Doctoral Program in Computer & Communication Sciences (EDIC)

Prof. Matthias Grossglauser
Program Director
Last 45 years were extraordinary

- 1970: computers used in business
- 2016: computers used everywhere
  - every home
  - every pocket
  - soon, every object
Last 10 years

- Facebook open to public: 2006
- iPhone introduced: 2007
- WhatsApp founded: 2009
- iPad introduced: 2010
- Uber starts service: 2011
- Facebook: 2016
The fun is not over

YOU can be part of it!

Human-Brain Project

Self-driving cars

Biological computers
Why a PhD?

PhD is about where IT revolution is going, and how you can be at the center of it all!

If you want

• Preparation for a startup
• Take leadership positions in industry R&D
• Be an academic

You should consider a PhD
Who should do a PhD?

• Fascinated by IT & have an aptitude for science & engineering

• Passionate about understanding how & why things work, the underlying fundamentals

• Want the breadth & depth for a vision to have an impact and make a difference
What is a PhD?

• Choose and define an important problem
  – One that no one has solved before
  – One that makes a difference in the field

• Find an effective solution
  – Learn to read and understand prior work
  – Learn to conduct research

• Disseminate
  – Present your results in writing and orally to the community and industry
Doctoral studies at EPFL
Path to PhD

- Courses
- Research
- Publish
- TA
- Attend Conferences
- Internships
- Defense

4~6 years
Computer & Communication Sciences: who we are

Over 40 faculty

• From peer schools
  (e.g., Berkeley, CMU, Cornell, MIT, Stanford, ...)
• Internationally recognized
  (e.g., Turing Award, US National Academies,
   ACM/IEEE Fellows)
• Strong industrial liaison
• Information theory to datacenters
IC Research

Information & Communication Theory

Erasure* Channels’ Capacity Achieved by Reed-Muller Codes (LTHC)

The LTHC researchers propose a solution to a long-standing conjecture in coding theory, that is, Reed-Muller codes, which were initially introduced in 1954, achieve capacity on erasure channels under optimal decoding and provide general proof for codes with sufficient symmetry.

All channels we encounter in life are noisy. It is therefore extraordinary to be able to distinguish, when you chose a specific channel, the exact amount of information possible to transmit through that channel. The original scientific study on channel capacity does not provide any constructive solutions on how to determine the amount of information to be transmitted through a specific channel. Researchers have been trying to devise a method on how to do this for over 60 years with little success.

Two functional approaches have been devised; one focusing on polar codes and the other codes based on graphs. The first one is still random but allows to decode practically, in a low-complexity manner. The latter is completely deterministic and very specific to the method used.

The LTHC team’s discovery demonstrates that a much wider set of processes and codes, allows one to achieve capacity, i.e. the maximum amount of information possible to transmit, and to be optimal. Indeed, it suffices to be structured and to have symmetry in order to achieve this optimality.

Reference
Shrinivas Kudekar, Santhosh Kumar, Marco Mondelli, Henry D. Pfister, Eren Sasoglu, Rüdiger Urbanke Reed-Muller Codes Achieve Capacity on Erasure Channels arxiv.org Best paper award at ACM Symposium on Theory of Computing (STOC) (2016)
Flying Object Detection from a Single Moving Camera (CVLAB)

Video-based modeling of shape and motion has many potential applications in areas such as medicine, surveillance, entertainment, and athletic training. However, it is an inherently difficult task because the image-data is often incomplete, noisy, and ambiguous. CVLAB’s research project is based on developing a novel approach to detecting flying objects such as UAVs and aircrafts when they occupy a small portion of the field of view, while possibly moving in complex backgrounds, and are filmed by a camera that itself moves.

Solving such a difficult problem requires combining both appearance and motion cues. To this end CVLAB proposes a regression-based approach to the motion stabilization of local image patches that allows the researchers to achieve effective classification on spatio-temporal image cubes and outperform state-of-the-art techniques.

Reference
The researchers propose a computational method for interactive 3D design and rationalization of surfaces via auxetic materials, i.e., flat flexible material that can stretch uniformly up to a certain extent.

A key motivation for studying such material is that one can approximate doubly-curved surfaces (such as the sphere) using only flat pieces, making it attractive for fabrication. The researchers physically realize surfaces by introducing cuts into approximately inextensible material such as sheet metal, plastic, or leather.

The cutting pattern is modeled as a regular triangular linkage that yields hexagonal openings of spatially-varying radius when stretched. In the same way that isometry is fundamental to modeling developable surfaces, the work leverages on conformal geometry to understand auxetic design.

The researchers then go on to compute a global conformal map with bounded scale factor to initialize an otherwise intractable non-linear optimization and demonstrate that this global approach can handle non-trivial topology and non-local dependencies inherent in auxetic material. Design studies and physical prototypes are used to illustrate a wide range of possible applications.

Reference
IC Research

Graphics & Vision/ Image Processing

3D Human Pose Estimation from Videos (CVLAB)

CVLAB proposes an efficient approach to exploiting motion information from consecutive frames of a video sequence to recover the 3D pose of people. Previous approaches typically compute candidate poses in individual frames and then link them in a post-processing step to resolve ambiguities. By contrast, the researchers directly regress from a spatio-temporal volume of bounding boxes to a 3D pose in the central frame.

The team shows that, for this approach to achieve its full potential, it is essential to compensate for the motion in consecutive frames so that the subject remains centered. This then allows us to effectively overcome ambiguities and improve upon the state-of-the-art by a large margin on the Human3.6m, HumanEva, and KTH Multiview Football 3D human pose estimation benchmarks.

Consequently, the researchers can disambiguate challenging poses with mirroring and self-occlusion and achieve state-of-the-art performance by combining appearance and motion cues from motion compensated, rectified spatio-temporal volumes (RSTVs).

Reference

IC Research

Networks and Computational Neuroscience

Rapid Path Planning Enabled by Attractor Network Dynamics (LCN)

Rodents navigating in a well-known environment can rapidly learn and revisit observed reward locations. While the mechanism for rapid path planning is unknown, the CA3 region in the hippocampus plays an important role, and emerging evidence suggests that place cell activity during hippocampal “preplay” periods may trace out future goal-directed trajectories.

The researchers show how a particular mapping of space allows for the immediate generation of trajectories between arbitrary start and goal locations in an environment, based only on the mapped representation of the goal, which can be implemented in a neural attractor network model, resulting in bump-like activity profiles resembling those of the CA3 region of hippocampus.

The research shows that, in networks with large place fields, the network properties cause the bump to move smoothly from its initial location to the goal, around obstacles or walls. The team’s results illustrate that an attractor network with hippocampal-like attributes may be important for rapid path planning.

Reference
The LAP researchers introduce a novel approach, called Fpresso, to model the delay and area of a wide range of largely different FPGA architectures quickly and with reasonable accuracy.

Tools, such as VTR i.e. retargetable toolchain, which map circuits onto hypothetical FPGA architectures, could in theory play a key role in the development of innovative FPGA architectures. However, the experiments conducted with these tools have been limited, as FPGA architects lack the ability to produce reliable delay and area models, which depend on transistor-level design techniques and require a different set of skills.

The team proposes an approach inspired by large scale transistor-size optimization, as performed by standard-cell flow, and applies the same concepts to FPGAs. Fpresso uses an ordinary logic synthesis tool to optimize the process within minutes by choosing the most fitting version of each cell and adding buffers wherever appropriate. The resulting delay and area characteristics can be automatically used for VTR. The LAP team’s results show that Fpresso provides models that are on average within some 10-20% of those by a state-of-the-art FPGA optimization tool and is orders of magnitude faster.

Reference
Best Paper Award
Until the present, Bitcoin users' patience may have been severely tried by the excessive time required for Bitcoin transactions to commit, while offering only probabilistic guarantees. The DEDIS team’s research project introduces ByzCoin, a novel Byzantine consensus protocol that leverages scalable collective signing to commit Bitcoin transactions irreversibly within seconds.

ByzCoin achieves Byzantine consensus while preserving Bitcoin's open membership by dynamically forming hash power-proportionate consensus groups representing recently-successful block miners. ByzCoin employs communication trees to optimize transaction commitment and verification under normal operation, while guaranteeing safety and liveness under Byzantine faults, up to a near-optimal tolerance of f faulty group members among 3f+2 total.

ByzCoin mitigates double spending and selfish mining attacks by producing collectively signed transaction blocks within one minute of transaction submission. Tree-structured communication further reduces this latency to less than 30 seconds. These optimizations enable ByzCoin to achieve a throughput higher than Paypal currently handles, with confirmation latencies of 15-20 seconds.

Reference
Lamp team’s research demonstrates why languages like Scala have foundations, which are not directly related via the Curry-Howard isomorphism to logic. Focusing on path-dependent types, the team shows the foundations for Scala from first principles.

Starting from a simple calculus $D<$: of dependent functions, adding records, intersections and recursion to arrive at DOT, the work establishes a calculus for dependent object types. The research shows an encoding of System F with subtyping in $D<$: and demonstrates the expressiveness of DOT by modeling a range of Scala constructs in it.

Reference

IC Research

Systems

Load Imbalance in Scale-out Data Serving Analyzed (DCSL and PARSA)

As a significant portion of contemporary web-scale applications is latency-sensitive. However, designing a datacenter scale system that guarantees low latency is challenging. The researchers demonstrate that despite the natural parallelism across lookups, performance of distributed key-value stores is often limited due to load imbalance induced by heavy skew in the popularity distribution of the dataset.

To avoid violating service level objectives expressed in terms of tail latency, systems tend to keep server utilization low and organize the data in micro-shards, which in turn provides units of migration and replication for the purpose of load balancing. These techniques reduce the skew, but incur additional monitoring, data replication and consistency maintenance overheads.

The research project demonstrates that the extreme scale-out further exacerbates the load imbalance problem. Consequently, the increase in load imbalance raises the frequency of migration and replication operations to keep the system at the desired level of utilization.

Reference

Recent works on reconstruction of room geometry from echoes assume that the geometry of the sensor array is known. The LCAV researchers demonstrate that echoes provide sufficient clues to reconstruct the room’s and the array’s geometries jointly, even from a single acoustic event.

Rather than focusing on the combinatorial problem of matching the walls and the recorded echoes, the work provides algorithms for solving the joint estimation problem in practical cases, when this matching is known and the number of microphones is small.

The researchers then explore the intriguing connections between this problem and simultaneous localization and mapping (SLAM), and show that SLAM can be solved by the same methods. The work demonstrates how effective the proposed methods are by numerical simulations and experiments with real measured room impulse responses.

Reference
Reliable packet delivery within stringent delay constraints is of paramount importance to mission-critical computer applications with hard real-time constraints. Because retransmission and coding techniques counteract the delay requirements, reliability may be achieved through replication over multiple fail-independent paths.

Existing solutions, such as the parallel redundancy protocol (PRP), replicate all packets at the MAC layer over parallel paths. PRP works best in local area networks. However, it is not viable for IP networks that are a key element of emerging mission-critical systems. This limitation, coupled with diagnostic inability and lack of security, renders PRP unsuitable for reliable data-delivery in these IP networks.

To address this issue, the researchers present a transport-layer solution: the IP parallel redundancy protocol (iPRP). Designing iPRP poses non-trivial challenges in the form of selective packet replication, soft-state and multicast support. iPRP replicates only time-critical unicast or multicast UDP traffic. iPRP requires no modifications to the existing monitoring application, end-device operating system or to the intermediate network devices.

It only requires a simple software installation on the end-devices. iPRP has a set of diagnostic tools for network debugging. With the researchers implementation of iPRP in Linux, it is possible to demonstrate that iPRP supports multiple flows with minimal processing-and-delay overhead. It is being installed in our campus smart-grid network and is publicly available.

Reference
EDIC - Overview

EDIC is the doctoral program of I&C School

Stats:
- Over 250 PhD students (largest program on campus)
- 40 per year join from ~ 600
- ~6 PhD students per IC faculty (+ affiliated faculty)

Info:
- 4-6 years
- In English
- Paid at 75% entry-level engineering salary
- One-year fellowships to outstanding applicants
EDIC - Admission cycle

1\textsuperscript{st} admission cycle (deadline Dec. 15\textsuperscript{th})
• This is the main admission cycle
• Synchronized with US/Canada
• Apply NOW!

Smaller 2\textsuperscript{nd} admission cycle (deadline April 15\textsuperscript{th})
• Fewer applications, fewer admissions
• Won’t get a chance to visit for Open House
EDIC - Admission cycle

Over 600 applications
Accept roughly 70
• Invite the top 50 ranked as “fellowship”

Dec. 15th
Application deadline

Mid Jan.
Admission decisions sent out

Mid March
2-day Open House

April 15th
Acceptance deadline
During your PhD at EPFL

You will have an advisor/co-advisor
  – Will be with you until you graduate
  – Courses, research, career planning
  – Official annual feedback (evaluations)

You will have a mentor
  – EDIC Committee contact person for 1st year
  – An IC faculty member beyond (from outside area)
  – Someone to talk to in general
Industrial fellowships / Internships

Top students participate in industrial fellowships and internships

• Highly selective
• Many include internships

Students also intern with our industrial affiliates
Where do our graduates go?

- Industry
- Start-ups
- Academia
Where do our graduates go?

Ivan Dokmanic

*Listening to Distances and Hearing Shapes: Inverse Problems in Room Acoustics and Beyond*, 2015

Audiovisual Communications Lab, Prof. Martin Vetterli

- Google European Doctoral Fellowship (2014)
- Denantes thesis award (2015)
- EPFL doctorate Award (2016)

Assistant prof. at University of Illinois
Where do our graduates go?

Pınar Tözün

*Transactions Chasing Scalability and Instruction Locality on Multicores*, 2014

Data-Intensive Applications and Systems Lab,
Prof. Anastasia Ailamaki

- ACM SIGMOD Jim Gray Doctoral Dissertation Award, Honorable Mention (2016)
- Expert at SIGMOD 2016 for the Careers in Industry Panel

Current research focuses on scalability and efficiency of data management systems on modern hardware.

Research staff member
IBM Almaden Research Center, USA
Where do our graduates go?

Volodymyr Kuznetsov

*Techniques for strengthening the security and reliability of systems software using program analysis and instrumentation*, 2016

Dependable Systems Lab, Prof. George Candea

- His work adopted in LLVM, Chrome, Android
- 2 issued patents in the USA

Chief Executive Officer & Founder

Cyberhaven (cyber security start-up)
Where do our graduates go?

Valentina Sintsova


Marina Boia

*Acquiring Broad Commonsense Knowledge for Sentiment Analysis Using Human Computation*, 2016

Artificial Intelligence Lab, Prof. Boi Faltings, Prof. Pearl Pu Faltings

Interns at Google last year.

*Both to Google Zurich this fall*
Need more information?

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or mail to

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