Solitonic neuromorphic hardware for pattern recognition and episodic memorization

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Neuromorphic models [1,2] are proving capable of performing complex machine learning tasks, overcoming the structural limitations imposed by software systems [3] and electronic neuromorphic models [4]. Recently a photon solitonic neuron model [5] has been developed that is able to receive information, process it and store it. The work we present creates a soliton neural network (SNN) through the interfacing of these neurons [6]. The networks consist of a succession of X-shaped junctions which, recognizing the information propagated within the guides, switch by identifying specific preferential trajectories which constitute bit-by-bit memories. The network can memorize and subsequently use the acquired information to recognize further unknown information. The peculiar characteristic of the SNN is its ability to learn in a plastic way, similarly to what happens in the biological tissue. In the nervous system, neurons exchange signals and recognize incoming patterns thanks to the creation, consolidation and destruction of synaptic bridges. Similarly, our neurons can save the information they receive by self-modifying their structures through variations in the refractive index. We propose a neuromorphic model based on a solitonic-waveguide X-junctions interfacing, as shown in fig. 1, obtained by interfacing two input soliton neurons (fig 1a), whose channels give rise to three layers: an input layer, a hidden layer and an output layer as reported in fig 1b. Fig 2. re-proposes network training on four different configurations. Each configuration is characterized by only one channel active while the others are off. Training consists in injecting for several cycles the signal that modifies the refractive index map. Then, inserting signals into all the input channels show a high output response only in correspondence with the trained channel.

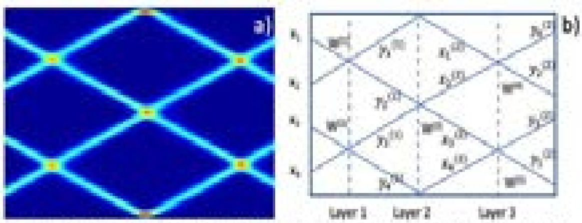

Figure 1. (a) Solitonic Neural Network with two input neurons, (b) schematic of the network structure.

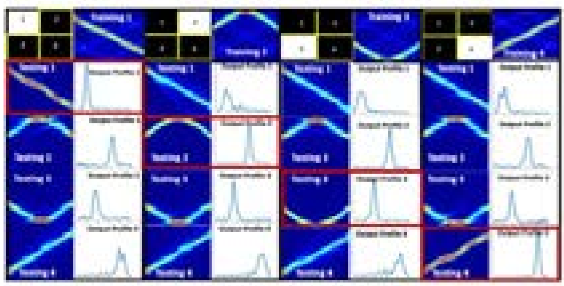
Figure 2 Learning and memorizing of the SNN with a single input

Recent Publications

1. Tari, H., Bile, A., Moratti, F. et al. Sigmoid Type Neuromorphic Activation Function Based on Saturable Absorption Behavior of Graphene / PMMA Composite for Intensity Modulation of Surface Plasmon Polariton Signals. Plasmonics (2022). https://doi.org/10.1007/s11468-021-01553-z
2. Bile, A., Pepino, R., Fazio, E., Study of Magnetic Switch for Surface Plasmon Polariton Circuits, AIP Advances (2021), Volume 11, issue 4. https://doi.org/10.1063/5.0040674
3. Bile, A., Tari, H., Grinde, A., Frasca, F., Siani, AM, Fazio, E., Novel model based on artificial neural networks to predict short-term temperature evolution in museum environment, Sensors, 2022 ; 22 (2): 615. https://doi.org/10.3390/s22020615.
4. B. Ianero, A. Bile, M. Alonzo, E. Fazio, Stigmergic Electronic Gates and Networks, J Comput Electron (2021). https://doi.org/10.1007/s10825-021-01799-0.
5. Bile, A., Moratti, F., Tari, H., Fazio, E., Supervised and unsupervised learning using a fully-plastic all-optical unit of artificial intelligence based on solitonic waveguides. Neural Comput & Applic 33, 17071– 17079 (2021). https://doi.org/10.1007/s00521-021-06299-7
6. Bile, A., Tari, H., Fazio, E., Episodic memory and information recognition using Solitonic Neural Networks based on photorefractive neuro-plasticity, submitted to Neural Computing and Application.

Biography

Alessandro Bile graduated in physics (2019) at the "Sapienza" University of Rome as part of the VIRGO experiment and in Electronic Music from the "Santa Cecilia" Conservatory (2018). In 2019 he entered the Electromagnetism PhD at the "Sapienza". He deals with mathematical modeling and design of intelligent hardware systems operating in the optics domain. Between 2019 and 2022 he signed two contracts with Sapienza on the European project "Collection Care" and on "Intelligent optical systems for the recognition and the sanitization of pathological microorganisms and nano-organisms" project. He also applies artificial intelligence techniques to the microclimate of cultural heritage to provide useful forecasts for the conservation of artistic artefacts. He was awarded the "Avvio alla Ricerca" funding in November 2020 and November 2021. In 2022 he won a scholarship funded by the French government to carry out his research in France and became Visiting Researcher at the Institut Femto-St.

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