Neuromorphic-based optimization algorithms

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This Postdoc will be carried out in ERC Generator program of the University of Lille and the framework of the PEPR (Programme et Equipement Prioritaire de Recherche IA project devoted to Artificial Intelligence.

Context

Many scientific and industrial disciplines are concerned by big optimization problems (BOPs). The goal of this work is to come up with breakthrough in optimization algorithms on neuromorphic based architectures composed of millions of spiking neurons. The convergence between optimization algorithms and brain inspired computing will represent a novel paradigm for solving BOPs.

Neuromorphic computing, a brain-inspired processing hardware, is a breakthrough technology and promising alternative to Von Neumann architectures. The brain manages billions of neurons and trillions of synapses, while consuming tens of watts. Neuromorphic computing reduces the power used by the algorithms by an important factor (1000 with current technologies), and then make optimization cleaner and greener. Low energy computing allows to target optimization problems involving Internet of Things (IoT) devices, embedded systems and mobile devices to improve their autonomy.

Research roadmap

Neuromorphic computing for optimization is in its infancy. One of the most challenging and innovative research in this project concerns the design of an efficient spiking neural network (SNN) model for metaheuristics. The event-based computing paradigm employed by spiking neurons of the brain contrasts with the Von-Neumann paradigm of current optimization algorithms. Using sparse and responsive events, SNNs hold the promise of greatly improved power efficiency and response latency.

Two important steps are involved: modelling and implementation. In terms of *modelling*, a mapping of metaheuristic algorithms on network of SNNs has to be developed.

The *modelling* step raises the following main questions:

- Spiking neural network organization (e.g. type of layers, number of neurons/layer, topology, recurrency). The SNNs model the decision variables, objective functions, and search. The oscillating neurons cooperate with each other through spikes, and modulate their decision using event-driven spikes. The encoding of solutions is carried out by spiking neurons with spike firing and spike timing. The firing rate is updated according to the quality of the solution it represents. When the neuron's synchronization is reached, one can consider that the SNN converges towards the states (i.e. firing rates) of an optimal solution.
- Neuron models and their representation in which we define a spike-based neural encoding of the optimization problem and algorithms. Various neuron models will be explored such as the Leaky-Integrate-and-Fire Model (LIF) and chaotic models.

In terms of *implementation*, NPUs (Neuromorphic Processing Unit) that implement SNNs gain an important attention in academia and industry. The simulation tools such as *NENGO* and *Brian2* will allow the comparison between various models. Then, a model to hardware mapping will be carried out. The developed SNN model for metaheuristics will be mapped on emerging low-power neuromorphic hardware such as IBM TrueNorth or Intel Loihi2.

Location: University of Lille and INRIA Lille
Duration: 18 months
Application: Candidates must have a master in computer science or other relevant fields. Good programming skills are required. Applications should be sent to El-ghazali.Talbi@univ-lille.fr
They should include:

- a curriculum vitae;
- a motivation letter;
- at least two referees with their e-mail addresses;
- links to PhD thesis and publications;
- links to software contributions.

References

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