Soutenance de thèse

Mercredi 17 Juillet

10h, Amphithéâtre - C2N

Neuro inspired computing with excitable microlasers

Amir Masominia

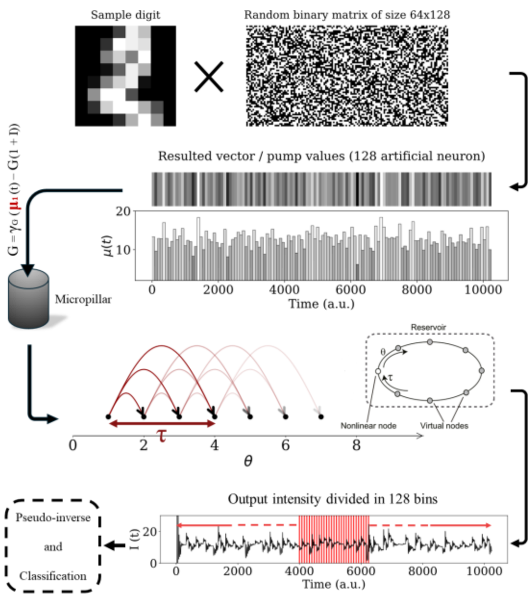
Jury Members :
M. Damien RONTANI - Rapporteur / Rapporteure
M. Guy VERSCHAFFELT - Rapporteur / Rapporteure
M. Damien QUERLIOZ - Examinateur / Examinatrice
Mme Teodora PETRISOR - Examinateur / Examinatrice
M. Massimo GIUDICI - Examinateur / Examinatrice

Abstract

This thesis presents research on alternative computing systems, with a focus on analog and neuromimetic computing. The pursuit of more general artificial intelligence has underscored limitations in conventional computing units based on Von Neumann architectures, particularly regarding energy efficiency and complexity. Brain-inspired computing architectures and analog computers are key contenders in this field. Among the various proposed methods, photonic spiking systems offer significant advantages in processing and communication speeds, as well as potential energy efficiency. We propose a novel approach to classification and image recognition tasks using an in-house developed micropillar laser as the artificial neuron.

The nonlinearity of the spiking micropillar laser, resulting from the internal dynamics of the system, allows for mapping incoming information, optically injected to the micropillar through gain, into higher dimensions.

This enables finding linearly separable regions for classification. The micropillar laser exhibits all fundamental properties of a biological neuron, including excitability, refractory period, and summation effect, with subnanosecond characteristic timescales. This makes it a strong candidate in spiking systems where the dynamics of the spike itself carries information, as opposed to systems that consider spiking rates only. We designed and studied several systems using the micropillar laser, based on a reservoir computer with a single physical node that emulates a reservoir computer with several nodes, using different dynamical regimes of the microlaser. These systems achieved higher performance in prediction accuracy of the classes compared to systems without the micropillar. Additionally, we introduce a novel system inspired by receptive fields in the visual cortex, capable of classifying a digit dataset entirely online, eliminating the need for a conventional computer in the process. This system was successfully implemented experimentally using a combined fiber and free-space optical setup, opening promising prospects for ultra-fast, hardware based feature selection and classification systems.



General overview of the proposed method for this study for an example system with 128 artificial neurons. Data, after undergoing a masking procedure that emulates the existence of artificial neurons, inputs to the micropillar through gain. τb and τp, and their relation to the relaxation time (τch), determine the level of neighboring neurons' interaction, based on the idea of Appeltant et al. The output of the micropillar, decoded using a binning system, where a single value for each bin will be chosen, then a pseudo-inverse process will create the weight matrix.