Workshop Title:
Deep Learning in Unconventional Neuromorphic Hardware

Organizers and Biographies

Daniel Brunner is an Associate Professor at the CNRS institut FEMTO-ST in Besancon, France. He is a pioneer in Reservoir Computing using photonic substrates, most notably semiconductor lasers. Furthermore he has pioneered new, fully parallel and photonically realized learning concepts. He is managing editor of Nanophotonics and was guest editor of one book and two special issues. He has unique experience in the organization of transdisciplinary workshops and has initiated and implemented the “Cognitive Computing: merging concepts and hardware” conference (120 participants, Hannover 2018), the “Computing with dynamical systems” workshop series and the fully virtual and online SPIE conference “Emerging Topics in Artificial Intelligence” (781 video views and 2612 slack discussion participations).

Irene Estébanez is a third year PhD student at the University of the Balearic Islands and a member of the IFISC (Institute for Cross-Disciplinary Physics and Complex Systems) in Palma de Mallorca, Spain. Her research is focused on hardware implementations of Reservoir Computing, combining experimental and numerical results. She has been engaged in the participation and organization of multiple outreach events, including Pint of Science, Open Doors Day, International Day of Women and Girls in Science, in recent years.

Claudio Gallicchio is Assistant Professor of Machine Learning at the Department of Computer Science of the University of Pisa, Italy. He received his PhD from the University of Pisa, where he focused on Reservoir Computing models and theory for structured data. His research is based on the fusion of concepts from Deep Learning, Recurrent Neural Networks and Randomized Neural Systems. He is founder and chair of the IEEE CIS Task Force on Reservoir Computing, and member of IEEE CIS Data Mining and Big Data Analytics Technical Committee, of the IEEE CIS Task Force on Deep Learning and of the IEEE Task Force on Learning for structured data. He (co-)authored several publications at major ML conferences, including ICML, AAAI and IJCNN/WCCI. He has (co-)organized several events (special sessions, workshops and tutorials) at ML international conferences (including AAAI, IJCNN/WCCI, ICANN, ESANN). He serves as a member of several program committees of conferences and workshops in ML and AI (including AISTATS, ICLR, IJCAI-PRICAI, ECML-PKDD, ICONIP, IJCNN/WCCI). He served as guest editor for Special Issues in ML journals including IEEE Transactions on Neural Networks and Learning Systems (TNNLS) and Cognitive Computation (Springer). He is an Academic Editor of PLOS ONE.

Xavier Porte is Marie-Skłodowska Curie fellow at the University of Bourgogne Franche-Comte, France. He received the Msc. degree in 2011 and the PhD. degree in 2015, both in Physics, from the University of the Balearic Islands (UIB), Spain. From 2016 to 2018 he was with the Technical University Berlin, Germany, where he was engaged in research work on external optical coupling of quantum-dot microlasers for nanophotonic applications. He is currently a postdoctoral researcher working on photonic spatiotemporal neural networks. His research interests range from nonlinear delay dynamics to nanophotonics and neuromorphic computing.

Nadezdha Semenova is a junior researcher at Saratov State University (Saratov, Russia). From 2014 to 2018, she worked as a teaching assistant and engineer in an educational laboratory attached to the chair of Radiophysics and Nonlinear Dynamics in SSU. In 2017, she defended her dissertation for the degree of Candidate of physical and mathematical sciences (Russian PhD equivalent) in the specialty “Radiophysics” (thesis “Poincare recurrences in ergodic systems”), now her research focuses on noise propagation in neuromorphic hardware. She has been co-organizer of two events: 1 - International Conference “Nonlinear Dynamics of Deterministic and Stochastic Systems” (Saratov, Russia, 2014) with 75 participants, and 2 - International Workshop “Spatio-Temporal Structures in Ensembles of Interacting Oscillators” (Saratov, Russia, 2016) with 20 participants.

Miguel C. Soriano is a senior researcher (tenure-track) of the University of the Balearic Islands and member of the IFISC (Institute for Cross-Disciplinary Physics and Complex Systems) in Palma de Mallorca, Spain. He is currently the PI of a Spanish national science project on quantum Reservoir Computing and has participated in two European projects on neuro-inspired computing with hardware (PHOCUS: towards a PHOtonic liquid state machine based on delay-CoUpled Systems and ADOPD: ADaptive OPtical Dendrites). His main research line covers topics of nonlinear dynamics in physical systems and information processing based on neuro-inspired machine learning methods, with a balanced interplay between theoretical and experimental work. He has co-organized special sessions and workshops in topics related to this proposal at several international conferences (Dynamics Days Europe in 2015 and 2016, NOLTA 2018) as well as the International Conference on Delayed Complex Systems (DCS2012) with ~100 participants. He currently serves as program committee member in several photonic-related conferences. He is co-editor of the book “Photonic Reservoir Computing: Optical Recurrent Neural Networks” (De Gruyer 2019) and two special issues in indexed journals (Cognitive Computation and Entropy.

Description of the scope and impact of the Workshop

The importance and impact of Deep Learning and Deep Neural Network methodologies are by now widely accepted. This exceptional success is nowadays associated with special purpose hardware acceleration technologies (e.g., GPUs, TPUs), based primarily on conventional electronic hardware. However, the observed architecture of biological neural systems fundamentally differs from von Neumann processors. Following a biological inspiration, unconventional neuromorphic hardware using photonics, 3D integration, spin-tronic, in-memory substrates and architectures attract increasing attention as a way to implement Deep Learning algorithms. The common objective is to leverage substrate or architecture inherent advantages in terms of speed, power consumption, latency, and scalability.

A significant effort to increase synergy between neuromorphic computing substrate developments and Deep Learning concepts is needed. This includes developing high-performance Deep Neural Networks topologies amenable to neuromorphic implementations, finding solutions to manage the intrinsic physical noise for neuromorphic computation, and exploring learning solutions alternative to Backpropagation. Simultaneously, inherent properties of neuromorphic substrates motivate novel Deep Learning models and algorithms with intriguing possibilities, for example leveraging intrinsic continuous dynamics offered by photonics. We expect a major boost from these ideas inspired, e.g., by the recent developments in physical substrates for Reservoir Computing, a computational framework suited for temporal/sequential data processing.

This workshop intends bringing researchers from different backgrounds (including without being limited to Physics, Computer Science, and Engineering) together to address the challenges posed by developing Deep Learning in unconventional neuromorphic hardware. It aims at providing the ideal platform for cross-pollination of views among the diverse covered fields. Accordingly, we call for contributions that address (without being limited to) the following topics:

- Deep Learning concepts for neuromorphic implementations, including
  - Deep Neural Networks based on linear dynamics and/or partially untrained layers
  - Neural ODEs and Continuous-depth neural architectures
  - Spiking Neural Networks
  - Noise-engineering (e.g., based on population-coding)
  - Learning in deep neural architectures beyond Backpropagation
- Computational and neuromorphic concepts, including
  - Analogue and distributed computing
  - Quantum hardware reservoirs
- Unconventional and next generation hardware, including
  - In memory computing
  - Massively parallel hardware networks
  - 3D integrated Neural Network integration
  - Photonic computing

Timeliness of the Topic

The goal of this workshop is to stimulate the synergy between the research areas of Deep Learning and physical implementations in neuromorphic hardware. From a Neural Networks perspective this synergy offers an unprecedented opportunity to explore innovative and timely solutions (e.g., models, topologies, and training algorithms) that leverage intrinsic properties of unconventional physical substrates (for instance, the intrinsic huge-dimensional and controllable input-driven dynamics). More in general, the topic of the proposed workshop has relations to several major active areas of research in the current development of Machine Learning, including randomized Deep Learning approaches and the lottery ticket hypothesis, learning algorithms beyond Backpropagation, continuous and implicit depth models, Neural Ordinary Differential Equations and Reservoir Computing.

While some previous workshops attempted at bringing researchers on Machine Learning and Physics together, those were mainly in the context of independent events or co-located with physics conferences. We believe that the time is now ripe to bring the discussion to a level of a major conference on Neural Networks.

Workshop Duration

Full day - 6 hours

Information on the Schedule

The workshop's schedule is tailored to an online event format. While we are ready to amalgamate perfectly within the main event organization, we plan to integrate live sessions by video conferencing, pre-recorded videos and discussions through a communication platform such as Slack. In addition to presentations of accepted contributions, the workshop will feature 3 Invited Talks. To further encourage the exchange of ideas and discussions, the workshop will conclude with a panel discussion including all invited and contributed speakers. Lunch and coffee breaks will be coordinated with the official schedule of the conference. During coffee breaks, the attendees will be encouraged to socialize and engage discussions through the communication platform.

Invited Speakers

Julie Grollier CNRS, Thales Laboratory, Paris, France; **reply pending**.
Prof. Grollier is a world leader in the implementation of novel Neural Network concepts in unconventional electronic hardware. An important aspect of her work is that she aims to bring these breakthrough concepts to the field leveraging demonstrated and mass-market compatible semiconductor technology. Her recent work also targets optimization concepts better suited for the integration in hardware substrates.

Kohei Nakajima University of Tokyo, Japan**; reply pending**
Prof. Nakajima is an early adopter and pioneer on the use of physical substrates for information processing, ranging from the exploitation of soft robotic arms to the perspective of harnessing the dynamics of quantum systems. As such, he can offer a multi-faceted vision on the field of unconventional neuromorphic computing. He has delivered numerous invited talks in scientific conferences and workshops, with experience in addressing an interdisciplinary audience.

Sylvain Gigan Sorbonne Université / Ecole Normal Superior, Paris, France.; **reply pending**.
Prof. Gigan is a pioneer of random, parallel and ultra-high dimensional random projections using complex photonic media. In the recent years he turned his focus in the exploitation of these concepts for the efficient and scalable implementation of random projection computing concepts

such as photonic Reservoir Computing. His latest demonstrations surpass the scaling and efficiency of GPU computing, and the concepts are the technological core of the Paris based Startup Lighton.

Links:

Claudio Gallicchio's homepage (contact person): https://sites.google.com/site/cgallicch/
After workshop acceptance we will set up a dedicated web page at the link:
https://sites.google.com/view/dl-neuromorphic-hw
Several of the organizers are members of the IEEE CIS Task Force on Reservoir Computing:
https://sites.google.com/view/reservoir-computing-tf/home