Laboratoire Génie électrique et électronique de Paris
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Study of spiking neural network inspired by the biological cortex using nonlinear RF devices

Études du traitement matériel de l'information en utilisant le réseau neurones impulsionnels inspiré par le cortex biologique

Context:

This work is part of the research activities carried out within GeePs on low power neuromorphic circuits and their extension to the artificial intelligence network. The work carried out on this theme aims to analyze the processing of information by spiking neural network (SNN) inspired by biological neurons. The computing capacity of an SNN mainly comes from the nonlinear activation function of neurons. The radiofrequency (RF) devices exhibit different nonlinearities, which can behave as neurons. Within this context, a smart network of RF devices can be established thanks to the SNN techniques, which enables decision autonomy and power autonomy.

The originality and ambition of this thesis are:

- Proposing a new concept of smart network of RF devices based on wireless neural networks.
- Exploring the wireless channels for information transmission among RF device neurons.
- Improving the training of the SNN for better accuracy and better matching with the physical properties of the RF devices.

Some studies on similarity between nonlinearity of RF devices and spiking neurons have been studied and explored at GeePs for the evaluation of the proposed techniques. Several algorithms and behavioral models have been proposed and evaluated recently and have been the subject of international publications. The objectives of this project are therefore four-fold:

- In-depth theoretical study on information processing by neural networks.
- Exploitation of effective techniques to modulate an analog signal to spikes in the SNN.
- Performance analysis of the SNN in the processing of the signal of different frequencies under the constraints imposed by the RF devices.
- Establishment of a hardware-in-the-loop (HIL) bench to process the radiofrequency (RF) signal with smart network of RF devices in real time.

Positioning:

The subject focuses on the functioning of ultra-low power circuits inspired by neurons and biological synapses from the point of view of information processing. These techniques will also find an echo in the processing of the acoustic signal, the RF signal, and the image.
Research on artificial intelligence (AI) systems are recently very popular in academia and industry. Most of these AI systems are made with ANN operated on conventional digital circuits which give an impressive performance, but which consume a lot of energy. Knowing that the density of a cerebral cortex of a human being is around 0.01W/cm² and that of a microprocessor of today's

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technique is 100W/cm², an intuitive idea is to propose new techniques that emulate neurons and synapses, which gives us neuromorphic circuits and SNN networks.
In biology, the signals received by neurons will be processed in a nonlinear way. The RF devices, such as power amplifiers (PA) and mixers, have similar behaviors when they are operating at high efficiency, which impose a distortion on the transmitted signals. Thanks to this nature, if each RF device is regarded as a neuron, the network of the RF devices become a neural network. A smart network of RF devices can be established using SNN techniques as illustrated in Fig. 1:

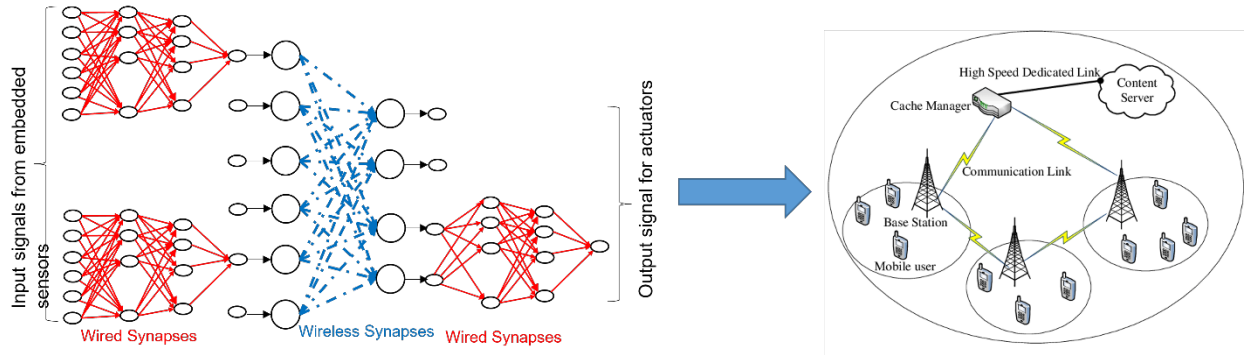

Figure 1: Projection of a wireless SNN on an RF device network

The automatic optimization of resource allocation within this smart network is aimed according to the signal transmission between base stations and user equipment. The idea of processing information in the RF device network as a neural network is revolutionary but remains far from a mature technique.

Objective:

The thesis will study in particular:

- Spike-based information transmission using the RF signal.
- Analysis and modeling of RF-devices-based neuron and of wireless synapses.
- Learning the SNN with these neuron and synapse models.
- The establishment of an overall assessment of the performance of the smart network of RF device network on the processing of the signal of different bandwidths and of different dimensions.

Research plan (3 years):

Year 1: The PhD candidate will work on the state-of-the art and will understand the theories of the traditional ANN and the SNN. He/she will study the similarity and connection between the ANN and SNN. He/she will then propose different ways to encode the ANN-friendly digital signals to an SNN-friendly spikes so that the SNN has easy processing and high precision. One international conference paper is expected from these works.

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Year 2: The candidate will study the wireless channel of spikes propagation among RF devices. He/she will propose the existing training algorithms for wireless NN. Two international conference papers are expected from these works.
Year 3: The candidate will construct a mathematical simulator of SNN-based RF device network. He/she will also devote to establish a full materialized testbench for experimental validation. One scientific journal paper is expected from these works.

Keywords:

spiking neural networks, machine learning, nonlinear RF device, signal processing, artificial intelligence.

Project Supervision:

This project is coordinated by Aziz BENLARBI DELAI, Full Professor (HDR) at Sorbonne University. Siqi Wang and Pietro FERREIRA will work in the same team as co-supervisors.
Aziz BENLARBI DELAI's research is mainly involved in green radio, intelligent ambient issues, and energy efficient solutions for RF communication and localization. Siqi WANG's research interests include artificial intelligence and spiking neural networks, RF device modeling, and energy efficiency optimization for wireless communication systems. Pietro FERREIRA's research interests are design methodologies, harsh environment, and microwave integrated circuits and neuromorphic systems.

Candidate:

For this project, the skills required in the following areas will be necessary:
- Analog and digital electronics.
- Digital communication.
- Signal processing.
- Reading and writing in English.

Prior knowledge of neural networks is desirable. It can also be acquired during the thesis.
The candidate must hold a master's degree or an equivalent degree.
A first research experience will be appreciated.

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