

## Research Topic for the ParisTech/CSC PhD Program

**Field:** Information and Communication Sciences and Technologies

**Subfield:** (Digital Electronics, Computer Science)

**ParisTech School:** Telecom ParisTech

**Title:** Selective Approximation for Low Energy Convolutional Neural Networks.

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### **Short description of possible research topics for a PhD:**

The main goal of this PhD. Thesis will be ultra-low energy implementation of deep learning algorithms. To this end we would like to use Binarized Neural networks where both the activations and weights of a Convolutional Neural network (CNN) are quantized to binary values (0,1). This leads to very efficient implementations in silicon using XNOR gates instead of multipliers. However there is a price to pay in terms of accuracy as it will lower the accuracy of predictions.

As a method to optimize Binarized neural networks the goal of this Phd. Thesis will be to use selective binarization. That is, we run experiments on a given CNN (K layers), and find out which layers we can binarize without affecting the accuracy significantly. Furthermore, we would like to attribute a specific quantization level for each layer. (e.g layer One: 9bits, layer Two: 1 bit, layer Three: 16 bits etc..) with the goal of optimizing a combined metric of "Power Consumption" of "Accuracy". The target application for our network (Approxinet) is unmanned drones tracking target objects, so power consumption is a very important criteria.

### **Required background of the student:**

Software Engineering, Algorithms, Probability & Statistics, Digital Electronics.

Desired: Hands-on experience of open-source software development with Python.

### **A list of 5 (max.) representative publications of the group:**

[1] Hao Cai, You Wang, Lirida Alves de Barros Naviner, and Weisheng Zhao. Approximate computing in mos/spintronic non-volatile full-adder. In Proceedings of ACM/IEEE International Symposium on Nanoscale Architecture, Beijing, China, July 2016.

[2] Hao Cai, You Wang, Lirida Alves de Barros Naviner, and Weisheng Zhao. Robust ultra-low power non-volatile logic-in-memory circuits in FD-SOI technology. IEEE Transactions on Circuits and Systems I: Regular Papers, 64(4):847--857, November 2016.

[3] Olivier Morillot, Laurence Likforman-Sulem, Emmanuèle Grosicki: New baseline correction algorithm for text-line recognition with bidirectional recurrent neural networks. J. Electronic Imaging 22(2): 023028 (2013)

[4] Cristina Oprean, Laurence Likforman-Sulem, Adrian Popescu, Chafic Mokbel: Handwritten word recognition using Web resources and recurrent neural networks. IJDAR 18(4): 287-301 (2015)

[5] Francisco Veirano, Fernando Silveira, Lirida A. B. Naviner: Minimum Operating Voltage Due to Intrinsic Noise in Subthreshold Digital Logic in Nanoscale CMOS. J. Low Power Electronics 12(1): 74-81 (2016)