SYNC 1: Advanced neuromorphic computing hardware: Towards efficient machine learning

Time: Monday 9:30–12:15 Location: HSZ 01

Invited Talk SYNC 1.1 Mon 9:30 HSZ 01

Photonic Reservoir Computing and its Application to Optical Communication — •Ingo Fischer and Apostolos Argyris — Instituto de Física Interdisciplinar y Sistemas Complejos IFISC (CSIC-UIB), Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain

Neuromorphic computing and its analog implementation in specific hardware has been gaining a significant revived interest in recent years. Photonic hardware and reservoir computing as method have found particular interest, due to their potential for ultra-fast and energy-efficient performance and possible photonic integration. In this talk, we present photonic reservoir computing platforms based on semiconductor lasers as nonlinear nodes. We discuss, how their high dynamical bandwidth and compatibility with optical fiber communication hardware make them attractive for signal recovery in optical communications. Presenting experimental and simulation results we demonstrate that state-of-the art performance can be achieved for different modulation schemes.

Invited Talk SYNC 1.2 Mon 10:00 HSZ 01

Metal-oxide resistance switching memory devices as artificial synapses for brain-inspired computing — •Sabina Spiga — CNR-IMM, via C. Olivetti 2, 20864 Agrate Brianza (MB), Italy

Memristive devices have been receiving an increasing interest for a wide range of applications, such as storage class memory, non-volatile logic switch, in-memory computing and neuromorphic computing. In particular, in bio-inspired systems, memristive devices can act as dispersed memory elements mimicking synapses in nervous systems, or as stochastic and non-linear elements in neuronal units. Among the proposed technologies, oxide-based resistance switching memory devices (RRAM) are based on redox reactions and electrochemical phenomena in oxides and are very promising because of low power consumption, fast switching times, scalability down to nm scale and CMOS compatibility. In our work, we focus on the switching dynamics of HfO2-based RRAMs and on their implementation as electronic synapses in spiking neural networks (SNN). The conductance of the RRAM devices can be tuned in an analog fashion over several states by using proper programming algorithms and by engineering the material stack. The device dynamics is used to emulate the biological potentiation (conductance increase) and depression (conductance decrease) processes, over several cycles. Moreover, the conductance value update can be achieved by a spike timing and rate dependent plasticity mechanism, which is demonstrated at hardware level, and that is exploited as learning rule in a SNN.

Invited Talk SYNC 1.3 Mon 10:30 HSZ 01

Towards brain-inspired photonic computing — •Wolfram Pernice — University of Münster, Münster, Germany

Photonic integrated circuits allow for designing computing architectures which process optical signals in analogy to electronic integrated circuits. Therein electrical connections are replaced with photonic waveguides which guide light to desired locations on chip. Through near-field coupling, such waveguides enable interactions with functional materials placed very close to the waveguide surface. This way, photonic circuits which are normally passive in their response are able to display active functionality and thus provide the means to build reconfigurable systems. By integrating phase-change materials nonvolatile components can be devised which allow for implementing hardware mimics of neural tissue. Here I will present our efforts on using such a platform for developing optical non-von Neumann computing devices. In these reconfigurable photonic circuits in-memory computing allows for overcoming separation between memory and central processing unit as a route towards artificial neural networks which operate entirely in the optical domain.

15 min. break

Invited Talk SYNC 1.4 Mon 11:15 HSZ 01

Photonic Recurrent Ising Sampler — •Charles Roques-Carmes[1], Yichen Shen[1], Cristian Zanoci[1], Mihika Prabhu[1], Fadi Atieh[1], Li Jing[1], Tena Dubček[1], Chenkai Mao[1], Miles Johnson[1], Vladimir Čeperić[1], John Joannopoulos[1,2], Dirk Englund[1], and Marin Soljačić[1] — [1]Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA — [2]Institute for Soldier Nanotechnologies, 500 Technology Square, Cambridge, MA 02139, USA

The inability of conventional electronic architectures to efficiently solve large combinatorial problems motivates the development of novel computational hardware. There has been much effort toward developing application-specific hardware across many different fields of engineering, such as integrated circuits, memristors, and photonics. However, unleashing the potential of such architectures requires the development of algorithms which optimally exploit their fundamental properties. We present the Photonic Recurrent Ising Sampler (PRIS), a heuristic method tailored for parallel architectures allowing fast and efficient sampling from distributions of arbitrary Ising problems. Since the PRIS relies on vector-to-fixed matrix multiplications, we suggest the implementation of the PRIS in photonic parallel networks, which realize these operations at an unprecedented speed. The PRIS provides sample solutions to the ground state of Ising models, by converging in probability to their associated Gibbs distribution. Our work suggests speedups in heuristic methods via photonic implementations of the PRIS.

Invited Talk SYNC 1.5 Mon 11:45 HSZ 01

Beyond von Neumann systems: Computational memory for efficient AI — •Irem Boybat — IBM Research - Zurich, Switzerland

The highly data-intensive AI applications call for innovations in computing architectures as the performance of conventional computing systems with separate processing and memory units are limited by data access and transfer. For example, training deep neural network models with millions of tunable weights takes days or even weeks using relatively powerful heterogeneous systems, and it consumes more than hundreds of kilowatts of power. In-memory computing is a promising avenue to accelerate AI workloads because computations take place within the memory itself, eliminating the need to move the data around. A new class of emerging memory devices - the so-called memristive devices - is gaining significant interest for in-memory acceleration owing to their scalability, non-volatility and fast access time. Arrays of memristive devices can be used to perform computationally expensive operations in place by exploiting their physical attributes. Deep learning training and inference can be realized with high area and energy efficiency with cascaded arrays of memristive devices. Moreover, memristive devices can also serve as the neuronal and synaptic compute primitives for the next generation of neural networks such as spiking neural networks.