convolutional operations (convolutional neural networks-CNNs) are commonly used to classify images, ranging from everyday objects to challenging medical images. However, despite their promising applications, deep neural networks are not commonly used yet in the field of EEG research.

In this project, we are developing deep learning approaches to decode stimulus-related information from EEG data. These approaches have the flexibility to (a) learn from large populations of heterogeneous participants, and (b) disentangle neural processes that are not locked in space or time. To this aim, we are training convolutional neural networks (CNNs) to discriminate EEG responses to external stimuli, such as sounds or images. Our results show that compared to more 'traditional' machine learning techniques, CNNs provide a stronger classification performance, taking advantage of single-trial spatio-temporal EEG features. Importantly, by combining CNNs with feature extraction techniques, we can visualize the EEG features that mostly contribute to an accurate classification. Importantly, CNNs have promising applications not only in the field of basic EEG research, but also in clinical studies, where inter-individual variability across patients is high, as CNNs can learn features from large and heterogeneous populations.

**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**

A large amount of data is commonly collected in the field of neuroscience, making imperative the use of advanced algorithmic techniques to analyse them. Algorithmic decisions are often reached through ML techniques and have the potential to facilitate clinical decision-making by improving diagnosis, or even majorly improve the lives of patients suffering from neurological disorders. 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.

The goal of this project is to raise awareness about the use of algorithmic decision-making in the field of neuroscience. We built an open resource

on the use of ML and signal-processing techniques for analysing neuroscientific data. We started with the specific case of EEG data, and present the rationale behind commonly used algorithms to process them. This resource is openly available on our website, with the goal of enhancing the accessibility of computational techniques to all academic and citizen scientists, and increasing transparency in algorithmic practices.

**Research staff:** Pinar Göktepe, Athina Tzovara

**Financial support:** Mozilla, Open Science Mini-Grant

### 3.4 Master's Theses

- Pinar Göktepe, "Machine learning techniques for classifying neural predictive processes based on magnetoencephalography", June 2020

### 3.5 Bachelor's Theses

- Corinne Alison Donnay, Scripps College, USA "Spike sorting during an auditory oddball paradigm in humans", December 2019

### 3.6 Further Activities

#### Talks

##### Athina Tzovara

- Sensory predictions in the human brain in the absence of consciousness, Zurich sleep and health seminar, Switzerland, June 2020
- Assessing subcortical oscillatory processes with MEG and iEEG, Higher School of Economics, Moscow, Russia, March 2020
- Machine learning for studying the sleep-wake, Sleep wake days Bern, Switzerland, December 2019

## Conference Committees

### Athina Tzovara

- Organization for Human Brain Mapping (OHBM), chair of Diversity and Gender Committee, 2019-2020

## Reviewing Activities

### Athina Tzovara

#### Journal Reviews

- Frontiers Neurology
- IEEE Journal of Biomedical and Health Informatics
- International Journal of Psychophysiology
- Nature Human Behaviour
- Neuroimage Clinical
- Neuropsychologia
- The Journal of Physiology

#### Grant Reviews

- National Science Centre, Poland
- Swiss National Science Foundation

## 3.7 Publications

### Journal Publications

- Castegnetti G., Tzovara A., Khemka S., Melinscak F., Barnes G.R., Dolan R., Bach D.R. (2020). Representations of probabilistic outcomes during risky decision-making. *Nature Communications*, 11: 2419.

- Fedele T.\*, Tzovara A.\*, Steiger B., Hilfiker P., Grunwald T., Stieglitz L., Jokeit H., Sarnthein J. (2020). The relation between neuronal firing, local field potentials and hemodynamic activity in the human amygdala in response to aversive dynamic visual stimuli. *Neuroimage*, 213. \* equal contribution.
- Johnson E., Kam J. Tzovara A., Knight R.T. (2020). Insights into human cognition from intracranial EEG: A review of audition, memory, internal cognition, and causality. *Journal of Neural Engineering*, doi: 10.1088/1741-2552/abb7a5.

## Preprints

- Ojala K.\*, Tzovara A.\*, Poser B., Lutti A., Bach D.R. (2020). Representations of probabilistic outcomes during risky decision-making. *BioRxiv*, 2020, \* equal contribution.

## 3.8 Science Outreach

- Organization for Human Brain Mapping. Live review for kids from *Frontiers for Young Minds*, June 2020.

## 4 Communication and Distributed Systems Group

### 4.1 Personnel

<b>Head:</b>	Prof. Dr. T. Braun	Tel.: +41 31 511 2631 Email: torsten.braun@inf.unibe.ch
<b>Office Manager:</b>	D. S. Schroth	Tel.: +41 31 631 8681 Email: daniela.schroth@inf.unibe.ch
<b>Scientific Staff:</b>	J. Carrera*	Email: jose.carrera@inf.unibe.ch (Until 31.10.2019)
	Dr. N.N. Dao	Email: nhungoc.dao@inf.unibe.ch (01.08.2019-29.02.2020)
	N. Emami*	Tel.: +41 31 511 2633 Email: negar.emami@inf.unibe.ch (As of 01.09.2020)
	M. Gasparyan	Email: mikael.gasparyan@inf.unibe.ch (Until 30.06.2020)
	E. Kalogeiton*	Email: eirini.kalogeiton@inf.unibe.ch (Until 30.04.2020)
	M. Karimzadeh	Email: mostafa.karimzadeh@inf.unibe.ch (Until 31.01.2020)
	A. Medeiros	Tel.: +41 31 511 2637 Email: alisson.medeiros@inf.unibe.ch (As of 01.11.2019)
	D. Oliveira	Tel.: +41 31 511 2639 Email: diego.oliveira@inf.unibe.ch (As of 01.08.2019)
	H. Santos	Tel.: +41 31 511 2634 Email: hugo.santos@inf.unibe.ch (As of 01.09.2019)
	D. Xenakis*	Tel.: +41 31 511 7631 Email: dimitrios.xenakis@inf.unibe.ch (As of 01.11.2019)
	Dr. Z. Zhao*	Email: zhongliang.zhao@inf.unibe.ch (Until 30.06.2020)

**External Ph.D. Students:**

L. Luceri	Email: luceri@inf.unibe.ch (Until 31.03.2020)
G. Manzo	Email: gaetano.manzo@hevs.ch
J. Schaerer	Email: jakob.schaerer@abilium.com

\*With financial support from a third party credit

## 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 (IoT). 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 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.

in 2019, 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.

On December 19th, 2019, 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.

By end of April 2020, the CDS group has successfully delivered the final technical report to the funding agent. A scientific publication is published based on this project [Villacrés et al., 2020].

**Research staff:** J. Carrera, H. Santos, 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

## **Intelligent Mobility Services**

Nowadays, huge amounts of data regarding pedestrian and vehicle mobility traces are available from Location Based Services (LBS). This data is pivotal for enabling intelligent mobility services such as navigation, localization and mobility prediction. In this project, we focus on developing improved methods to achieve that. More specifically, the research has been divided into two distinct aspects; the localization and the mobility prediction. Both these components are discussed below in more detail.

### **- Indoor & Outdoor Localization**

Different location-based services come with different positioning accuracy requirements. For outdoor applications (e.g. car navigation), most often, global navigation satellite systems (e.g. GPS) can inexpensively cover the needs. Yet, applications in indoor environments (e.g. COVID19 tracking indoors), where satellite signals are not available, are more challenging. Therefore, considering (i.e. fusing) many types of signal sources such as Bluetooth/Wi-Fi signals, magnetometer, accelerometer, gyroscope, etc. is critical for achieving accurate positioning indoors. Apropos to this and within the frame of the research that has been conducted by the communication and distributed systems group, we propose a new methodology for enhancing the positioning accuracy in such systems by taking advantage of signals (e.g. Low Energy Bluetooth) which can be exchanged between different mobile devices (e.g. smartphones). This way, instead of tracking individually each mobile device, we consider at the same time all exchanged signals, eventually positioning them as a

system (or a swarm of devices).

### **- *Mobility & Congestion Prediction Services***

Today society is highly relying on mobility. Trajectory prediction plays a key role in enabling and enhancing the performance of a diverse range of applications. Managing traffic congestion, providing route recommendations and emergency services from one hand, networking, collision prediction in autonomous cars, service migration and handover optimization on the other hand, are only some of the many applications that immensely benefit from mobility prediction. Thanks to the availability of enormous location data which provides this possibility to analyze and infer mobile users' daily behaviors and consequently the urban dynamics. The main focus and plans of this project are designing advanced machine learning and deep learning models in order to precisely predict the future location, trajectory, and traffic flow of both humans and vehicles. We have developed a Recurrent Neural Network-based mobility predictor which is a very compatible model for time-series data and can reach quite high accuracy with respect to the normal Neural Networks or non-Neural Networks. To automate and optimize the complex process of hyper-parameter selection, we have implemented a Reinforcement Learning-based model. However, the attained training time is still remarkable. We are trying to design other comparable models and means expecting to find a fine compromise between accuracy and training time.

**Research staff:** D. Xenakis, N. Emami, T. Braun.

**Financial support:** Swiss National Science Foundation (SNSF) [Contract No. 184690]

## **Context Awareness Engine**

The Context Awareness Engine project funded by Orange explores network context information to discover, reason, and predict network and subscriber situations by appropriate computation and information modelling based on collected network data from various data sources (network nodes, devices, applications). The purpose is to propose recommendations or request actions (context awareness) using advanced machine learning and deep 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).

From August 2019 to April 2020, the CDS group continued to work on the defined topics and spent most of the efforts on cleaning and processing the dataset provided by Orange in November 2019. This large dataset includes nearly 1,300,000 anonymized mobile users' cellular connection information, including the total number of 131 base station within 63 days (from July 2019 until September 2019) near the city of Paris. The dataset holds information such as the anonymized unique ID of a connecting base station, corresponding connection time of the user to a base station, and 'IMSI' as the anonymized ID of the user itself, per sample for each individual user. By the end of April, the CDS group has successfully validated the developed algorithms on the Orange dataset, and finished the last deliverable, which provides the detailed 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. To automate the process of hyper-parameter selection, we have implemented RL-LSTM framework, which uses reinforcement learning to discover high-performance LSTM predictors. It also includes some preliminary results about the identification of mobility similarity and clustering, such that group trajectory prediction can be supported to save prediction computation for users with similar movement patterns. Experiment results show that the new algorithm can reach an average prediction accuracy of around 75%, which outperforms other state-of-the-art prediction algorithms, and the proposed optimization schemes of reinforcement learning and transfer learning can significantly reduce the algorithm convergence time.

In June 2020, the CDS group has made a final project presentation and a live demo online. The live demo successfully shows how the mobile user trajectory prediction can be supported. The demo and presentation have been both approved by Orange SA. After the final presentation the demo, Orange proposed to continue the project and make a further extension until end of 2020 such that all the know-how developed by the CDS group can be fully transferred to Orange for their future utilization.

**Research staff:** Z. Zhao, M. Karimzadeh, H. Santos, L. Pacheco, N. Emami, T. Braun.

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

## **Analysis of Online Social Network Risks**

The rise of Online Social Networks (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. In fact, social connections among OSN users result in a network structure, which enables the spreading of information, behaviors, and opinions across the OSN population through online interactions.

Along this research direction, we explore to what extent an individual's privacy can be violated by leveraging information provided by other users in the OSN [Luceri et al., 2020a]. In particular, we examine the problem of location privacy by developing methods to assess users' privacy risks and strategies to control the public exposure of their data. Results show that users' privacy is not under individual control as public information can be efficiently used to predict their behavior, and in turn, violate their privacy. Online interactions and social influence play also a crucial role in the manipulation of peoples' belief and opinion. Manipulation campaigns have raised particular concerns in the political context, e.g., in the 2016 U.S. Presidential election. Bots (i.e., software-controlled accounts) and trolls (i.e., state-sponsored human operators) are the main actors responsible for these campaigns. Despite the attempt of OSN service providers to suspend malicious actors and maintain a healthy conversation on OSNs, nefarious activity has not entirely stopped. It is, therefore, of pivotal importance to enhance and enable countermeasures for the detection of malicious accounts. In [Luceri et al., 2019], we study the behavior of bot accounts that keep escaping detection and continuously act in OSNs. For this purpose, we explore the evolution of social bots during the last two US elections, i.e., the 2016 Presidential election and the 2018 Midterms. We examine the strategies implemented by bots to avoid the suspension from OSNs and to manipulate the opinion of OSN users. Also, we analyze how human users deal with these automated accounts as it is of paramount importance to understand how humans handle the manipulation attempts. The results of our analysis reveal the effectiveness and the mutable nature of such increasingly sophisticated bot accounts. Our insights can inform

actionable policies to detect social bots and fight online abuse. Differently from bots, the automated identification of troll accounts is an open challenge for the research community. In [Luceri et al., 2020b], we examine the online activity of Russian trolls during the 2016 US Presidential election and we propose a novel approach based on Inverse Reinforcement Learning (IRL) to capture troll behavior and identify troll accounts in OSNs. We employ IRL to infer a set of online incentives that may steer user behavior, which in turn highlights behavioral differences between troll and non-troll accounts, enabling their accurate classification.

**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. L-SCN is a two-layered Service-Centric Networking architecture. The L-SCN design splits the network into domains and specifies communication protocols for service provider information propagation. Nodes in a domain receive substantial knowledge about the available resources (e.g., CPU, RAM) and available services within the domain, while the communication between different domains is realized through supernodes. We have extended L-SCN with new communication mechanisms [Gasparyan et al., 2020], which improve the processing time and provide lower protocol overhead for service request processing. The two proposed mechanisms are named event-driven and provider-driven. The event-driven mechanism propagates service provider information based on an event (e.g., high overload). The provider-driven mechanism propagates service provider information periodically.

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

## **Bloom Filter-based Content Discovery and Retrieval for Information-Centric Networks**

L-SCN uses supernodes for intra-domain and inter-domain routing. However, L-SCN lacks algorithms to select supernodes. Therefore, in

[Marandi et al., 2020a], we proposed to create a Dominating Set (DS) or a Connected Dominating Set (CDS) over the network topology and select the dominator nodes as supernodes. We proposed distributed algorithms for DS and CDS construction. Then, we developed Bloom Filter (BF)-based intra-domain and inter-domain routing protocols for DS-based and CDS-based SCN. We evaluated the performance of our protocols and observed from the results that: 1) the bandwidth overhead required to construct DS and CDS increases with the topology size, 2) the proposed CDS construction algorithm requires more bandwidth overhead than our DS construction algorithm, 3) for large topologies, the proposed CDS-based routing protocol requires drastically less bandwidth overhead to route service requests than both our DS-based routing protocol and vanilla NDN with multicast strategy, and 4) we observe that the CDS-based routing protocol achieves slightly better service retrieval time than DS-based routing, while both DS-based and CDS-based routing protocols have much less service retrieval time compared to NDN with multicast strategy.

Previously, we developed pull-based BFR as a routing protocol for NDN. Network Coding (NC) is a well-known technique to accelerate content retrieval delay. In [Marandi et al., 2020b], we presented a multi-session NC protocol that benefits from the received BFs sent during the pull-based content discovery phase to select network codes of the requested Data packets. Further, to manage the multi-session codeblock size, we let the nodes collaborate by sending local feedbacks about their available capacity for accepting new variables in their equation systems, a BF containing their decoded variables that they do not need to receive in linear combinations, and a BF containing the variables that are involved in the equation system. These feedback messages allow nodes to assign utility values to the available variables and solve an instance of a linear program to select network codes. We compared the proposed network coding-based protocol with push-based and pull-based BFR. The results made clear that the proposed network coding-based protocol outperforms push-based and pull-based BFR in terms of the required bandwidth resources for content discovery and average content block retrieval delay [Marandi et al., 2020b].

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

## **Vehicular Ad Hoc Networks (VANETs)**

Vehicular Ad Hoc Networks (VANETs) are characterised by intermittent connectivity and path breaks between nodes since vehicles can travel with high speeds in different locations. These path breaks lead to high packet loss, reducing the Quality of Service (QoS) requirements that VANET applications demand. In our project named CONtext and conTent Aware CommunicaTions for QoS support in VANETs (CONTACT), we study three different architectures: Named Data Networking (NDN), Floating Content (FC) and Software Defined Networking (SDN). We apply these architectures in VANETs to achieve the QoS requirements of applications by using one or more combined paradigms.

[Kalogeiton et al., 2019, Kalogeiton et al., 2020] enable NDN in VANETs by using only vehicle to vehicle communication. We equip vehicles with directional antennas to provide directivity in message forwarding. This achieves higher and faster content retrieval, because vehicles that are outside of the spreading area of the message can perform other tasks. Furthermore, we combine SDN and NDN to study the impact that SDN have when applied in VANETs. SDN centralises the network, allowing the vehicles to follow the instructions provided by an SDN controller. The SDN controller is connected to RSUs that act as gateways and instructs them to change their transmission power to connect with more vehicles. The SDN controller, also, calculates routing paths between vehicles to achieve multi-hop connectivity between them.

[Manzo et al., 2019] presents a data-driven centralized approach to resource-efficient, QoS-aware dynamic management of FC. We propose a Deep Learning strategy, which employs a Convolutional Neural Network (CNN) to capture the relationships between patterns of users mobility, of content diffusion and replication, and FC performance in terms of resource utilization and of content availability within a given area. [Rizzo et al., 2020b] introduces a new version of FC, called Cellular Floating Content (CFC), which optimizes the use of bandwidth and memory by adapting the content replication and storage strategies to the spatial distribution of users, and to their mobility patterns. [Rizzo et al., 2020b] partitions users into small “local communities”, optimally weights their contributions to the FC paradigm according to their specific mobility features and the resources required. Our main goal is to achieve a target performance level.

In [Manzo et al., 2020] we combine FC, NDN and SDN to address the issue of persistent partitioning that arises in VANETs. We propose Deep-NDN, a communication scheme that allows content retrieval in fragmented



and highly dynamic network topologies with applications that require tight delay constraints. Our goal is to achieve the application's required hit ratio in an efficient, resource aware, manner. To manage the DeepNDN algorithm we employ a CNN architecture for capturing the relations between spatio-temporal patterns of vehicular mobility and content requests of vehicles.

**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 and from other Internet sources. Based on this information, we developed a vehicular traffic re-routing that considers traffic conditions and public safety issues [Souza et al., 2019a]. We proposed an efficient algorithm named as Better Safe Than Sorry (BSTS), based on Pareto-efficiency. Simulation results have shown a better trade-off between mobility and safety than state-of-the-art approaches. Furthermore, we introduced Safe and Sound (SNS) [Souza et al., 2019b], a non-deterministic multi-objective re-routing approach for improving traffic efficiency and reduce public safety risks. Simulation results revealed that when compared to state-of-the-art approaches, SNS reduces the CPU time of the re-routing algorithm in approximately 99% and decreases the average safety risk for drivers and passengers in at least 30% while keeping efficient traffic mobility.

We also explored how emerging technologies can be used to enhance automated driving systems from different perspectives, such as driving safety and transportation efficiency [Souza et al., 2020]. We conduct a case study using real-world data to show how 5G networks and Edge Computing can be used together to provide a more reliable path planning service considering predicted future urban dynamics. Finally, we investigate the design principles for Fog-enabled Vehicular Software Defined

Networking (VSDN) focusing on the perspectives of the systems, networking, and services [Souza et al., 2019a]. We evaluated these design principles in a use case of a traffic management system for a fast traffic accident rescue, using real traffic accident data.

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

### **Mobility-induced Service Migration in Urban Environments**

Disruptive applications for mobile devices that can be enhanced by Edge Computing facilities are emerging, such as the Internet of Things, Immersive Media, and Connected and Autonomous Vehicles. In this context, Edge Computing is an architecture expected to meet requirements imposed these applications. Edge Computing aims to introduce computing capabilities in the path between the user and the Cloud to execute tasks closer to where they are consumed, thus mitigating issues, such as latency, context awareness, and mobility support. The present project aims to create models to understand urban mobility and its impact on mobile applications provisioned at the edge. We aim to model different aspects of mobility and evaluate emerging classes of mobile applications. We will create models to understand mobility and mobile applications, thus allowing the creation of better mobility management algorithms and protocols. We first developed an origin-destination mobility flow clustering tool that was used to evaluate public transportation systems with real data.

**Research staff:** D. O. Rodrigues, T. Braun

### **Low Latency Service Management for Vehicular Fog Computing**

Smart cities will enable the deployment of innovative applications, such as connected and autonomous vehicles. In this context, smart transportation and cooperative sensing services will be essential to improve traffic safety. The concept of Vehicular Fog Computing (VFC) expands cloud resources in the far edge with vehicles on-board units. We raise the challenges of stable quality of service provision, service migration schemes, and proactive VFC resources mapping for the continuous service execution. Specifically, we propose a mobility aware service management to automate the service assignment for mobile service requester and mobile

fog nodes. We suggest a distributed clustering of fog nodes with similar trajectories at the same time into service zones. To validate the impact of the proposed service management approach, we consider vehicles interested in cooperative sensing services that share their trajectories plans and on-board cloud resources. For results, we expect to provide quality of service assurance for greedy and low latency services for VFC.

**Research staff:** H. Santos, 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 [Schärer et al., 2019]. 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. 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.

## **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 148 parallel threads

(74 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 Ph.D. Theses

- Mikael Gasparyan "Service-Centric Networking", May, 2020. URL: <http://tiny.cc/saytsz>
- Luca Luceri "Privacy Leakage And the Manipulation of Public Opinion in Online Social Networks", March, 2020. URL: <http://tiny.cc/2bytsz>
- José Luis Carrera Villacrés "Indoor Positioning and Tracking Methods for Mobile Wireless Devices", October, 2019. URL: <http://tiny.cc/7bytsz>

## 4.5 Master's Theses

- Jesutofunmi Ademiposi Ajayi "Live eNodeB Container Migration in LTE Mobile Networks", September, 2019. URL: <http://tiny.cc/jc6nsz>

## 4.6 Bachelor's Theses

- Jonas Furrer "A Deep Learning Approach for Indoor Localization", June, 2020. URL: <http://tiny.cc/zdytsz>
- Christoph Noetzli "Field of View Prediction based on Neural Networks for 360deg Video Streaming", May, 2020. URL: <http://tiny.cc/0eytsz>
- Mattia Pedrazzi "Evaluation of MPTCP in Satellite Networks", February, 2020. URL: <http://tiny.cc/2eytsz>
- Dave Meier "A comparative study of route update strategies in SDN based WSN", January, 2020. URL: <http://tiny.cc/3eytsz>
- Vincent Hofer "Bloom Filter-based Routing for Dominating Set-based Service-Centric Networks", December, 2019. URL: <http://tiny.cc/6eytsz>
- Balz Aschwanden "Management of SDN/NFV based Mobile Networks", September, 2019. URL: <http://tiny.cc/aeysz>

- Ryan David Aebi "Reinforcement Learning-designed LSTM for Trajectory and Traffic Flow Prediction", September, 2019. URL: <http://tiny.cc/eeysz>

## 4.7 Awards

- Best Poster Award from the AdHoc-Now 2019 conference for the paper "Floater: Post-disaster Communications via Floating Content".

## 4.8 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 Matura Exams at Gymnasium Langenthal
- 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
- Guest editor Special Issue Elsevier Computer Communications

## Public events

- **Study Week on Fascinating Informatics:** At this event, Jakob Schärer taught three high school students how to use microcontrollers to address the propagation delay and internal clocks inaccuracy within a network of nodes, 6-11 September, 2019. Further details are available at: <https://bit.ly/2ZP1eDW>
- **Summer School 2019:** A 3-day seminar organized together with the TNS group of University Fribourg and the IIUN of University Neuchâtel, at Gruyères, Switzerland, 28-30 August, 2019. Further details are available at: <https://bit.ly/2FwS9cd>

## Conference Program Committees

### Torsten Braun

- 11th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT 2019), Dublin, Ireland, October 28-30, 2019.
- 11th ICT Innovations Conference 2019, Ohrid, Macedonia, October 17-19, 2019.
- 16th IEEE Consumer Communications and Networking Conference (CCNC 2020), Las Vegas, USA, January 10-13, 2020.
- 21st IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM) 2020, August 31 - September 3, 2020
- IEEE Global Communications Conference (GLOBECOM 2019), December 9-13, 2019, Waikoloa, HI, USA

- IEEE/IFIP Network Operations and Management Symposium 20-24 April 2020, Budapest, Hungary
- The 35th ACM Symposium On Applied Computing Brno, Czech Republic, March 30-April 3, 2020
- 31st International Teletraffic Congress (ITC 31), 27-29 Aug. 2019, Budapest, Hungary
- IEEE International Conference on Communications, 7-11 June 2020
- 18th International Conference on Ad Hoc Networks and Wireless (AdHoc-Now 2019), Luxembourg, 1-3 October 2019
- IEEE/ACM International Symposium on Quality of Service, 15-17 June 2020
- The 16th IEEE International Conference on Mobile Ad-Hoc and Smart Systems, Monterey, CA, USA, November 4 - 7, 2019
- 22nd ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems, November 25th - 29th, 2019, Miami Beach, USA
- IEEE/ACM International Symposium on Quality of Service, 15-17 June 2020
- 12th IFIP Wireless and Mobile Networking Conference September 11-13, 2019, Paris, France
- 3rd Workshop on Advances in Slicing for Softwarized Infrastructures (S4SI). June-29, 2020
- 7th International Workshop on the Recursive InterNetwork Architecture (RINA 2020), February 24, 2020, Paris, France
- IEEE ACM International Conference on Utility and Cloud Computing, 02 - 05 Dec 2019, Auckland, New Zealand
- 19th International Conference, NEW2AN 2019, and 12th Conference, ruSMART 2019, St. Petersburg, Russia, August 26-28, 2019



## **Project and Person Reviewing Activities**

### **Torsten Braun**

- Research Council of Norway
- Luxembourg National Research Fund
- Academy of Finland
- European Science Foundation
- Swiss National Science Foundation
- Deutsche Forschungsgemeinschaft
- Tampere University, Finland
- Universität Hamburg

## **Journal Article Reviewing Activities**

### **Torsten Braun**

- Springer Informatik Spektrum
- Elsevier Computer Communications
- Transactions on Emerging Telecommunications Technologies

## **Talks and Tutorials**

### **Torsten Braun**

- Evolution der Mobilfunknetze von 4G über 5G zu 6G, Digitaltag, Bern, September 3, 2019
- Keynote talk: "5G Edge Computing to Support Education Services", World 5G Convention, Beijing, November 22, 2019
- Invited Talk: "Communication Mechanisms for Service-Centric Networking", COST Action RECODIS MCM Meeting, Gdansk, February 5, 2020
- Keynote talk: "Mobile Edge Computing to Support Augmented and Virtual Reality Applications", International Forum of Ocean Information 2020, Harbin, April 10, 2020

## PhD Committee Memberships

### Torsten Braun

- Saleem Raza (PhD Jury), Otto-von-Guericke-Universität Magdeburg, March 11, 2020
- Antonio di Maio (PhD Jury), University of Luxembourg, June 3, 2020

## 4.9 Publications

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

### Journal Papers

- Rizzo, G., Marsan, M.A., Braun, T., Manzo, G. (2020b). Optimal Strategies for Floating Anchored Information with Partial Infrastructure Support. In *Vehicular Communications*, <https://doi.org/10.1016/j.vehcom.2020.100287>, August 2020.
- Santos, H., Alencar, D., Meneguette, R., Rosário, D., Nobre, J., Both, C., Cerqueira, E., Braun, T. (2020). A multi-tier fog content orchestrator mechanism with quality of experience support. In *Computer Networks*, vol. 177, <https://doi.org/10.1016/j.comnet.2020.107288>, May 2020.
- Luceri, L., Andreoletti, D., Tornatore, M., Braun, T., Giordano, S. (2020a). Measurement and control of geo-location privacy on Twitter. In *Online Social Networks and Media*, vol. 17, <https://doi.org/10.1016/j.osnem.2020.100078>, May 2020.
- Villacrés, D.C., Villacrés, J.L.C., Braun, T., Zhao, Z., Gómez, J., Carabalí, J.Q. (2020). Fog Harvesting and IoT based Environment Monitoring System at the Ilalo volcano in Ecuador. In *International Journal on Advanced Science, Engineering and Information Technology*, vol. 10, <https://doi.org/10.18517/ijaseit.10.1.10775>, April 2020.

- Na, W., Dao, N.N., Kim, J., Ryu, E.S., Cho, S. (2020). Simulation and measurement: Feasibility study of Tactile Internet applications for mmWave virtual reality. In *ETRI Journal*, vol. 42, <https://doi.org/10.4218/etrij.2019-0284>, April 2020.
- Souza, A.M., Oliveira, H.F., Zhao, Z., Braun, T., Villas, L.A., Loureiro, A.A.F. (2020). Enhancing Sensing and Decision-Making of Automated Driving Systems With Multi-Access Edge Computing and Machine Learning. In *IEEE Intelligent Transportation Systems Magazine*, <https://doi.org/10.1109/MITS.2019.2953513>, March 2020.
- Machado, J.S., Costa, I., Canto, J.V.S., Barbosa, J.L.V., Braun, T., Pessin, G. (2020). Toward a More Reliable System for Contingency Selection in Static Security Analysis of Electric Power Systems. In *IEEE Systems Journal*, vol. 14, <https://doi.org/10.1109/JSYST.2019.2938607>, March 2020.
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- Souza, A.M., Braun, T., Botega, L.C., Cabral, R., Garcia, I.C., Villas, L.A. (2019a). Better safe than sorry: a vehicular traffic re-routing based on traffic conditions and public safety issues. In *Journal of Internet Services and Applications*, <https://doi.org/10.1186/s13174-019-0116-9>, September 2019.
- Luceri, L., Deb, A., Giordano, S., Ferrara E. (2019). Evolution of bot and human behavior during elections. In *First Monday*, vol. 24, <https://doi.org/10.5210/fm.v24i9.10213>, September 2019.

## Chapters

- Dao, N.N., Tran, Q.D., Dinh, N.T., Cho, S., Braun, T. (2020). Edge computing architectures. In *Edge Computing: Models, technologies and applications*, *IET*, [https://doi.org/10.1049/PBPC033E\\_ch2](https://doi.org/10.1049/PBPC033E_ch2), June 2020.

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- Xenakis, D., Gasparyan, M., Braun, T. (2020). Running Written Exams Online at Bern University amid the COVID-19 Pandemic. In *ACM Sigcomm Education Workshop and Community Discussion (SIGCOMM Edu 2020)*, Virtual Workshop, August 5-6, 2020.
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- Marandi, A., Braun, T., Salamatian, K., Thomos, N. (2020b). Network Coding-based Content Retrieval based on Bloom Filter-based Content Discovery for ICN. In *IEEE International Conference on Communications (ICC 2020)*, Dublin, Ireland, June 7-11, 2020.
- Marandi, A., Hofer, V., Gasparyan, M., Braun, T., Thomos, N. (2020a). Bloom Filter-based Routing for Dominating Set-based

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- Manzo, G., Otálora, S., Braun, T., Marsan, M. A., Rizzo, G., Nguyen, H. (2019). DeepFloat: Resource-Efficient Dynamic Management of Vehicular Floating Content. In *IEEE 31st International Teletraffic Congress (ITC 31)*, Budapest, Hungary, August 27-29, 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

### 3D Integrable Frame Fields for Hexahedral Meshing

Hexahedral meshes play an important role in computational engineering, e.g. simulations, due to its superior numerical behavior than tetrahedral meshes, such as faster convergence and higher precision. Although algorithmic hexahedral meshing with guarantees on robustness and quality has been a hot research topic in the past decades, it remains an unsolved problem. One of the promising directions called parameterization-based hexahedral meshing 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 problem can be split into two steps: (1) generation of a surface-aligned 3D frame field and (2) construction of an integer-grid map that best aligns to the frame field. The main robustness issue stems from the fact that smooth 3D frame fields generated with the state-of-the-art methods are often not integrable such that heavy distortions and degeneracies appear in integer-grid maps.

The non-integrability of the 3D frame field, from the singular graph point of view, can be further categorized as (1) global topological inconsistencies such as the invalid singular node where a valence 3 singular arc and a valence 5 singular arc meet, and (2) local topological inconsistencies,

e.g. complex singular arc types, and geometric distortion of singular arcs. Finding a 3D frame field with a globally hex-meshable singularity structure has been a "holy grail problem" and is not in the scope of this project. Instead, we focus on optimizing for an as-integrable-as-possible 3D frame field which satisfies the matching constraints of the initial 3D frame field obtained with the state-of-the-art method, together with the tetrahedral mesh where the frame field live. Since the problem is highly non-linear and non-convex, we break it down into two sub-problems: optimizing the underlying tetrahedral mesh and optimizing the 3D frame field. In the mesh optimization step, the mesh vertices are taken as variables and the singular graph is smoothed because the integrability energy tends to align the singular edges with the frame field direction. Combined with remeshing operations, the local defects of the singular graph are eventually fixed. In the field optimization step, we seek for an as-integrable-as-possible frame field that commits to the matchings of the initial frame field. In the end, the algorithm results in a 3D frame field based on which an integer-grid map of higher quality in terms of geometric distortion and local degeneracies can be constructed.

**Research staff:** Heng Liu, David Bommes

**Financial support:** European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program, project AlgoHex, No. 853343

## **Restricted Polyhedron Hexahedral-dominant Meshing**

While a robust algorithm for high-quality pure hexahedral meshing remains elusive, hexahedral-dominant meshing is an attractive alternative that trades a number of non-hexahedral elements in the output for increased robustness. Especially for cases where pure-hexahedral meshing algorithms fail to mesh (sometimes large) parts of the input, it can be desirable to at least have some conforming volumetric mesh in those problematic regions. A restriction to a limited number of legal polyhedra, i.e., tetrahedrons, wedges, and pyramids make the resulting meshes more readily usable with existing FEM software as opposed to allowing arbitrary polyhedra.

Such additional allowed polyhedra are not just a stopgap solution, they can also be seen as the natural way to allow for spatially varying element sizes, or conversely, constant element sizes on difficult domains such as



ramps, where one side of the ramp requires a much lower number of hexahedral sheets than the other. As the aforementioned polyhedra can all be obtained by merging the vertices of hexahedrons, they are well-suited to accommodate such geometry.

Nonetheless, it is still preferable to keep the number of non-hex elements low and away from locations that are critical to downstream applications.

In this research project we aim at developing a robust algorithmic pipeline for this task, while providing control over the location of non-hexahedral elements.

**Research staff:** Martin Heistermann, David Bommers

**Financial support:** European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program, project AlgoHex, No. 853343

## **Quad Mesh Generation for Computer Graphics and Simulation**

Quad meshes are discrete surface representations. Consider for example the surface of the earth tessellated by parallel and meridian lines. If we sample the coordinates in space of the points of intersection of parallel and meridian lines and replace the arcs that joined them by straight line segments, we obtain a discrete quad mesh of the earth's surface. Except for the poles, all vertices of this quad mesh are regular, they are adjacent to four quadrilateral faces. Singular vertices are those with more or less than four adjacent faces. Apart from cartography of the earth, which is already a well-understood problem, many applications require similarly a coordinate system on the surface, that can be easily subdivided, and oriented to salient features or curvature lines for example, or design constraints like a budget on the number of quadrilaterals while keeping a good approximation of the original surface.

This project aims to produce algorithms that support such designer or domain-specific constraints for the generation of quad meshes, with the appropriate degree of control over the different quality criteria. State-of-the-art methods decompose the generation of quad meshes into frame field generation followed by its parametrization. In simple words two linearly independent vector fields representing the desired orientations of the quad mesh edges and its lengths at every sampling point are prescribed or

computed from the constraints, then the integration of the frame field produces a parameterization, that may be similar or arbitrarily different from the frame field depending on how integrable the frame field was.

We focus on the computation of integrable frame fields that are meshable with low alignment errors. We have decided to work on the frame-field based approach because it allows the most flexible setting to consider the user's constraints. Formulating and optimizing integrability energies is a promising approach for the quad meshing problem. In this project we target a direct optimization of integrability via an elegant formulation in a polar representation of the frame field.

**Research staff:** Nicolas Gallego-Ortiz, David Bommès

## **Injective Mapping of Volumetric Domains**

Mapping an arbitrary volumetric domain to another one in an injective way is a challenging problem. If the domain is decomposed into tetrahedra, current methods tend to create "flipped" elements, making the mapping locally non-injective. While most mapping methods generally take a global approach by trying to minimize a particular energy, some others focus on local operations, i.e. changing the mesh's topology.

Such a method called "Progressive Embeddings" focuses on two local operations, namely "edge collapsing" and "vertex splitting" to solve this issue on surfaces. By successively collapsing edges, one can reduce a surface mesh to its boundary and a single interior vertex. This interior vertex can then be split in successions, carefully placing the new vertex in a way that does not create flipped triangles. At the end of this second step, the mesh presents the same topology as the original surface but without any flipped triangles, making it an injective mapping.

However, this method cannot directly be applied to volumetric domains because there is no guarantee that collapsing edges will result in a single interior vertex. Collapsing edges not satisfying the so-called "link condition" will change the mesh's topology in an irremediable way and are thus prohibited. As it happens, collapsing edges in a tetrahedral mesh can lead to blocking configurations where all remaining (interior) edges are not collapsible.

This project aims at adapting the "Progressive Embedding" method to work with volumetric tetrahedral meshes. A key observation is that those uncollapsible edges are generally connected into triangle structures. Those are

triangles in the sense that they are made of three connected edges but are not part of the mesh's faces. Furthermore, in most cases, there is an edge of valence 3 at the "center" of this triangle. By splitting those valence-3 edges and then collapsing one of the new edges created by the split, this uncollapsible configuration is resolved and the originally uncollapsible edges become collapsible. However, those cycles can also appear even without a valence-3 edge. Those corner cases are studied in the current work.

The main difference between our approach and the original "Progressive Embedding" method is that we allow to alternate between edge splits and collapses, whereas the original method uses a sequence of edge collapses only, then followed by vertex splits only. This difference also represents a challenge to make our split-collapse sequence reversible.

**Research staff:** Valentin Nigolian, David Bommes

**Financial support:** European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program, project AlgoHex, No. 853343

## Surface Reconstruction

With the advent of increasingly affordable and powerful 3D scanning devices capable of capturing high resolution range data about real-world objects, surface reconstruction has become an increasingly studied subject. The huge amount of data captured by the scanning devices requires fast and reliable algorithms to turn a point cloud into a different representation better suited for a variety of applications domain.

In this project, we tackle in particular the reconstruction of a surface from an unoriented point cloud captured from a 3D scanning device. Current state of the art methods often rely on the assumption that the reconstructed surface is watertight or that the input data is oriented. In this work, we want to relax this assumptions and even be able to find a suitable space representation depending on the data, for example by switching to a curve (1-Manifold) representation where suitable. Another challenge we want to address it the ability to preserve sharp feature where they are likely.

We are inspired by previous work on sketch drawings simplification and vectorization, where it has been successfully shown that techniques used for quad-meshing can be applied to efficiently solve the problem. One of

the main challenge involved is to lift the pipeline from a 2D, pixel based approach, to the 3D space. This is not trivial as some of the involved algorithms are well defined and studied in the 2D case but become much more complicated when you want to apply them in the 3D domain.

The main difference with previous approaches is the smaller number of assumptions we make on the input data, the ability to represent our reconstructed domain with different representations and the ability to adapt the output representation intuitively to some desired scale provided by the user.

**Research staff:** Simone Raimondi, David Bommes

## 5.4 Further Activities

### Invited Talks

#### David Bommes

- “Integer-Grid Map Optimization for Hexahedral Mesh Generation”. CECAM-Lorentz Workshop: “Computing Complex Mechanical Systems”, EPFL Lausanne, Switzerland, January 2020.
- “Integer-Grid Maps for Quadrilateral and Hexahedral Mesh Generation”. Keynote Talk at International Meshing Roundtable, Buffalo, USA, October 2019.
- “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.

### Editorial Boards

#### David Bommes

- Computer Graphics Forum (CGF) Journal, Associate Editor

- Graphical Models (GMOD) Journal, Associate Editor
- Computers & Graphics (CAG), Associate Editor

## Conference Organization

### David Bommes

- Shape Modeling International (SMI) 2020, Program Co-Chair, June 2 – 4, 2020, Strasbourg, France
- Eurographics Symposium on Geometry Processing (SGP) 2019, Program Co-Chair, July 6 – 10, 2019, Milan, Italy

## Conference Program Committees

### David Bommes

- ACM SIGGRAPH 2019
- EUROGRAPHICS (EG) 2019
- Symposium on Geometry Processing (SGP) 2020
- Graphics Interface (GI) 2019
- Geometric Modeling and Processing (GMP) 2019 & 2020
- Solid and Physical Modeling (SPM) 2020
- Vision, Modeling and Visualization (VMV) 2019 & 2020
- CAD/Graphics 2019

## Reviewing Activities

### David Bommes

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

## 5.5 Publications

### Journal Publications

- David Palmer, David Bommes, Justin Solomon: Algebraic representations for volumetric frame fields, *ACM Transactions on Graphics*, Volume 39(2), (Presented at ACM SIGGRAPH), 2020.
- Paul Zhang, Josh Vekhter, Edward Chien, David Bommes, Etienne Vouga, Justin Solomon: Octahedral Frames for Feature-Aligned Cross Fields, *ACM Transactions on Graphics*, Volume 39(3), (Presented at ACM SIGGRAPH), 2020.
- Max Lyon, David Bommes, Leif Kobbelt: Cost Minimizing Local Anisotropic Quad Mesh Refinement, *Computer Graphics Forum*, Volume 39(5), (Presented at SGP), 2020.
- Tibor Stanko, Mikhail Bessmeltsev, David Bommes, Adrien Bousseau: Integer-Grid Sketch Simplification and Vectorization, *Computer Graphics Forum*, Volume 39(5), (Presented at SGP), 2020.
- 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.

## 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 quantities

about objects in the scene, or semantic attributes such as their category, their function, etc. In order to achieve this aim, we use a systematic approach based on three steps: 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 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 synthetic and real data. Currently, our efforts in imaging 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

### Unsupervised Learning of Depth and Camera Pose from Video

Structure from motion (SfM) is the process of estimating the 3D structure from 2D images. Robust SfM solutions support many applications such as robotics, autonomous driving and augmented reality. Traditionally, SfM is solved by pure geometric reasoning. Conventional methods leverage handcrafted geometric features (e.g. SIFT) or rely on Bundle Adjustment.



Although these methods are effective in regular scenes, they fail in areas of low texture, complex geometry and occlusions due to the reliance on feature correspondences. Recent years have witnessed the development of deep learning. To overcome the weakness of traditional methods, many deep learning based methods have been proposed to solve SfM. The aim of our project is to train a model on monocular videos to predict dense depth map and camera pose by unsupervised deep learning. In common with prior works, we use view synthesis as the supervisory signal. The novelty of our approach is that we are investigating the impact of geometric data augmentation on depth and pose prediction.

**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

## Unsupervised Learning of Image Representations

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 design of these pretext tasks appears to be mostly based on intuition and trial and error. The recognition of image transformations has emerged as one successful principle for SSL tasks in the literature (e.g., classifying image rotations, recognizing artifacts, or classifying arrangements of patches). We studied why such pretext tasks learn good features. We observe that common to these tasks is that recognizing the image transformation is not possible by only observing local image patches (i.e., local image statistics), but rather requires modeling global image statistics, e.g., the shape of objects. Indeed, we find experimentally that such tasks do not perform well on datasets where the tasks can be solved based on local statistics alone (e.g., recognizing image rotations on images of faces). Following this insight, we design a novel learning-based image transformation called Limited Context Inpainting (LCI). In LCI a random image patch is extracted, inpainted based on only a thin border of context pixels, and pasted back in the image. The result is an image with natural local statistics but unnatural global statistics. Our experiments show that recognizing LCI, image warpings, and image rotations combined leads to state-of-the-art unsupervised feature performance.

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

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

## Self-Supervised Video Representation Learning

Supervised representation learning on video data via action recognition has a tendency to focus on appearance rather than motion features. This is due to the fact that action categories can often be recognized based on a single video frame. To build features that accurately represent motion features we design self-supervised learning tasks by recognizing transformations of the temporal domain. To build temporal transformations we

consider not only alterations of the natural frame order, but also alterations of the playback speed. We thus train a 3D-CNN to recognize if videos are played at different speeds, exhibit random re-orderings, show periodic motions, or have a warped temporal evolution, i.e., a temporally varying playback speed. Networks pre-trained using this SSL task achieve state-of-the-art performance on action recognition benchmarks. We also demonstrate that these representations perform better on time-related tasks such as video synchronization or recognizing the order of two non-overlapping video sequences.

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

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

## **Self-Supervised Feature Learning for 3D Human Pose Estimation**

Annotations for 3D human pose estimation require calibrated multi-view setups with specialized motion capture sensors and are thus expensive to obtain. We explore the use of self-supervised learning to reduce the amount of necessary 3D annotations. To this end, we exploit multi-view synchronized video data of a shared scene of a person performing different actions. As a self-supervised learning task, we pose the task of recognizing whether two different views are synchronized or not and whether they underwent the same horizontal flipping or not. To solve this task a network has to recognize non-rigid deformations in the human pose (assuming movement between un-synchronized frames). This in turn should require accurate modeling of the underlying 3D pose. We find that the learned features outperform prior SSL methods by a large margin when transferred to monocular 3D pose estimation with small amounts of labeled data.

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

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

## 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 less 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

## Boosting Bio-Signals Classification Generalization by Learning the Phase-Amplitude Coupling

Various hand-crafted feature representations of bio-signals rely primarily on the amplitude or power of the signal in specific frequency bands. The phase component is often discarded as it is more sample specific, and thus more sensitive to noise, than the amplitude. However, in general, the phase component also carries information relevant to the underlying biological processes. In fact, in this project we show the benefits of learning the coupling of both phase and amplitude components of a bio-signal. We do so by introducing a novel self-supervised learning task, which we call *phase-swap*, that detects if bio-signals have been obtained by merging the amplitude and phase from different sources. We show that neural networks trained on this task generalize better across subjects and recording sessions than their fully supervised counterpart.

**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.

## **Emergence of Object Segmentation in Perturbed Generative Models**

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

## **Unsupervised Depth Estimation**

The aim of this project is to build a model that can learn to estimate a depth map from a collection of random images. While typically this task requires

expensive and time-consuming human annotation, we aim to solve it in an unsupervised manner. We aim to first build a generative model that can generate realistic images of objects and their corresponding depth maps. The learning of the correct depth maps is encouraged via the introduction of different image transformations that do not affect image realism only when the depth map is also realistic. We also investigate different ways to deal with occlusions and artifacts that are introduced with 3D transformations. Once the generative model is trained, one can build an encoder to map real images to their depth map by going through the generator.

**Research staff:** Adam Bielski, Paolo Favaro

## **Sleep Physician Assistant System (SPAS)**

The ultimate goal of the project is to develop a platform to empower the sleep physicians and to simplify effectively their work. SPAS will act like a young apprentice, taking care of tedious job and learning continuously from the expert physician. A new personalized approach for the polysomnography (PSG) scoring and a data miner for whole data exploitation will ease the scoring procedure and will improve general diagnosis and treatment. Existing automated and semi-automated scoring software cannot provide personalized scores in the same way as the expert physician's judgement. Sleep scoring is the procedure of classifying PSG recordings (EEG, EOG and EMG). The whole night recording is divided into 30-s windows and the physician has to classify each epoch into one of the five sleep stages: awake W, stage N1, stage N2, stage and stage REM. Since 1960 several techniques have been employed to solve this task automatically. However, up to now, no system has proven to be a valid substitute for the sleep physician. The goal is to improve and optimize the recent deep learning-based scoring systems. SPAS aims to develop an automatic sleep scoring algorithm able to interactively query the sleep physician and to learn from his knowledge. In order to release an optimized interactive system, we focused on three closely related challenges: clustering sleep recordings – the deep learning architectures need to be trained on subgroups of PSG recordings; confidence estimation methods for sleep scoring neural networks – the system gives in output the final sleep scores along with the degree of confidence; query the physician and update the network – detect the uncertain forecast, the sleep physician corrects the uncertain (not-confident) answers of the network and the network will be updated (fine-tuning) by using this external knowledge. Considering the

architecture for an application in real-time, we are developing a scoring network that needs to process only temporal information related to the one preceding and the one succeeding epoch. A reduced memory requirement (less parameters to be trained) and low-latency characteristic may be advantageous in a real-time implementation.

**Research staff:** Luigi Fiorillo, Paolo Favaro

## 6.4 Master's Theses

- Dušan Mihajlov, "Self-Supervised Learning Using Siamese Networks and Binary Classifier", March 2020.

## 6.5 Bachelor's Theses

- Maurice Rupp, "StitchNet: Image Stitching using Autoencoders and Deep Convolutional Neural Networks", September 2019.
- Luca Rolshoven, "Facial Expression Recognition in the Wild", September 2019.
- Raoul Grossenbacher, "A Study of 3D Reconstruction of Varying Objects with Deformable Parts Models", July 2019.
- Alvaro Juan Lahiguera, "Motion deblurring in the wild replication and improvements", January 2019.

## 6.6 Further Activities

### Ph.D. Thesis Examiner

**Paolo Favaro**

- "Visual Recognition From Weakly Structured Supervision", Rodrigo Fonseca Santa Cruz Oliveira, Australian National University, 2019
- "Improving Wasserstein Generative Models For Image Synthesis And Enhancement", Jiqing Wu, ETH, 2019
- "An investigation into cues and priors for occlusion-free imaging", Jonna Sankaraganesh, IIT Kharagpur, 2020



- “Computational Light Field Photography Depth Estimation, Demosaicing, and Super-Resolution”, Yongwei Li, Mid Sweden University, 2020

## Invited Talks

### Paolo Favaro

- “Light Field Imaging”, Mid Sweden University, June 2020
- “Beyond Supervised Learning”, University of Edinburgh, February 2020
- “Model Based to Deep Learning Methods”, Google Computational Imaging Workshop, February 2020
- “Model Based to Deep Learning Methods”, Leica, Computational Imaging – Wetzlar Network Symposium, October 2019
- “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.

## 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
- ICPR 2020
- ECCV 2020

## **Journal Committees**

### **Paolo Favaro**

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

## **Reviewing Activities**

### **Paolo Favaro**

- NeurIPS 2019
- ICCP 2019
- ICML 2020

### **Simon Jenni**

- CVPR 2020
- ECCV 2020
- TPAMI 2020
- ICPR 2020

### **Adrian Wälchli**

- ICPR 2020

## Refereed Conference Proceedings

- Q. Hu, A. Wälchli, T. Portenier, M. Zwicker and P. Favaro, “Learning to Take Directions One Step at a Time”, International Conference on Pattern Recognition (ICPR), 2020.
- A. Lemkhenter and P. Favaro, “On the Importance of Learning the Phase-Amplitude Coupling in Bio-signals Classification”, German Conference on Pattern Recognition (DAGM GCPR), 2020.
- S. Jenni and P. Favaro, “Video Representation Learning by Recognizing Temporal Transformations”, European Conference on Computer Vision (ECCV), 2020.
- J. Page and P. Favaro, “Learning to Model and Calibrate Optics via a Differentiable Wave Optics Simulator”, IEEE International Conference on Image Processing (ICIP), 2020.
- G. Meishvili, S. Jenni and P. Favaro, “Learning to Have an Ear for Face Super-Resolution”, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), 2020.
- S. Jenni, H. Jin and P. Favaro, “Steering Self-Supervised Feature Learning Beyond Local Pixel Statistics”, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), 2020.
- L. Fiorillo, M. Wand, I. Marino, P. Favaro, F. D. Faraci, “Temporal dependency in automatic sleep scoring via deep learning based architectures: An empirical study”, 42nd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2020.
- A. Bielski and P. Favaro, “Emergence of Object Segmentation in Perturbed Generative Models”, Conference on Neural Information Processing Systems (NeurIPS), 2019.

## Technical Reports

- S. Jenni and P. Favaro, “Self-Supervised Multi-View Synchronization Learning for 3D Human Pose Estimation”, under review (ACCV), 2020.

- J. Page, F. Saltarin, Y. Belyaev, R. Lyck and P. Favaro, “Learning to Reconstruct Confocal Microscope Stacks from Single Light Field Images”, under review, 2020.
- A. Szabó, G. Meishvili and P. Favaro, “Unsupervised 3D Shape Learning from Image Collections in the Wild”, arXiv:1910.00287, Technical Report, 2019.

## 7 Cryptology and Data Security Group

### 7.1 Personnel

- Head:** Prof. Dr. Christian Cachin  
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- Office Manager:** Bettina Choffat  
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- Anna Parker  
email: anna.parker@inf.unibe.ch  
(July 2020–August 2020)
- Alex Pellegrini  
email: alex.pellegrini@inf.unibe.ch
- Luca Zanolini  
email: luca.zanolini@inf.unibe.ch

### 7.2 Overview

The Cryptology and Data Security Group has been established in 2019 by Christian Cachin at the University of Bern. The research of the group broadly investigates security and privacy in a digital world. Concrete top-

ics include 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

### Advanced Consensus Protocols

Protocols for reaching agreement among the nodes in a distributed network have received renewed interest in recent years due to their relevance for blockchain systems. In principle, every transaction executed on a blockchain requires a consensus decision from the participating nodes. Platforms like Bitcoin, Ethereum, Ripple, and many others have relaxed key assumptions made in earlier models and operate agreement protocols over the Internet today.

Although research on distributed consensus has been a central and well-investigated problem in distributed computing, the resurging interest from practice has brought up new questions. At the same time, many blockchain consensus algorithms operating today lack formal analysis. This project addresses *advanced consensus protocols* on a fundamental level and aims at extending the understanding of protocols for distributing trust.

In particular, the project devises consensus protocols with *asymmetric quorums*, which allow the expression of flexible and subjective trust. Every participating node should freely choose which other nodes it trusts, unlike current approaches. We have already developed agreement protocols with asymmetric trust and intend to show further how existing Byzantine fault-tolerant (BFT) consensus methods with symmetric trust can be generalized to subjective assumptions.

A second goal of this project concerns *scalable non-linear consensus protocols*. These protocols allow for parallel execution and promise a large increase in transaction throughput. Instead of a hash chain of blocks, such protocols create a directed acyclic graph (DAG) through hash function ap-

plications (a *hash DAG*), which commits a partially ordered transaction history that may contain concurrent operations. This project aims at understanding the safety and liveness properties of hash-DAG consensus protocols formally and relating them to established notions in distributed computing.

The third part of the project realizes a *flexible consensus models*. Current implementations of BFT consensus protocols use threshold quorums as their trust model, where all  $n$  nodes are treated equally and some fraction  $f < n/3$  of them may become faulty. This assumption can be justified by independence among the nodes. Yet, node failures are often dependent on each other. In this context, general Byzantine quorum systems and asymmetric quorums show a way to implement consensus with flexible trust. This work develops practically useful instantiations of consensus with generalized and asymmetric trust models and demonstrates them in a toolkit for consensus.

**Financial support:** Swiss National Science Foundation (SNSF), grant agreement Nr. 200021\_188443.

## 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.

Research in the area of distributed cryptography has explored the combination of a threshold-cryptography library with different distributed communication and consensus platforms.

## Quorum systems

Quorum systems are a key mathematical abstraction in distributed fault-tolerant computing for capturing trust assumptions. A quorum system is a collection of subsets of all processes, called quorums, with the property that each pair of quorums have a non-empty intersection. They can be found at the core of many reliable distributed systems, such as cloud computing platforms, distributed storage systems and blockchains. In this project we aim at finding a new *algebraic model for quorum systems*. We start with classical majority-based quorum systems and extend this to Byzantine quorum systems with qualified majorities. We are developing an algebraic representation of the theory underlying quorum systems, by making use of polynomial ideals, and incorporate properties of quorum systems into a representation using algebraic varieties. To achieve this goal, we exploit properties of Boolean Gröbner bases. Our work provides a novel approach to test quorum systems properties from both algebraic and algorithmic perspectives.

**Financial support:** Swiss National Science Foundation (SNSF), grant agreement Nr. 200021\_188443.

## 7.4 Master's Theses

- Christina Müller (jointly supervised with Pascal Felber, University of Neuchatel), "Execution of smart contracts with ARM TrustZone", August 2019.
- Jovana Micic, "Security analysis of Ripple consensus", August 2019.
- Heng Xin Fun (submitted to the Faculty of Informatics, USI Università della Svizzera italiana), "End-to-end verifiable Internet voting", September 2019.
- Nathalie Froidevaux, "Threshold cryptography with Tendermint Core", January 2020.
- Patrick Hodel, "BLS Signatures in PROTECT", June 2020.

## 7.5 Bachelor's Theses

- Angela Keller, "Quorum systems", August 2019.



- Sabine Brunner, “Evaluating the B3-condition in asymmetric quorum systems”, March 2020.
- Roland Widmer, “Byzantine-fault tolerant algorithms in DistAlgo”, July 2020.

## 7.6 Further Activities

### Invited Talks

#### Christian Cachin

- “Cryptographic tools for distributed computing.” 3rd Summer School on Practice and Theory of Distributed Computing (SPTDC), Virtual Event, July 2020.
- “Blockchain – Eine Einführung.” Schweizerische Bundesversammlung, Kommission für Wirtschaft und Abgaben des Nationalrats (WAK-N), Jan. 2020.
- “Distributing trust with blockchains.” Department of Informatics, Université de Fribourg, Jan. 2020.
- “Consensus with asymmetric trust.” Santa’s Crypto Get-Together (SantaCrypt), Prague, Czech Republic, Dec. 2019.
- “Consensus with asymmetric trust.” Workshop on Large-Scale Consensus and Blockchains, Simons Institute for the Theory of Computing, Berkeley (CA), USA, Oct. 2019.
- “Foundations of distributed trust.” School on Security & Privacy for Blockchains and Distributed Ledger Technology (BDLT), Vienna, Austria, Sept. 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.

## Conference Organization

### Christian Cachin

- **Program Chair** for 39th Symposium on Principles of Distributed Computing (PODC 2020), Online event.
- Tutorial Chair for 1st ACM Conference on Advances in Financial Technologies (AFT), Zurich, Switzerland.
- **Co-Chair** for Workshop on Blockchain Technology and Theory (BTT 2019), Budapest, Hungary.

## Conference Program Committees

### Christian Cachin

- Member of Program Committee for Crypto Valley Conference on Blockchain Technology (CVCBT) 2020, Online event.
- Member of Program Committee for Cryptoeconomic Systems Conference (CES '20), Boston, USA.
- 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.

### Giorgia Marson

- Member of Program Committee for Asiacrypt 2020 Conference, Online event.

## 7.7 Publications

### Conference Papers

- C. Cachin, D. Collins, T. Crain, and V. Gramoli, “Byzantine fault tolerant vector consensus with anonymous proposals,” in *Proc. 23rd European Symposium On Research In Computer Security (ESORICS)* (L. Chen, N. Li, K. Liang, and S. Schneider, eds.), vol. 12308 of *Lecture Notes in Computer Science*, pp. 133–152, Springer, 2020.
- C. Cachin and B. Tackmann, “Asymmetric distributed trust,” in *Proc. 23rd International Conference on Principles of Distributed Systems (OPODIS)* (P. Felber, R. Friedman, S. Gilbert, and A. Miller, eds.), vol. 153 of *Leibniz International Proceedings in Informatics (LIPIcs)*, pp. 7:1–7:16, Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, 2019. Preliminary version appears as arXiv:1906.09314 [cs.DC], <https://arxiv.org/abs/1906.09314>, 2019.
- C. Cachin, A. De Caro, P. Moreno-Sanchez, B. Tackmann, and M. Vukolić, “The transaction graph for modeling blockchain semantics,” in *Proc. Cryptoeconomic Systems Conference (CES ’20)*, Mar. 2020. Preliminary version appears as Cryptology ePrint Archive Report 2017/1070, <https://eprint.iacr.org/2017/1070>, 2017.
- M. Brandenburger, C. Cachin, R. Kapitza, and A. Sorniotti, “Trusted computing meets blockchain: Rollback attacks and a solution for Hyperledger Fabric,” in *Proc. 38th Symposium on Reliable Distributed Systems (SRDS)*, Oct. 2019. Preliminary version appears as arXiv:1805.08541 [cs.DC], <https://arxiv.org/abs/1805.08541>, 2018.

### Proceedings, Books and Book Chapters

- Y. Emek and C. Cachin, eds., *Proc. 39th ACM Symposium on Principles of Distributed Computing (PODC ’20)*, ACM, 2020.
- C. Cachin, “Byzantine faults,” in *Concurrency: The Works of Leslie Lamport* (D. Malkhi, ed.), pp. 67–81, ACM, 2019.

## Preprints and Other Publications

- O. Alpos and C. Cachin, “Consensus beyond thresholds: Generalized Byzantine quorums made live.” e-print, arXiv:2006.04616 [cs.DC], 2020.
- A. Pellegrini and L. Zanolini, “An Algebraic Model For Quorum Systems.” e-print, arXiv:arXiv:2005.08536 [cs.DC], 2020.
- C. Cachin and L. Zanolini, “Asymmetric Byzantine consensus.” e-print, arXiv:2005.08795 [cs.DC], 2020.

## 8 Logic and Theory Group

### 8.1 Personnel

<b>Head:</b>	Prof. Dr. T. Strahm	Tel.: +41 (0)31 631 49 98 email: thomas.strahm@inf.unibe.ch
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	N. Savić*	Tel.: +41 (0)31 511 76 08 email: nenad.savic@inf.unibe.ch (until June 2020)
	A. Rohani*	Tel.: +41 (0)31 511 76 09 email: atefeh.rohani@inf.unibe.ch
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<b>Emeriti:</b>	Prof. Dr. G. Jäger	email: gerhard.jaeger@inf.unibe.ch
<b>Guests:</b>	H. Künzi	University of Cape Town December 2019 - January 2020

\* 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)

## Explicit Reasons

This project is concerned with reasons why one believes something, reasons why one knows something, and reasons why one ought to do something. We develop formal languages in which reasons can be represented explicitly and investigate the logical properties of explicit reasons. To achieve this, we rely on the framework of justification logic. In particular, we present non-normal deontic logics with justifications. Further, we develop a semiring framework for justifications, and we engineer a possible world semantics for justifications that supports additional structure like graded justifications or probability distributions on justifications. Moreover, we add justifications and belief dynamics to Artemov's new foundations for epistemic logic.

**Research staff:** M. Baur, E. Lehmann, A. Rohani, N. Savić, T. Studer

**Financial support:** Swiss National Science Foundation (No. 184625)

## 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

- N. Savić: Non-classical Reasoning and Justifications

## 8.5 Master's Theses

- M. Baur: Semirings of Evidence

## 8.6 Bachelor's Theses

- B. Zahnd: Beispiele schwacher Implementationen des RSA-Kryptosystems

## 8.7 Awards

### Thomas Studer

- Recognition of outstanding achievements in teaching for "Modal Logic" (HS 2019)

### Jan Walker

- Paul Bernays Award for his PhD thesis "Finitist Axiomatic Truth"

## 8.8 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

- *ATR* and parameters, ABMV Meeting, Ludwig-Maximilians-Universität, Munich, December 2019

### Nenad Savić

- Justifications and Incomplete Information, Logic and Applications, Dubrovnik, Croatia, September, 2019.
- Non-classical Reasoning with Justifications, Bern/Prague Logic Seminar, May, 2020.

### Thomas Studer

- A problem with probabilistic CTL, Logic and Applications, Dubrovnik, September 2019
- Bayesian confirmation and justification, European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty, Belgrade, September 2019
- Subset semantics for justification logics, Workshop on Proof Theory, Modal Logic and Reflection Principles, Barcelona, November 2019
- Belief Expansion in Subset Models, Logical Foundations of Computer Science, Deerfield Beach, Florida, January 2020
- The proof theory of common knowledge and other modal fixed point logics, Logical Foundations of Computer Science, Deerfield Beach, Florida, January 2020
- No-go theorems for data privacy, Cryptology 2020, online, June 2020

## Technical and Research Committees

### Gerhard Jäger

- Member of the Scientific Council of the European Association for Computer Science Logic

### 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)
- 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
- Board member of the Swiss Society for Logic and Philosophy of Science
- Member of the Jury for Bernays Award
- Member of the Jury for Priz Schläfli
- Member of the Committee for the Promotion of Young Talents (Kommission Nachwuchsförderung) of ScNat
- Member of the Kantonale Maturitätskommission, Hauptexperte Informatik

### **Organized Events**

#### **Thomas Studer**

- Logic and Application, Inter University Centre Dubrovnik, 23-27 September 2019
- Deontic Logic, Annual Meeting of the SSLPS, Bern, 24-25 October 2019

## 8.9 Publications

- Michael Baur and Thomas Studer. Semirings of Evidence. *M. Dastani, H. Dong, L. van der Torre, editors, Proceedings of Logic and Argumentation CLAR 2020, volume 12061 of LNAI.* 42-57. Springer, 2020.
- Michael Bärtschi and Gerhard Jäger. Having a look again at some theories of proof-theoretic strength around  $\Gamma_0$ . *R. Kahle, M. Rathjen (eds.), The Legacy of Kurt Schütte.* Springer, 2020.
- Dragan Doderand and Paola Glavan and Bojan Marinkovic and Zoran Ognjanović and Thomas Studer. Probabilistic Consensus of the Blockchain Protocol. *G. Kern-Isberner, Z. Ognjanovic, editors, Symbolic and Quantitative Approaches to Reasoning with Uncertainty - ECSQARU 2019, volume 11726 of LNAI.* 469-480. Springer, 2019.
- Dragan Doder and Zoran Ognjanović and Nenad Savić. Multi-agent Logics for Reasoning About Higher-Order Upper and Lower Probabilities. *Journal of logic, language and information.* 77-107. Springer Netherlands 2019.
- Federico Faroldi and Meghdad Ghari and Eveline Lehmann and Thomas Studer. Impossible and Conflicting Obligations in Justification Logic. *A. Marra, F. Liu, P. Portner, F. Van De Putte, editors, Proceedings of DEON 2020.* 2020
- Silvia Ghilezan and Jelena Ivetic and Simona Kasterovic and Zoran Ognjanović and Nenad Savić. Towards Probabilistic Reasoning in Type Theory - The Intersection Type Case. *Herzig, Andreas; Kontinen, Juha (eds.) Foundations of Information and Knowledge Systems. Lecture Notes in Computer Science: Vol. 12012.* 122-139, Springer, 2020.
- Gehrard Jäger. Predicative Hierarchies. *T. Piecha, P. Schroeder-Heister (eds.), Proof-Theoretic Semantics.* University of Tübingen, 2019.
- Gerhard Jäger and Silvia Steila. From Mathesis Universalis to fixed points and related set-theoretic concepts. *S. Centrone, S. Negri, D. Sarikaya, P.M. Schuster (eds.), Mathesis Universalis, Computability*

*and Proof, Synthese Library, Studies in Epistemology, Logic, Methodology, and Philosophy of Science, Volume 412.* 113-129, Springer, 2019.

- Ioannis Kokkinis and Zoran Ognjanović and Thomas Studer. Probabilistic Justification Logic. *Journal of Logic and Computation*, 30(1). 257-280, 2020.
- Ioannis Kokkinis and Nenad Savić and Thomas Studer. Justification Logics with Probability Operators. *Z. Ognjanovic, editor, Probabilistic Extensions of Various Logical Systems.* 215-234. Springer, 2020.
- Eveline Lehmann and Thomas Studer. Belief Expansion in Subset Models. *S. Artemov, A. Nerode, editors, Proceedings of Logical Foundations of Computer Science LFCS'20, volume 11972 of LNCS.* 85-97, Springer, 2020.
- Hamzeh Mohammadi and Thomas Studer. Bayesian Confirmation and Justifications. *G. Kern-Isberner, Z. Ognjanovic, editors, Symbolic and Quantitative Approaches to Reasoning with Uncertainty - ECSQARU 2019, volume 11726 of LNAI.* 408-418. Springer, 2019.
- Thomas Studer. No-Go Theorems for Data Privacy. *Proceedings of the 7th International Cryptology and Information Security Conference 2020.* 74-84, 2020.

## 9 Pattern Recognition and Data Science Group

### 9.1 Personnel

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### 9.2 Overview

The Pattern Recognition and Data Science Group has been established in 2020 by Kaspar Riesen at the University of Bern. We broadly investigate algorithms and complex data structures in the field of pattern recognition and data science. In particular, the group has a strong expertise in graph based representation in intelligent information processing.

Due to fast developments in both storage media and data acquisition, we observe rapidly increasing amounts of data available in diverse areas in both science and industry. Simultaneously, we observe that in many applications the underlying data is inherently complex, making graphs the most useful and adequate data structure available to date. These two developments evoke the need for ongoing research of robust and efficient methods that assist humans in understanding and handling their pools of big sets of complex data.

The group's research is devoted to the development of novel graph based algorithms for pattern recognition and data science that actually provide feasible and robust solutions for this need.

## 9.3 Research Projects

### Graph Based Signature Verification

Handwritten signatures are widely used and well-accepted biometrics for personal authentication. Based on only a few genuine specimens, signature verification is a challenging task even for humans. Automatic verification systems are still far from human performance but their accuracy has improved significantly in the past decade, making it possible to rely on machines in some restricted cases or to support human experts.

Most of the current methods for automatic signature verification are based on feature vector representation and statistical classification, either taking into account local or global features. Known limitations of this approach include the inability to capture the global structure of the signatures and the relations between their subparts in a standardized way. Graph based representation and structural matching can overcome this limitation by providing a more intuitive, powerful, and flexible mechanism for formally representing and comparing handwritten signatures.

We propose in this project to explore the use of graphs and the potential benefits of structural pattern recognition methods for signature verification. A central aspect of the structural verification system is to include a signature stability model that distinguishes stable from variable subparts based on the analysis of genuine reference samples. Besides potential improvements in the verification accuracy, such a stability model provides a novel graph based interpretation of signatures, which can be valuable for supporting human experts.

**Financial support:** Swiss National Science Foundation Project No. 162852

### Novel State-of-the-Art Graph Matching Algorithms

A large amount of graph based methods for pattern recognition and related fields have been proposed. One of these methods is *graph edit distance* – a powerful and flexible graph dissimilarity measure and actually one of the main subjects of this project. Regarding graph edit distance (or more generally graph matching) we observe two substantial gaps in research that we aim to research and bridge. Formally, within the present project we research...

1. ... encodings of matching information in a novel data structure to formalize the stable cores of specific classes by means of graphs. The

rationale of this matching-graph representation is that it can be beneficial to focus on stable/important parts of graphs during algorithmic comparisons (rather than on complete graphs).

2. . . . hierarchical graph representations in conjunction with linear time graph embedding. This procedure is motivated by the fact that hierarchical representations (including fast and expressive graph embeddings) can be exploited in *filter-and-verify* strategies in order to substantially speed up and improve the matching processes.

By verifying both hypotheses we plan to make significant advances in the field of structural pattern recognition and establishing novel paradigms that go beyond the current understanding. In particular, the overall objective is the development and research of novel, robust graph edit distance methods that outperform the current state-of-the-art in graph matching on existing and novel data sets stemming from different real world scenarios. Hence, the proposed project involves both research on fundamental algorithms and solving concrete problems in applications.

**Financial support:** Swiss National Science Foundation Project No. 188496

## 9.4 Further Activities

### Editorial Boards

#### Kaspar Riesen

- Associate editor for Pattern Recognition, 2015–, Elsevier.

### Conference Program Committees

#### Kaspar Riesen

- Member of Program Committee for 12th International workshop on Graph-Based Representation in Pattern Recognition, Tours, France.
- Member of Program Committee for 25th International Conference on Pattern Recognition (ICPR2020), Milano, Italy.
- Member of Program Committee for International Workshops on Statistical Techniques in Pattern Recognition (SPR) and Structural and Syntactic Pattern Recognition (SSPR), Padua, Italy

## Project and Person Reviewing Activities

### Kaspar Riesen

- Evaluation of a research proposal for the Israel Science Foundation, 2020

## PhD Committee Memberships

### Kaspar Riesen

- “Deep learning onto graph space: Application to image-based insect recognition”, Maxime Martineau, Université de Tours, 2020.
- “Distilling Structure from Imagery: Graph-based Models for the Interpretation of Document Images”, Pau Riba, Universitat Autònoma de Barcelona , 2020.
- “Graph-Based Offline Signature Verification”, Paul Märgner, Universität Fribourg , 2020.

## 9.5 Publications

### Journal Publications

- Michael Stauffer, Andreas Fischer, Kaspar Riesen: Filters for graph-based keyword spotting in historical handwritten documents. *Pattern Recognit. Lett.* 134: 125-134 (2020)
- Kaspar Riesen, Miquel Ferrer, Horst Bunke: Approximate Graph Edit Distance in Quadratic Time. *IEEE/ACM Trans. Comput. Biology Bioinform.* 17(2): 483-494 (2020)
- Narayan Schütz, Alexander B. Leichtle, Kaspar Riesen: A comparative study of pattern recognition algorithms for predicting the inpatient mortality risk using routine laboratory measurements. *Artif. Intell. Rev.* 52(4): 2559-2573 (2019)
- Kaspar Riesen, Roman Schmidt: Online signature verification based on string edit distance. *IJDAR* 22(1): 41-54 (2019)



- Mohammad Reza Ameri, Michael Stauffer, Kaspar Riesen, Tien D. Bui, Andreas Fischer: Graph-based keyword spotting in historical manuscripts using Hausdorff edit distance. *Pattern Recognit. Lett.* 121: 61-67 (2019)
- Paul Maergner, Vinaychandran Pondenkandath, Michele Alberti, Marcus Liwicki, Kaspar Riesen, Rolf Ingold, Andreas Fischer: Combining graph edit distance and triplet networks for offline signature verification. *Pattern Recognit. Lett.* 125: 527-533 (2019)

## Refereed Conferences

- Hans Friedrich Witschel, Kaspar Riesen, Loris Grether: KvGR: A Graph-Based Interface for Explorative Sequential Question Answering on Heterogeneous Information Sources. *ECIR (1) 2020*: 760-773
- Michael Stauffer, Paul Maergner, Andreas Fischer, Kaspar Riesen: Cross-Evaluation of Graph-Based Keyword Spotting in Handwritten Historical Documents. *GbRPR 2019*: 45-55
- Michael Stauffer, Paul Maergner, Andreas Fischer, Kaspar Riesen: Graph Embedding for Offline Handwritten Signature Verification. *ICBEA 2019*: 69-76
- Michael Stauffer, Paul Maergner, Andreas Fischer, Rolf Ingold, Kaspar Riesen: Offline Signature Verification using Structural Dynamic Time Warping. *ICDAR 2019*: 1117-1124

## Proceedings, Books and Book Chapters

- Michael Stauffer, Paul Maergner, Andreas Fischer, Kaspar Riesen: A Survey of State of the Art Methods Employed in the Offline Signature Verification Process. In *New Trends in Business Information Systems and Technology* (Springer), 2020

## 10 Research Center for Digital Sustainability Group

### 10.1 Personnel

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\*with financial support from a third party

## 10.2 Overview

The Research Centre for Digital Sustainability can look back on a number of successes in 2020. Firstly, the head of the Research Centre, PD Dr. Matthias Stürmer, passed his habilitation successfully and is now a “Privat Dozent”. Adding to this, Matthias Stürmer heads two new courses: Once the “Grundkurs Programmieren” which the Vice Rectorate Teaching assigned to him in connection with the digitalisation strategy of the University of Bern. The course is open to all students of all faculties and provides an introduction to programming with web technologies (CSS, HTML) as well as with Python. The course that is taught in the inverted classroom format takes place every semester and could register over 300 registrations of interested students in both the spring and the autumn semester. The second course is the lecture “Digitale Nachhaltigkeit” at the institute of computer science. The course for third semester students is about digitalisation and digital transformation, digital sustainability, data protection and privacy, open source licenses, and the ethical questions concerning artificial intelligence. Regarding the last topic, artificial intelligence, there is a new research project using natural language processing funded by the Swiss National Science Foundation on “Open Justice vs Privacy”. The

project is part of the National Research Programme "Digital Transformation" (NRP 77) and aims at finding legal and technical solutions to meet the two demands for the access to court decisions on one hand and privacy based on fundamental rights on the other hand. This project is a collaboration between the Digital Sustainability Research Centre, the Competence Centre for Public Management and the Institute of Economics.

And lastly, the Research Centre was awarded the contract to develop the Campus Mobile App for the University of Bern. The has been in development all year and contains all important features from core areas such as KSL and Ilias, news and events, the library, Unisport, the cafeteria, as well as room- and area-plans. The app is released in spring 2021.

## 10.3 Research Projects

### NFP73 - Sustainable Public Procurement

In Switzerland, over 40 billion Swiss francs are spent annually on public procurement at the federal, cantonal and municipal levels. Based on existing bidding data and taking into consideration various sustainability indicators, effective criteria to foster sustainable procurement are developed. So far, procurement offices can already define ecological and social guidelines by means of suitable criteria. In accordance with new international and national procurement law and international agreements, sustainability criteria are to be taken into account to an even greater extent. Within the framework of this research project sustainability criteria for public tenders are developed that base on previous procurement and performance indicators from the sustainability reports of companies. The result will be an inventory of procurement-specific suitability and approval criteria, checked and tested in procurement practice. The aim of the research project is to initially determine the status quo of Swiss procurement regarding sustainability criteria. For this purpose, over 50,000 computerised procurement tenders will be evaluated. The project thus contributes towards sustainable development in general and a sustainable economy in Switzerland in particular.

**Research staff:** T. Welz, M. Stürmer.

**Financial support:** National Research Project NRP 73 Sustainable Economy, SNSF project No. 407340-172351

## **NFP77 - Open Justice vs. Privacy**

Justice should be open and transparent to ensure the public understanding of court decisions. On the other hand, each person should have the right to privacy and in particular the right to be forgotten. With this work we try to find a balance in this antagonism. The literature for anonymization of unstructured text documents is thin and for court decisions virtually non-existent. We plan to implement an end-to-end system for anonymization and re-identification of Swiss court decisions. This system will serve as a proof of concept that both the re-identification of a large part of manually anonymized court decisions is possible and that re-identification can be made significantly harder with the automated anonymization of our system. Our system will relieve legal experts of the burdensome task of manually anonymizing court decisions. Additionally, we hope to advance the knowledge in the field of text anonymization in general which will also serve many other fields.

**Research staff:** J. Niklaus, M. Stürmer.

**Financial support:** National Research Project NRP 77 Digital Transformation, SNSF project No. 407740-187477

## **10.4 Further Activities**

### **Memberships**

#### **Matthias Stürmer**

- President of the Digital Impact Network
- Vice President of CH Open
- Board Member of Opendata.ch
- Member of Smart Capital Region
- Managing Director of Parldigi (Parlamentarische Gruppe Digitale Nachhaltigkeit)

#### **Tobias Welz**

- Member of Sustainable Europe Research Institute (SERI), German Chapter, 2010-.
- Member of European Roundtable for Sustainable Consumption and Production (ERSCP), 2020-.

## Conference and workshop organization

### Matthias Stürmer

- IT-Beschaffungskonferenz 2019, conference on IT procurement, Bern, Switzerland, August 29, 2019
- DINAcon 2019, conference on digital sustainability, Bern, Switzerland, October 18, 2019

## Invited Talks

### Matthias Stürmer

- "Open Data und interaktive Datenvisualisierungen" 25 June 2020, CAS Forschungsmanagement Modul 6 "Kommunikation, Transfer und Marketing von Forschung", University of Bern
- "Open Data, Datenvisualisierungen und HTML-Übung" 11 June 2020, Einführung für Sozial-und Geisteswissenschaftler\*innen in Data literacy und digitale Methoden by Prof. Tobias Hodel, University of Bern
- "Der kniffligen Hardware-Entscheid für Schulen: Lernstick vs. Tablets vs. Laptops vs. Chromebooks" 25 April 2020, Virtual Open Education Day by CH Open and PH Bern
- "Technologische Bausteine der digitalen Transformation" 19 March 2020, Modul 2 within CAS Digitale Transformation of University of Bern, virtual teaching
- "Digitale Nachhaltigkeit – ein Konzept mit Zukunft" 10 March 2020, Lions Club Sensetal, Flamatt
- "Open Source, Open Data, Open Access etc. - The Concept of Digital Sustainability" 6 March 2020, course "The Importance of Open Science and Research Integrity for Scientific Progress", University of Bern
- "Der App-etit wächst: Mobile Government Apps gestern, heute und morgen" 4 March 2020, Swiss eGovernment Forum 2020, Bern
- "Das Konzept der Digitalen Nachhaltigkeit" 28 February 2020, Reclaim Democracy congress 2020

- "Konkrete ethische Herausforderungen und Lösungsansätze bei KI-Technologien" 18 February 2020, AI Meetup Bern, Bern
- "Digitale Nachhaltigkeit: Alternative zur Privatisierung des Wissens?" 27 Januar 2020, Volkshochschule beider Basel, course "Roboter und Ethik", Basel
- "Digitale Nachhaltigkeit und Open Source Software" 5 December 2019, University of Applied Sciences and Arts Northwestern Switzerland, course "Digital Business and Value Networks", Basel
- "Das Konzept der Digitalen Nachhaltigkeit" 28 February 2020, Reclaim Democracy congress 2020
- "Künstliche Intelligenz in unserem Alltag" 21 November 2019, SATW & Stiftung Risikodialog, Bern
- "Das Konzept der digitalen Nachhaltigkeit" 21 November 2019, Rotary Club Konolfingen "Chance Zukunft", Grosshöchstetten
- "Digitale Nachhaltigkeit" 6 November 2019, Ringvorlesung "Nachhaltigkeit in Design und Kunst", Lucerne University of Applied Sciences and Arts, Luzern
- "Open Government Data (OGD): Chancen, Risiken und Nebenwirkungen" 30 October 2019, Arbeitskreis IP / IT, Bundesverwaltungsgericht St.Gallen
- "Digital Sustainability" 17 October 2019, Omics lecture "From Genomes to Metabolomes", University of Bern
- "Status Quo Open Source Software in der Schweiz: Einführung, Herausforderungen, Praxisbeispiele, juristische Aspekte" 15 October 2019, Bundesamt für Bauten und Logistik (BBL)
- "Chatbots" 10 October 2019, Steuerverwaltung Kanton Bern
- "What the heck is digital sustainability?" 5 October 2019, Sustainability Week, University of Bern
- "Digitale Nachhaltigkeit, ein Konzept mit Zukunft" 20 September 2019, Geophysikalische Prospektionsmethoden und digitale Nachhaltigkeit in der Archäologie, University of Bern

- “Digitale Nachhaltigkeit – ein Konzept für die digitale Zukunft” September 5th, 2019, Forum Wirtschaft + Ethik, Thementag “Digitalisierung & Ethik”, Thun
- “Digitalisierung und Lernen” September 3rd, 2019, Digitaltag “tell”, Bern
- “Technologische Bausteine der digitalen Transformation” August 24th, 2019, CAS Marktorientierte Betriebswirtschaftslehre, Modul 3: Digitalisierung und neue Technologien, Bern
- Moderation “Podium Zusammenarbeit zwischen Stadt Zürich und Startups” August 20th, 2019, Zürich
- “Fake News und E-Voting: Herausforderungen für die Demokratie von morgen?” August 17th, 2019, 97. Auslandschweizer-Kongress, Montreux

### **Tobias Welz**

- “Facts und Trends bei nachhaltigen ICT-Hardware Beschaffungen.” IT-Beschaffungskonferenz 2020, Bern, Switzerland, August 2020
- “Monitoring sustainability performance in public procurement through life cycle thinking.” 74th Discussion Forum on Life Cycle Assessment, Wädenswil, Switzerland, June 2020
- “Nachhaltigkeit im öffentlichen Beschaffungswesen.” Seminar on Trends im öffentlichen Beschaffungswesen, University of Zurich, Switzerland, November 2019

## **10.5 Publications**

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

### **Conference Papers**



- Welz, T., Stürmer, M. (2020). *Sustainability of ICT hardware procurement in Switzerland: A status-quo analysis of the public procurement sector* 7th International Conference on ICT for Sustainability (ICT4S), Bristol, United Kingdom, June 21-26 2020. [dl.acm.org/doi/pdf/10.1145/3401335.3401352](https://dl.acm.org/doi/pdf/10.1145/3401335.3401352)

## Journal Papers

- Stürmer, M., Hitz-Gamper, B., Neumann, O., Schmidhuber, L., Matt, C. (2019). *Joining forces for public value creation? Exploring collaborative innovation in smart city initiatives* Government Information Quarterly, Volume 36, Issue 4, October 2019

## Other Publications

- Welz, T. (2020). *Nachhaltigkeitskriterien für öffentliche Ausschreibungen*. In Pusch - Thema Umwelt 1/2020

# 11 Software Composition Group

## 11.1 Personnel

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\*with financial support from a third party

## 11.2 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.

## 11.3 Research Projects

### 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.** Code comments play a substantial role in program comprehension, development, and maintenance tasks. Given the unstructured nature of comments and different standards, developers get confused about which conventions to follow while writing comments. Therefore, they post questions related to comment convention on external platforms such as Stack Overflow, Quora, and mailing lists. We investigated these sources to get insight into the challenges developers face. We presented their challenges in taxonomy and also collected the recommendations provided by experts to resolve the challenges. The taxonomy can help tool developers and researchers to identify the gaps in the current tools, and design future tools to satisfy developer information needs. Furthermore, we conducted a background literature study to characterize the reproducibility concerns of the studies that mine external sources. We addressed these concerns in our study by building a prototype tool and using it to conduct our study pipeline.

Along with facing challenges in writing comments, developers also face challenges in understanding comments due to availability of several kinds of information in the comments and lack of tools to identify these information types automatically. With the increasing use of polyglotism (use of multiple languages) in open source projects, researchers observed anti-patterns such as mismatching of language paradigms and too much clustering of information, which makes these systems hard to maintain and difficult to extract information from them. To handle these challenges, we investigated the language-specific commenting practices of three programming languages: Python, Java, and Pharo. We systematically analyzed the similarities and differences of the information types found in comments of projects developed in these languages. We proposed an approach that leverage text analysis and natural language processing techniques to identify the information type present in the comments automatically.

Additionally, code comments tend to be treated with less care compared to source code, which increases the chances of them diverging significantly from the source code and becoming outdated, complicating program comprehension. We have developed a technique that would assist programmers in keeping their documentation up to date with the source code during code change, relying on natural language cues present both in program comments and the source code. Our technique establishes a correspondence between the source code and its respective comments and allows to detect code-comment inconsistencies that arise when the code is changed, but its respective documentation is not accordingly updated. We have centered our work around Java programming language, as it has extensive public code bases which can be used for the technique evaluation. We have performed a preliminary evaluation of our technique on several public datasets of code-comment inconsistencies and have obtained satisfactory results in the precision with which code and comment units are linked together. We continue to develop the technique to not only pinpoint code-comment inconsistencies, but also suggest possible fixes to the developer, automating documentation maintenance.

We have also studied the applicability of this technique in the context of detecting cloned comments — another reason for having misleading documentation — which occurs when programmers copy documentation from one place to another without adapting it. The technique allowed us to significantly improve previous results in comment clone detection. We were able to improve the classification of severity of the clones and provide more detailed feedback about the code and documentation mismatch to the developers.

- **Executable domain models.** To facilitate non-technical stakeholder participation in software engineering (SE) activities, such as requirements engineering (RE) and software modeling, appropriate methodology and corresponding tools must be developed. We studied 112 RE tools published at top SE venues to characterize their limitations and to reflect on the rigor (*i.e.*, how extensive the evaluations were) and relevance (*i.e.*, accessibility of the tools). We also explored the potential of immersive augmented reality (IAR) to support various requirements engineering activities. One of the ways to enable non-technical stakeholders' participation in RE activities is by encouraging them to specify natural language scenarios. By using various behavior-driven development (BDD) tools, such scenarios are tied to

test cases. We studied existing BDD tools to characterize their limitations and subsequently proposed an approach and prototype implementation to improve the interaction capabilities for non-technical stakeholders within an IDE. Finally, we studied a plethora of RE artifacts to characterize their properties. Subsequently, we proposed a prototype implementation to model a selection of RE artifacts within an IDE to close the gap between requirements specification and implementation.

- **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, and the Inter-Component Communication (ICC) framework. We found that the majority of available apps suffer from issues that could lead to privacy leaks, or even worse, compromised handsets for millions of users.

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 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, and that web API security smells exist in every second web-enabled Android app.

We continue to explore weaknesses in HTTPS web API clients, and protective measures in programming languages to make mobile devices not only smart, but secure.

In other research, we previously showed that developer experience has no correlation with developer performance in using cryptographic APIs. Our results highlight the fact that developers have difficulty in using crypto APIs correctly.

To help the software developer community, we built CryptoExplorer, a web-based platform to provide simplified, clear crypto API usage examples for developers. CryptoExplorer enables the users to search for misuse or correct use of a specific crypto API, or make comparisons between misuse and correct use of an API.

We further explored the reasons why developers do not securely use such APIs by conducting a survey with 50 developers. Our analyses revealed that there is no significant difference between nine characteristics of the developers and their self-reported knowledge regarding cryptography.

We carried out research on how users who provide accepted answers on crypto-related discussions on Stack Overflow use cryptography on their open-source projects on GitHub. The results of our investigation explain that there is no significant difference in crypto activity on Stack Overflow between users who do not have crypto contributions on GitHub and the users who have such contributions. Furthermore, having more crypto contributions on GitHub does not necessarily indicate a high level of crypto activities on Stack Overflow.

We used latent Dirichlet allocation (LDA), a generative statistical model, to observe what topics users mainly talk about in crypto-related discussions on Stack Overflow. The results of LDA designate that the users mainly talk three topics, namely digital certificate and configurational problems, programming issues in cryptography, hash/passwords. We conducted a manual investigation on a sample set of documents to get more insights.

We studied how we can expedite the process of discovering vulnerabilities in software. We first reviewed all research papers from 2015 to 2020 that are published in the software fuzzing field. We identified six fuzzers that have concolic execution engine to increase the discovered breadth and depth branches in software. As such fuzzers lack a proper benchmark, we aim at running a benchmark for such fuzzers to evaluate their performance. We are working on improving the AFL fuzzer with the help of CodeQL. Our preliminary result is promising as our proposed solution outperformed the current state of the art fuzzers.

We evaluated the proposed methods in order to halt the DNS re-binding attack on browsers. We noticed that the existing preventive methods, such as digital certificates, have some drawbacks. Therefore, we proposed a browser plugin that does not suffer from the drawbacks of the previous methods.

For further details, please consult:

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

## 11.4 Master's Theses

- Mathias Birrer. Analysis of developer information needs on collaborative platforms. Masters thesis, University of Bern, July 2020. URL: <http://scg.unibe.ch/archive/masters/Birr20a.pdf>.

- Melike Geçer. Debugging Spark applications — a study on debugging techniques of Spark developers. Masters thesis, University of Bern, May 2020. URL: <http://scg.unibe.ch/archive/masters/Gece20a.pdf>.
- Rathesan Iyadurai. On demand runtime information — a language- and ide-agnostic approach to provide runtime information. Masters thesis, University of Bern, January 2020. URL: <http://scg.unibe.ch/archive/masters/Iyad20a.pdf>.
- Ivan Kravchenko. Moldable scenario builder. Masters thesis, University of Bern, June 2020. URL: <http://scg.unibe.ch/archive/masters/Krav20a.pdf>.

## 11.5 Bachelor's Theses and Computer Science Projects

- Said Ali. Profiling cryptography developers. Bachelor's thesis, University of Bern, August 2020. URL: <http://scg.unibe.ch/archive/projects/Ali20a.pdf>.
- Noah Bühlmann. Exploring security issues in open source software. Bachelor's thesis, University of Bern, June 2020.
- Pascal Gerig. Investigating phishing on demand. Bachelor's thesis, University of Bern, May 2020. URL: <http://scg.unibe.ch/archive/projects/Geri20a.pdf>.
- Timm Gross. Threats to validity in TDD research. Bachelor's thesis, University of Bern, May 2020. URL: <http://scg.unibe.ch/archive/projects/Gros20a.pdf>.
- Simon Kafader. FluentCrypto, a fluent wrapper for the NodeJS crypto API. Bachelor's thesis, University of Bern, July 2020. URL: <http://scg.unibe.ch/archive/projects/Kafa20a.pdf>.
- Basil Schöni. Automatically retrofitting cordova applications for stricter content security policies. Bachelor's thesis, University of Bern, February 2020. URL: <http://scg.unibe.ch/archive/projects/Scho20a.pdf>.

- Brian Schweigler. An investigation into vulnerability databases. Bachelor's thesis, University of Bern, May 2020. URL: <http://scg.unibe.ch/archive/projects/Schw20a.pdf>.
- Alain Stulz. Assessing and improving the software quality of an iOS app framework. Bachelor's thesis, University of Bern, February 2020. URL: <http://scg.unibe.ch/archive/projects/Stul20a.pdf>.
- Julian Weyermann. Simple MLE deployer — a simple (web) tool for exercising the Oracle multilingual engine. Bachelor's thesis, University of Bern, July 2020. URL: <http://scg.unibe.ch/archive/projects/Weye20a.pdf>.
- Christian Zürcher. Test name recommendation — a study of the unit test naming and naming traditions. Bachelor's thesis, University of Bern, January 2020. URL: <http://scg.unibe.ch/archive/projects/Zuer20a.pdf>.

## 11.6 Further Activities

### Invited Talks

#### Mohammad Ghafari

- Software and security: towards a happy marriage. University of Innsbruck, Austria, 14 July 2020 (remote talk)
- Software and security: towards a happy marriage. IMC University of Applied Sciences Krems, Austria, 06 May 2020 (remote talk)
- Secure and robust software in smart devices. Lancaster University, UK, 14 Feb 2020 Taming Security for Mainstream Developers. University of Auckland, New Zealand, 4 Dec 2019

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

## **Program Committees**

### **Oscar Nierstrasz**

- PC Member of SANER 2020 (27th IEEE International Conference on Software Analysis, Evolution and Reengineering — London, Ontario, Canada, Feb. 18-21, 2020)
- General Chair of SLE 2019 (ACM SIGPLAN International Conference on Software Language Engineering — Athens, Greece, Oct. 21-22, 2019)

### **Mohammad Ghafari**

- PC member of SEAD 2020 (Collocated with ESEC/FSE): 3rd Workshop on Software Security from Design to Deployment
- PC member of VISSOFT 2020: 18th IEEE Working Conference on Software Visualization
- PC member of NEXTA 2020 (Collocated with ICST): 3rd IEEE Workshop on NEXt level of Test Automation

## **Reviewing Activities**

### **Oscar Nierstrasz**

- Deutsche Forschungsgemeinschaft

### **Nataliia Stulova**

- Journal of Open Source Software (JOSS)

**Reza Hazhirpasand**

- SANER 2019

**Pooja Rani**

- SANER 2020

## 11.7 Publications

### Journal Papers

- Pooja Rani, Sebastiano Panichella, Manuel Leuenberger, Mohammad Ghafari, and Oscar Nierstrasz. What do class comments tell us? An investigation of comment evolution and practices in Pharo. *arXiv preprint arXiv:2005.11583*, 2020.

### Conference Papers

- Pascal Gadiant, Mohammad Ghafari, Marc-Andrea Tarnutzer, and Oscar Nierstrasz. Web APIs in Android through the lens of security. In *27th edition of the IEEE International Conference on Software Analysis, Evolution and Reengineering (SANER)*, March 2020. URL: <http://scg.unibe.ch/archive/papers/Gadi20a.pdf>, doi:10.1109/SANER48275.2020.9054850.
- Mohammadreza Hazhirpasand, Mohammad Ghafari, and Oscar Nierstrasz. CryptoExplorer: An interactive web platform supporting secure use of cryptography APIs. In *27th edition of the IEEE International Conference on Software Analysis, Evolution and Reengineering (SANER)*, pages 632–636, March 2020. URL: <http://scg.unibe.ch/archive/papers/Hazh20a.pdf>, doi:10.1109/SANER48275.2020.9054799.
- Mohammadreza Hazhirpasand, Mohammad Ghafari, and Oscar Nierstrasz. Tricking Johnny into granting web permissions. In *Proceedings of the Evaluation and Assessment in Software Engineering, EASE 2020*, pages 276–281, New York, NY, USA, 2020. Association for Computing Machinery. doi:10.1145/3383219.3383248.
- Manuel Leuenberger. Exploring example-driven migration. In *Proceedings of the Conference Companion of the 3rd International*

*Conference on Art, Science, and Engineering of Programming*, Programming '19, pages 29:1–29:3, New York, NY, USA, April 2019. ACM. URL: <http://scg.unibe.ch/archive/papers/Leue19a.pdf>, doi:10.1145/3328433.3328463.

- Leonel Merino, Ekaterina Kozlova, Oscar Nierstrasz, and Daniel Weiskopf. VISON: An ontology-based approach for software visualization tool discoverability. In *VISSOFT'19: Proceedings of the 7th IEEE Working Conference on Software Visualization*. IEEE, 2019. URL: <http://scg.unibe.ch/archive/papers/Meri19b-vison.pdf>, doi:10.1109/VISSOFT.2019.00014.
- Nitish Patkar, Mohammad Ghafari, Oscar Nierstrasz, and Sofija Hotomski. Caveats in eliciting mobile app requirements. In *Proceedings of the Evaluation and Assessment in Software Engineering, EASE 2020*, pages 180–189, New York, NY, USA, 2020. Association for Computing Machinery. URL: <http://scg.unibe.ch/archive/papers/Patk20.pdf>, doi:10.1145/3383219.3383238.
- Nitish Patkar, Leonel Merino, and Oscar Nierstrasz. Towards requirements engineering with immersive augmented reality. In *Proc. Programming'20 Companion*, pages 55–60. ACM, 2020. URL: <http://scg.unibe.ch/archive/papers/Patk20b.pdf>, doi:10.1145/3397537.3398472.

## Other Publications

- Manuel Leuenberger. Can I remove this method? How live feedback from the ecosystem supports co-evolution. Presented at International Workshop on Smalltalk Technologies 2019, August 2019. URL: <http://scg.unibe.ch/archive/papers/Leue19b.pdf>.

## 12 Administration

### University:

- T. Braun: Member of the Committee for Computing Services (Kommission für Informatikdienste)  
Member of Committee for Wyss Academy  
Representative of University of Bern in SWITCH Stiftungsrat  
SWITCH Stiftungsratsausschuss (until November 2019)
- T. Studer: Member of *Kantonale Maturitätskommission*

### Faculty:

- T. Braun: Member Faculty Strategy Committee (from 1.1.2020)  
Joint Master in Computer Science of the Universities of Bern, Fribourg and Neuchâtel: Member of Branch Committee
- 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 (to end of 2019)  
Member Digitalisation Strategy Working Group  
Deputy Faculty delegate  
Faculty contact person for digitalization
- T. Studer: Member of the Strategy Board  
Representative of high Mittelbau in faculty meetings

### Institute:

- T. Braun: Managing Director of INF
- P. Favaro: Deputy Director of INF
- D. Bommers: Director of Studies
- C. Cachin: Deputy Director of Studies  
Member of Library Committee on behalf of INF  
Representative to CUSO Doctoral School in Computer Science

O. Nierstrasz: Member of Hauskommission Engehalde

T. Studer: Member of Hauskommission Exakte Wissenschaften