ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

1st annual

ENGINEERING PhD SUMMIT

Data-driven engineering in the life sciences

November 7, 2018
BC 420

13 exceptional graduating PhD students from universities worldwide :

- Compete for the EPFL Engineering PhD Summit Prize
- Present their research work at a 1-day workshop

https://phdsummit.epfl.ch

Welcome to EPFL !

On behalf of the organizing committee of the EPFL Engineering PhD Summit, we welcome you to EPFL Campus in Lausanne, Switzerland.

The PhD Summit is a workshop for final year PhD students interested in a career in academia. Each year, we invite to campus, on a competitive basis, a group of exceptional graduating PhD students from institutions worldwide.

In this inaugural edition, the Summit is focusing on the theme of « Data-Driven Engineering in the Life Sciences ». Advancements in information technology, sensing, computing, and storage capabilities have dramatically increased the stream of data available for analysis. New data-driven models and engineering design concepts offer the promise of more accurate prediction, control, and personalized treatment. Applying emerging data-driven engineering design concepts to the field of Life Sciences will likely have strong impact on future design and treatment practices.

We have received many outstanding applications from universities worldwide and selected a short list of 13 students from 10 universities and 7 countries.

The candidates will present their research during the Summit and interact with faculty from the School of Engineering and the School of Life Sciences. Each candidate will also be visiting EPFL laboratories and meeting students and researchers. The Engineering PhD Summit Prize for the best presentation and research impact will be awarded during the summit.

We would like to thank all those involved in the organization of this event for their valuable contributions.

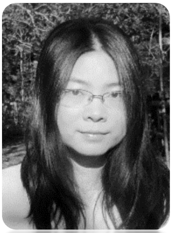
We hope you will enjoy your time at EPFL.

Pascal Frossard
Associate Dean for Research
School of Engineering, EPFL

Ali H. Sayed
Dean of Engineering, EPFL

Selected candidates

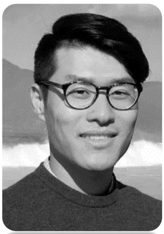
Yuxin Sun
UCL, London



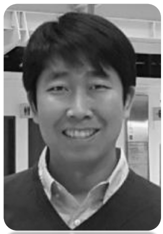
Souptik Barua
Rice University, USA

Shachi Mittal
University of Illinois, USA

Xiaokang Li
EPFL, Switzerland



Hyoyoung Jeong
U. of Texas at Austin, USA



Wenjun Xu
NUS, Singapore

Tiffany Corbet
EPFL, Switzerland

Hannelore Aerts
U. of Ghent, Belgium

Daniela Zöller
EPFL, Switzerland

Baran Gözcü
EPFL, Switzerland

Tushar Chouhan
NTU, Singapore

Alessio Buccino
U. of Oslo, Norway

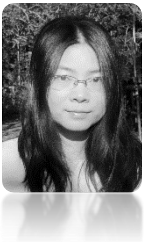
Jérôme Dockès
INRIA, France

8h45 – 9h15	Welcome coffee
9h15 - 9h30	Welcome address Ali H. Sayed, Dean of the Faculty of Engineering
9h30 - 10h45	**PhD Summit Session 1**
Yuxin Sun	University College London, United Kingdom. Department of Computer Science, Lab. of Prof. John Shawe-Taylor “Identification of antigen-specific T-cell receptors using an L1-L2 regularised algorithm”
Souptik Barua	Rice university, Houston, Texas, USA. Department of Electrical and Computer Engineering, Lab. of Dr. Arvind Rao “Towards Personalized Treatment: Leveraging Structure in Cancer Imaging to Guide Therapies”
Shachi Mittal	University of Illinois, Urbana Champaign, USA. Department of Bioengineering, Lab. of Prof. Rohit Bhargava “Combining Data Science and Chemical Imaging for Automated Cancer Diagnosis”
10h45 - 11h00	Coffee break
11h00 - 12h40	**PhD Summit Session 2**
Xiaokang Li	Ecole Polytechnique Fédérale de Lausanne, Switzerland. Bionanophotonic Systems Laboratory, Lab. of Prof. Hatice Altug “Chatting with cells: Label-free Nanoplasmonic Biosensor Enables Real-time Monitoring of Live Cell Cytokine Secretion”
Hyoyoung Jeong	University of Texas at Austin, USA. Departments of Electrical and Computer Engineering, Lab. of Prof. Nanshu Lu “Modular and Reconfigurable Stretchable Electronic Tattoos with Wireless Power and Data Communication Capabilities”

Wenjun Xu	National University of Singapore, Singapore. Dept. Biomedical Engineering. Lab. of Prof. Hongliang Ren “Modeling and Task Automation for Flexible Surgical Manipulators via Data-driven Approaches”
Tiffany Corbet	Ecole Polytechnique Fédérale de Lausanne, Switzerland. Defitech Foundation Chair in Brain-Machine Interface. Lab. of Prof. José del R. Millán “Sensory electrical stimulation a novel feedback modality for brain-machine interfaces”
12h40 - 13h45	Lunch break
13h45 - 15h00	**PhD Summit Session 3**
Hannelore Aerts	Ghent University, Belgium. Faculty of psychology and educational sciences. Lab. of Prof. Daniele Marinazzo “Optimizing brain tumor surgery using large-scale brain network modeling”
Daniela Zöller	Ecole Polytechnique Fédérale de Lausanne, Switzerland, Medical image processing lab, Prof. Dimitri Van de Ville and University of Geneva, Switzerland, Lab. of Prof. Stephan Eliez “Dynamic features of multimodal MRI data reveal functional signatures of psychosis in 22q11.2 deletion syndrome”
Baran Gözcü	Ecole Polytechnique Fédérale de Lausanne, Switzerland. Laboratory for information and interference systems, Lab. of Prof. Volkan Cevher « Learning-based Magnetic Resonance Imaging”
15h00 – 15h30	Coffee break

15h30 - 16h45	**PhD Summit Session 4**
Tushar Chouhan	Nanyang Technological University, Singapore. School of Computer Science and Engineering (SCSE), Lab. of Prof Cuntai Guan “Decoding Neurophysiological Mechanisms and Complex Brain Networks using Electroencephalogram (EEG) and Machine Learning in Brain-Computer Interfaces (BCI)”
Alessio Buccino	University of Oslo, Norway. Center for Integrative Neuroplasticity (CINPLA), Lab. of Prof. Gaute Einevoll and University of California San Diego, USA, Department of Bioengineering, Lab. of Prof. Gert Cauwenberghs “A computationally-assisted approach to neural electrophysiology”
Jérôme Dockès	Institut national de recherche en informatique et en automatique, France. Parietal team, Lab. of Prof. Bertrand Thirion “Predicting the spatial distribution of neuroimaging observations from text reports”
16h45 – 17h25	**Keynote lecture**
Silvestro Micera	Bertarelli Foundation Chair in Translational Neuroengineering, Center for Neuroprosthetics, Campus Biotech, EPFL Geneva “NeuroBionics: understanding and restoring nervous system functions for a better quality of life”
17h25 - 17h40	**Closing remarks and award ceremony**
17h40 – 18h30	Networking apero

List of abstracts



Yuxin Sun

University College London, United Kingdom. Department of Computer Science, Lab. of Prof. John Shawe-Taylor

"Identification of antigen-specific T-cell receptors using an L1-L2 regularised algorithm"

The clonal selection theory proposes that memory T cells quickly proliferate after being attacked by their counter-specific antigens in the adaptive immune response. The enormous diversity and possible correlations of T-cell receptors (TcRs) make it extremely challenging to identify TcRs that respond to a specific antigen. L1-regularised algorithms such as Lasso discover uncorrelated features efficiently, while a group-based L1-L2 regularised algorithm works well with correlated features at a high computational cost. In our project, we improved the L1-L2 regularised algorithm to efficiently select correlated features by dividing the optimisation problem into subproblems. Our method further provides flexibility in choosing more biologically meaningful features and offers more stable solutions by controlling both type I and type II errors. Our approach has proved successful in both synthetic and real-world datasets, identifying TcRs that are relevant to the immune response to cytomegalovirus (CMV).

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Souptik Barua

Rice university, Houston, Texas, USA. Department of Electrical and Computer Engineering, Lab. of Dr. Arvind Rao

"Towards Personalized Treatment: Leveraging Structure in Cancer Imaging to Guide Therapies"

Despite their promise, traditional methods of cancer treatment such as radiation therapy, or newer ones, such as immunotherapy are seen to be not effective for all patients. In some cases, they may lead to severe side-effects such as organ failure or even death. These issues have made precision medicine a rapidly emerging field of research, which tailors therapy to the individual patient. In my thesis, I have designed data-driven frameworks that can be used to discover signatures of clinical outcome from a patient's imaging data. I demonstrate the effectiveness of these frameworks on two cancer imaging modalities: multiplexed Immuno-fluorescence, or mIF imaging (pathology), and Computed Tomography, or CT imaging (radiology).

First, I quantify the spatial structure in mIF imaging, in terms of proximities of cancer cells and different categories of immune cells, using an algorithm based on the multitype nearest neighbor distribution function G(r). We then design several G(r)-based metrics that we show are associated with overall survival in pancreatic cancer (PDAC) and lung cancer (NSCLC), and with risk of progression in a different type of pancreatic cancer (IPMN). Further, my framework can be used to identify the specific cell types whose proximities potentially impact patient outcomes.
Second, I leverage temporal structure in radiology, specifically CT images acquired over time, to predict long-term effects of radiation treatment. Specifically, we use ideas from functional data analysis to extract temporal signatures that can be used to predict two outcomes of interest: tumor response, and risk of osteo-radio necrosis, or ORN.
Overall, my research aims to use data-driven techniques to leverage structure in cancer imaging data and show their association with clinical outcome. I envisage that these frameworks can assist clinicians in designing personalized immunotherapy or radiation therapy plans. I further aim to utilize computational techniques to address fundamental questions concerning the biology of poorly understood cancers, which can lead to more precise design of drugs and clinical trials.

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Shachi Mittal
University of Illinois, Urbana Champaign, USA. Department of Bioengineering, Lab. of Prof. Rohit Bhargava

"Combining Data Science and Chemical Imaging for Automated Cancer Diagnosis"

Breast cancer is diagnosed via histopathology, a process that involves biopsy, tissue staining followed by manual examination by a pathologist. This is susceptible to under-diagnosis, over-diagnosis and low concordance rates across pathology labs. To overcome this, a combinatory and quantitative diagnostic approach utilizing imaging coupled to pattern recognition tools is developed for holistic patient analysis. The proposed approach integrates both the spatially resolved and quantitative information of biological samples. The major goal of this project is to establish the feasibility of mid-infrared (IR) chemical imaging technology for automated cellular identification, recognition of disease and characterization of both the tumor its microenvironment. This study provides rapid, objective and automated diagnostic and prognostic information. This will address the long recurring need of reducing pathologic inter - observer variability, thereby impacting surgical treatment and patient outcomes.

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Xiaokang Li
Ecole Polytechnique Fédérale de Lausanne, Switzerland.
Bionanophotonic Systems Laboratory, Lab. of Prof. Hatice Altug

"Chatting with cells: Label-free Nanoplasmonic Biosensor Enables Real-time Monitoring of Live Cell Cytokine Secretion"

Unraveling the dynamics of cell signaling activities such as cell secretions provides invaluable insights for understanding the mechanisms of currently incurable diseases and developing novel therapies. It requires the implementation of a real-time monitoring methodology for data-driven precise analysis. An innovative nanoplasmonic biosensor based on periodically patterned gold nanohole arrays has been introduced for real-time monitoring of cell secretory activities. We primarily demonstrated the monitoring of vascular endothelial growth factor directly secreted by microfluidic-cultured cancer cells for over 10 hours. The system was further upgraded by incorporating a multifunctional microfluidic system with low-volume microchamber and regulation channels for reliable analysis of cytokine secretion from single cells. Different spatiotemporal profiles of interleukin-2 secretion are detected and distinguished from single lymphoma cells. This innovative biosensor system is anticipated to be a powerful tool to probe live cell signaling for basic and clinical research, disease diagnostics and novel therapy development.

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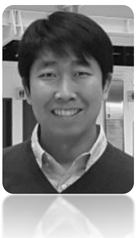

Hyoyoung Jeong
University of Texas at Austin, USA. Departments of Electrical and Computer Engineering, Lab. of Prof. Nanshu Lu

"Modular and Reconfigurable Stretchable Electronic Tattoos with Wireless Power and Data Communication Capabilities"

Recently, noninvasive, soft, and multifunctional epidermal electronics (e-tattoos) have been considered for potential applications in mobile healthcare, activity tracking, human-machine interface, and so on. Near field communication (NFC) is a standard protocol that can wirelessly transmit both power and data. To implement NFC in such e-tattoos, I invented a "cut-solder-paste" process that allows for freeform patterning of any thin film utilizing an automated cutting system. By adopting this cost-and time-effective fabrication method, I was able to demonstrate a modular-design multilayered NFC e-tattoo. Such NFC e-tattoos are stretchable up to 20% and capable of wireless real-time monitoring of electrocardiogram (ECG), skin hydration, skin temperature, heart rate, and oxygen saturation level (SpO2). I also investigated reconfiguration of such modular e-tattoo by disassembling and reassembling each layers multiple times, utilizing the design's recyclability. The combination of a rapid, freeform manufacturing process and the modular-design establishes a new era for personalized wearable soft bioelectronics

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Wenjun Xu
National University of Singapore, Singapore. Dept. Biomedical Engineering. Lab. of Prof. Hongliang Ren

"Modeling and Task Automation for Flexible Surgical Manipulators via Data-driven Approaches"

With the advancement of new surgical paradigms such as keyhole surgery and natural orifice transluminal surgery, flexible/soft robot manipulators have become promising solutions due to the capability of navigating through torturous and confined tissue environments and reaching surgical sites that are inaccessible to their rigid counterparts. Their inherent compliance brings about safer tool-tissue interaction. The unique actuation mechanism such as tendon-driven method enables the separation of distal manipulators from the bulky proximal actuation systems. Nevertheless, challenges exist in modeling and controlling these robots due to actuation redundancy and various nonlinear effects. The level of complexity increased when unknown tool-tissue contact dynamics are involved. Data-driven approaches provide an efficient tool to model the kinematics and derive control policies without prior knowledges. Therefore, my thesis aims at leveraging data-driven methods to address the above issues and ultimately achieve the automation of surgical sub tasks for flexible/soft surgical manipulators.

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Tiffany Corbet

Ecole Polytechnique Fédérale de Lausanne, Switzerland. Defitech Foundation Chair in Brain-Machine Interface. Lab. of Prof. José del R. Millán

"Sensory electrical stimulation a novel feedback modality for brain-machine interfaces"

Recently, several studies showed that brain-machine interface (BMI) based on EEG-driven electrical stimulation or robotic therapies could enhance motor recovery for severely impaired patients. The purpose of my PhD is to develop a BMI to induce corticospinal tract plasticity and foster motor recovery. During my PhD I investigated sensory electrical stimulation as a new feedback modality for BMI systems. Through different experiments, I showed that BMI based on sensory electrical stimulation fostered cortical activation during motor imagery, enhanced subjects' performances and increased BMI robustness. Moreover, BMI based on sensory electrical stimulation leaded to an increase of corticospinal tract excitability compared to standard BMI systems based on visual feedback. A new experiment is now investigating the underlying mechanisms of intensive BMI training on brain plasticity and motor recovery of chronic stroke patients. EEG-driven sensory electrical stimulation is then, a promising solution for BMI applied for motor rehabilitation.

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Hannelore Aerts

Ghent University, Belgium. Faculty of psychology and educational sciences. Lab. of Prof. Daniele Marinazzo

"Optimizing brain tumor surgery using large-scale brain network modeling"

Presurgical planning for brain tumor resection aims at delineating eloquent tissue in the vicinity of the lesion to spare during surgery. To this end, non-invasive neuroimaging techniques such as functional MRI and diffusion weighted MRI are currently employed. However, taking into account this information is often still insufficient, as the complex non-linear dynamics of the brain impede straightforward prediction of functional outcome after surgical intervention. Large-scale brain network modeling using The Virtual Brain carries the potential to bridge this gap by integrating neuroimaging data with biophysically based models of brain functioning to predict collective brain dynamics. Results of our first study establish the basis for this purpose, by demonstrating individual specificity of biophysical model parameters, differences in model parameters dependent on distance from a tumor, and associations between model parameters and structural network topology and cognitive performance.

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Daniela Zöller
Ecole Polytechnique Fédérale de Lausanne, Switzerland, Medical image processing lab, Prof. Dimitri Van de Ville and University of Geneva, Switzerland, Lab. of Prof. Stephan Eliez

"Dynamic features of multimodal MRI data reveal functional signatures of psychosis in 22q11.2 deletion syndrome"

Medical imaging technologies bare a large potential to transmit advancements in data science into medicine for the better understanding of human brain anatomy and function in health and disease. In this work, I analyze multimodal magnetic resonance imaging data from patients with 22q11.2 deletion syndrome, a neurodevelopmental disorder coming with a high risk for psychosis.
Combining different measures of functional brain dynamics with multivariate analysis approaches, I revealed patterns of altered brain development related to psychosis. Further, I used network control theory to investigate how the brain's structural wiring may support these aberrant functional dynamics. The results uncovered that altered structural controllability coincides with abnormal brain dynamics, both implicating mainly frontal brain regions known for their involvement in self-monitoring and salience processing.
Overall, by using multimodal imaging data analysis, this work opens new avenues towards better insights into the development of psychosis, with the potential to improve diagnostics and treatments.

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Baran Gözcü
Ecole Polytechnique Fédérale de Lausanne, Switzerland. Laboratory for information and interference systems, Lab. of Prof. Volkan Cevher

"Learning-based Magnetic Resonance Imaging"

In the area of magnetic resonance imaging (MRI), an extensive range of non-linear reconstruction algorithms have been proposed that can be used with general Fourier subsampling patterns. However, the design of these subsampling patterns has typically been considered in isolation from the reconstruction rule and the anatomy under consideration. We propose a learning-based framework for optimizing MRI subsampling patterns for a specific reconstruction rule and anatomy, considering both the noiseless and noisy settings. Our learning algorithm has access to a representative set of training signals, and searches for a sampling pattern that performs well on average for the signals in this set. We present a novel parameter-free greedy mask selection method, and show it to be effective for a variety of reconstruction rules and performance metrics. Moreover we also support our numerical findings by providing a rigorous justification of our framework via statistical learning theory.

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Tushar Chouhan
Nanyang Technological University, Singapore. School of Computer Science and Engineering (SCSE), Lab. of Prof Cuntai Guan

"Decoding Neurophysiological Mechanisms and Complex Brain Networks using Electroencephalogram (EEG) and Machine Learning in Brain-Computer Interfaces (BCI)"

It is hypothesized that the very basis of cognition, motion and emotion lies in the balance between the integration of information from and functional specialization of segmented brain areas. However, modelling such complex interaction is an extremely challenging task. My research focusses on uncovering the dynamic brain networks during different hand movements and emotion processing in health and disease. This is achieved by using data-driven methods and Network Neuroscience to estimate functional and causal interactions between different brain regions. The result is a dynamic functional "connectome" which can be analysed using statistical tools to reveal pathological network characteristics. Moreover, such interactions can be modelled using machine learning to predict different hand movements directly from brain signals. This finds important applications in Stroke rehabilitation. In this way, I hope to use my research to not only help develop new humanitarian technology but also shed light on how our complex brain works.

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Alessio Buccino
University of Oslo, Norway. Center for Integrative Neuroplasticity (CINPLA), Lab. of Prof. Gaute Einevoll and University of California San Diego, USA, Department of Bioengineering, Lab. of Prof. Gert Cauwenberghs

"A computationally-assisted approach to neural electrophysiology"

Extracellular electrophysiology is one of the most important and widely-used approach to investigate how the brain functions. Recent advances in both instrumentation, for example Multi-Electrode Arrays with high spatial density and channel count, and computational modeling, give us powerful tools to improve standard techniques involved in the electrophysiological pipeline. The latter consists of several steps, starting with spike sorting, neural cell-type classification and localization, and finally electrical stimulation.
In my talk, I will show how each of the aforementioned steps can benefit from novel methods that combine computer simulations and data-driven approaches. Realistic biophysical simulations can be used, for example, to construct recordings of known-ground-truth for spike sorting evaluation and validation, to employ supervised learning methods, such as deep learning, for cell-type recognition and 3D localization, and to optimize stimulation paradigms that increase cell selectivity and accuracy.

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Jérôme Dockès
Institut national de recherche en informatique et en automatique, France. Parietal team, Lab. of Prof. Bertrand Thirion

"Predicting the spatial distribution of neuroimaging observations from text reports"

Functional neuroimaging aims to discover which brain regions are involved in particular mental processes. Functional Magnetic Resonance Imaging (fMRI) publications typically describe an experiment and report the spatial locations where significant brain activations were measured.
We aim to extract quantitative mappings from terms used by neuroscientists to brain regions. To do so, we collect 14,000 fMRI articles, and train linear models that predict the spatial distribution of reported activations, given a simple representation of an article's text. We demonstrate that least absolute deviations regression, also known as robust regression, outperforms least squares for predicting the activations reported in left-out articles. We propose an efficient solver for robust regression. The trained coefficients provide brain maps associated with each term in the vocabulary of neuroscience. They also provide a way to embed text-only documents into brain space, opening new perspectives for statistical meta-analysis of the neuroimaging literature.

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Prof. Silvestro Micera - Keynote lecture
Bertarelli Foundation Chair in Translational Neuroengineering, Center for Neuroprosthetics, Campus Biotech, EPFL Geneva

"Title"

The goal of the Translational Neural Engineering (TNE) Laboratory is to develop implantable neural interfaces and robotic systems to restore sensorimotor function in people with different kinds of disabilities (spinal cord injury, stroke, amputation, etc.). In particular, the TNE lab aim is to be a technological bridge between basic science and the clinical environment. Therefore, TNE novel technologies and approaches are designed and developed, also starting from basic scientific knowledge in the field of neuroscience, neurology and geriatrics, with the idea that better understanding means better development of clinical solutions.

Prof. Silvestro Micera holds the Bertarelli Foundation Chair in Translational Neuroengineering at the School of Engineering at the Ecole Polytechnique Fédérale de Lausanne. He received the Laurea degree in Electrical Engineering from the University of Pisa and the PhD in Biomedical Engineering from the Scuola Superiore Sant'Anna. In 2009 he was the recipient of the "Early Career Achievement Award" of the IEEE Engineering in Medicine and Biology Society. Prof. Micera's research interests include the development of hybrid neuroprosthetic systems (interfacing the nervous system with artificial systems) and of mechatronic and robotic systems for function and assessment restoration in disabled and elderly persons.

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