ST7 – 82 – PHYSICAL NEURO-INSPIRATORY SYSTEMS FOR INFORMATION PROCESSING

Dominante : PNT (Physics and NanoTechnology)
Langue d'enseignement : English
Campus où le cours est proposé : Metz

Engineering problem

In a context of constant increase of the volume of information to be processed, it is necessary to define new analysis strategies. Automatic classification methods based on machine learning are promising, but their numerical implementations remain slow and very energy-consuming. An alternative solution consists in designing hardware architectures called neuro-inspired, which allow to lift a large part of these barriers. This theme is attracting growing interest both in fundamental research and among start-ups and large high-tech groups such as IBM and Google.

In this context, and through a specific architecture known as the reservoir computer (an artificial neural network for which only a final reading layer is trained), we propose to students to discover the design principles of physical neural networks. For this, students will use many optimization techniques such as ridge regression and gradient descent, as well as their accelerated versions, or stochastic heuristics (e.g. simulated annealing, genetic algorithms).

The objective will be to simulate and test a prototype of a physical neuro-inspired processing architecture comprising several tens, even hundreds of thousands of neurons and to demonstrate its low energy consumption, to determine the equivalent number of floating operations per second achievable compared to a computer on classification tasks.

Advised prerequisites

Knowledge of equations and dynamical systems. Courses in statistics, signal processing and automation, good command of a programming language (e.g. Matlab, Python, or C/C++).

Context and issue modules: These modules include an introductory conference on the theme by personalities from the academic and industrial worlds, presentations on the technological and scientific obstacles, and a presentation of the associated projects.

Specific course (60 HEE) : *Optimization for learning physical systems*

Short description: This course presents the physical and mathematical tools for the realization and training of artificial neural networks: echo state network (ESN), electronic and photonic implementations, memory and computational capacity of physical architectures, supervised and unsupervised learning, ridge regression and regularization, accelerated gradient descent techniques, heuristic methods, hardware approaches for deep networks, emerging technologies (e.g. integrated photonics, nano-photonics and spintronics)

Project: *High performance and low energy cost classification of video signals and images by photonic systems*

- Associated partners: Start-up Light On, CentraleSupélec / Photonics Chair and FEMTO-ST Institute

- Location: Metz campus

- Short description : The project will focus on the learning/optimization of an experimental photonic architecture of a neuro-inspired analog computer (developed in CentraleSupélec laboratories in collaboration with the FEMTO-ST Institute). Students will have to choose learning/optimization strategies from the course and implement them so that the photonic architecture can perform image/video signal classification or solve industrially oriented problems proposed by our industrial partner Light-On. The organization of the project is as follows:

1) Rapid bibliographical study of the image or video signal classification task (or task proposed by the Light-On partner)

2) Numerical simulation on a realistic model of the architecture (provided) under Matlab. Implementation of learning methods based on linear/ridge regression, multi-logistic regression, or stochastic heuristics (unknown cost function model).

3) Identification of important physical hyper-parameters (experimentally adjustable) for the photonic architecture

4) Experimental tests, performance analysis, evaluation of the computational capacity (flops) and comparative study of the energy performance (energy cost per processed image/video sequence) compared to software methods.