Integrated machine-learning hardware for near-sensor computing applications

November 18th, 2019

IEMN, Villeneuve d'Ascq, France

Technical workshop sponsored by IEEE-CAS and GDR/SOC2

Organizers :

Kévin Hérissé, Benoit Larras, Antoine Frappé (IEMN, Yncréa ISEN)

With the growing amount of Smart Sensors, decreasing the energy consumption of the devices must be a priority to increase the battery lifetime and enable wearable and continuous monitoring. Since communication interfaces are the most energy-hungry parts of the sensor nodes, the "Near-Sensor Computing" concept aims at pre-processing the input data in order to keep only relevant information and thus limit the amount of data to transmit. Machine learning techniques are used to determine the relevance depending on the targeted application. The objective of this workshop is to detail how the embedded processing circuits can be integrated into the hardware and interfaced as close as possible to the sensor.

Seven excellent speakers are scheduled to cover many aspects of integrated processing and machine learning hardware, including a distinguished lecturer from the IEEE Circuit and Systems Society. The application fields range from biomedical signals (EEG, ECG) to audio signals (silicon cochlea, voice activity detection) to vision and general concepts of analog-to-feature conversion. The contributions will cover circuit-level, system-level and integration challenges.

Registration is mandatory: https://events.vtools.ieee.org/m/204142

Schedule :

10h00 – 11h30: Jerald Yoo, National University of Singapore, IEEE CASS Distinguished Lecturer
On-Chip Epilepsy Detection: Where Machine Learning Meets Wearable, Patient-Specific Wearable Healthcare

11h30 – 12h30: Minhao Yang, EPFL
Towards Near-Zero-Power Audio Inference Sensing

12h30 – 14h00: Lunch Break

14h00 – 14h30: Deepu John, UC Dublin
Low Power Sensor Design for Wearable Health Monitoring

14h30 – 15h00: Benoit Larras, Univ Lille, Yncrea Hauts-De-France, IEMN
Distributed Clique-Based Neural Networks for Data Fusion at the Edge

15h00 – 15h30: Jean Martinet, Université Côte d'Azur, I3S, CNRS, Polytech Nice Sophia
Towards a Neuro-Inspired Machine Learning for Vision

15h30 – 15h45: Coffee break

15h45 – 16h15: Sébastien Pecqueur, IEMN
Sensing Paradigms in a Neuromorphic Framework: What are the New Sensing Hardware Figure-of-Merits?

16h15 – 16h45: Antoine Back, LTCI, Télécom Paris, Institut Polytechnique de Paris
Feature Selection Algorithms for the Design of a Flexible Analog-To-Feature Converter

ABSTRACTS

Jerald Yoo, National University of Singapore, IEEE CASS Distinguished Lecturer

On-Chip Epilepsy Detection: Where Machine Learning Meets Wearable, Patient-Specific Wearable Healthcare

Epilepsy is a severe and chronic neurological disorder that affects over 65 million people worldwide. Yet current seizure/epilepsy detection and treatment largely rely on a physician interviewing the subject, which is not effective in infant/children group. Moreover, patient-to-patient and age-to-age variation on seizure pattern make such detection particularly challenging. To expand the beneficiary group to even infants, and to effectively adapt to each patient, a wearable form-factor, patient-specific system with machine learning is crucial. However, the wearable environment is challenging for circuit designers due to unstable skin-electrode interface, huge mismatch, and static/dynamic offset.

This lecture will cover the design strategies of patient-specific epilepsy detection System-on-Chip (SoC). We will first explore the difficulties, limitations and potential pitfalls in wearable interface circuit design, and strategies to overcome such issues. Starting from a 1 op-amp instrumentation amplifier (IA), we will cover various IA circuit topologies and their key metrics to deal with offset compensation. Several state-of-the-art instrumentation amplifiers that emphasize on different parameters will also be discussed. Moving on, we will cover the feature extraction and the patient-specific classification using Machine Learning technique. Finally, an on-chip epilepsy detection and recording sensor SoC will be presented, which integrates all the components covered during the lecture. The lecture will conclude with interesting aspects and opportunities that lie ahead.

Minhao Yang, EPFL

Towards Near-Zero-Power Audio Inference Sensing

Intelligent acoustic sensing that has inference capabilities finds a wide range of applications with stringent energy constraints, from mobile and wearable voice wake-up and control to unattended field acoustic object detection. To reduce the always-on sensing power towards near zero for prolonged uninterrupted operation, researchers resort to analog and mixed-signal circuits for signal processing and computing. This general design philosophy will be demonstrated through the most common function in low-power speech processing systems, i.e. voice activity detection (VAD), throughout the talk. A VAD system can be divided into the feature extraction part and the classification part. First, I will present the effort of designing a 55μW 64×2-channel silicon cochlea with event-driven output for acoustic feature extraction (AFE); and then, I will show how a 1μW 100class/s VAD system can be developed using a dedicated AFE front-end with higher power efficiency and a classifier back-end based on a binarized deep neural network. Finally, I will briefly discuss the on-going work of reducing the VAD system power further by ~10× without compromising the classification throughput.

Deepu John, UC Dublin

Low Power Sensor Design for Wearable Health Monitoring

Healthcare expenditure is increasingly becoming the most significant component in the national spending of many countries. Real-time monitoring of one's physiological data using Internet of Things (IoT) enabled wearable sensors is widely touted as an effective way to address this issue. Long term monitoring of data acquired from IoT sensors using deep learning techniques in cloud servers can facilitate early detection and proactive actions. However, there are several challenges including the cost of transmitting large amounts of data, the latency incurred in the network, the complexity of processing large quantities of data in the cloud, etc.

In this talk, the system architecture, challenges, and approaches to tackle the challenges for wearable sensor design will be introduced. Signal processing and data compression techniques that can reduce system power consumption will be presented along with performance and measurement results. On-sensor AI techniques to detect the integrity of data before transmission and its performance will be discussed.

Benoit Larras, IEMN, Yncréa ISEN

Distributed clique-based neural networks for data fusion at the edge

Distributed smart sensors are more and more used in applications such as biomedical or domestic monitoring. However, each sensor broadcasts data wirelessly to the others or to an aggregator, which leads to energy-hungry sensors not ensuring data privacy. To tackle both challenges, this work proposes to distribute a part of a clique-based neural network in each sensor. This scheme allows standardizing data at the sensor level, ensuring privacy if the data is intercepted. Besides, a lower number of bits is transmitted, thus limiting the communication overhead. The circuit implementation is possible with the use of single-cluster iterative clique-based circuits.

Jean Martinet, Université Côte d'Azur, I3S, CNRS, Polytech Nice Sophia

Towards a Neuro-Inspired Machine Learning for Vision

In this talk, I will discuss our work regarding the use of Spiking Neural Networks (SNN) for computer vision. After a brief introduction to the context and motivation of the project, I will argue in favor of a paradigm change in computer vision and machine learning, with respect to data-hungry and power-hungry popular methods. SNN show many interesting features for this paradigm change, such as their unsupervised training with Spike-Timing-Dependant Plasticity rules, and their implementation on ultra-low-power neuromorphic hardware. And yet, a number of challenges lie ahead before they become a realistic alternative for facing the ever-growing demand in machine learning. Finally, I will give an overview of the intended work in the upcoming CHIST-ERA project APROVIS3D -- Analog PROcessing of bioinspired Vision Sensors for 3D reconstruction, that will start in Spring 2020.

Sébastien Pecqueur, IEMN

Sensing Paradigms in a Neuromorphic Framework: What are the New Sensing Hardware Figure-of-Merits?

As the interface between physical and virtual worlds, sensing hardware provides information from environments to machines. While sensors have to obey to well-defined figure-of-merits, opportunities to recognize physically-non-trivial patterns appear to unlock new applications thanks to artificially intelligent algorithms (such as neural networks). And in today’s context where computers themselves mutate to neuro-inspired architectures, one can question on how to embed sensing into these non-von-Neumann structures, and also on the new excellence criteria of such sensing networks for high-dimensional environmental pattern classification. For the particular case of ion-sensing aiming neuro-sensing via neuromorphic computing, we report that by relevantly exploiting the multi-parametric transient response of organic electrochemical transistors, one could exploit the large materials’ property distributions to classify frequency-dependent voltage patterns (with recognition performances associated to the input-layer property). By pointing that lack of repeatability might enrich the sensing response in relevant information descriptors, we support the emergence of unconventional processes of new materials and device technologies for a new sensing paradigm: such as in situ bottom-up growths of sensitive materials onto functional networks, which actually resemble furthermore neural matter’s behaviors.

Antoine Back, LTCI, Télécom Paris, Institut Polytechnique de Paris

Feature Selection Algorithms for the Design of a Flexible Analog-To-Feature Converter

Classical approaches for signal acquisition are based on Shannon's sampling theorem: the sampling frequency should be greater than twice the maximum frequency of the original signal. Compressed sensing allows for the reduction of the number of acquired samples but it needs a very complex signal reconstruction step. For applications that need only some specific pieces of information, reconstructing the entire signal is not efficient. In the context of wireless sensors, the energy consumption of wireless communication systems represents a significant part of the total consumption. Analog-to-feature conversion is an acquisition method thought for IoT devices, in order to increase their battery life. The aim of this method is to decrease the number of acquired samples by only extracting useful information and then use these samples in a machine-learning-based classifier, able to detect anomalies in the signal and thus to transmit only the classification result. The aim is to build a generic A2F converter in order to acquire low-frequency signals (ECG, EEG, EMG...).

The proposed A2F converter is based on non-uniform wavelet sampling (NUWS). The space of possible wavelets is extremely important, so we have to find solutions to select a small set of wavelets that can be efficiently generated and that provides good classification performance. We use feature selection algorithms to reduce the number of wavelets. We test different feature selection algorithms in order to find, for each type of signal, the best set of wavelets. Some simulations show that we can obtain a classification performance of 98% with 6 features, obtained with Haar wavelets, by using sequential forward search and a neural network classifier. This selection step will then enable to specify the characteristics of the wavelet generators for future hardware design.