Ph.D. Project: Energy-Efficient Learning Algorithms

Work Package 3, task 3.1

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Abstract

This project proposes the development of low-complexity online estimation algorithms suitable for the short-wordlength regime required in energy-efficient IoT devices. The methods should increase the energy-efficiency of least mean square (LMS) and recursive least-squares (RLS) algorithms, combining the advantages of several techniques for reducing the energy requirements of adaptive filters, such as set-membership, sums-of-powers-of-two (SOPOT) and power-of-two error LMS algorithms, with recent advances on low-cost RLS algorithms based on dichotomous coordinate descent (DCD) iterations, which allows the design of numerically robust RLS filters, appropriate for fixed-point implementations. In order to reduce the impact of coarse quantization in the input signals, techniques such as subband adaptive filtering and cooperative learning will be used.

1 Scholarship Requirements

The fellowship will be granted to a student of PPGEE/EPUSP (Graduate Program in Electrical Engineering (PPGEE) - Escola Politécnica da Universidade de São Paulo). Information about the application process for PPGEE is available at `http://ppgee.poli.usp.br/?page_id=1914`.

Notice the application period is 02/05/2019 to 17/05/2019.

The Direct Doctorate scholarship is intended for students who are regularly enrolled in stricto sensu post-graduate programs of public or private higher education institutions in the State of São Paulo, without the title of master, for the development of a research project that results in thesis. The analysis of direct doctoral scholarship applications prioritizes a candidate who has just graduated, within the normal term of his / her term with an excellent academic record and, preferably, a successful scientific initiation stage. More information at: `http://www.fapesp.br/bolsas/dd`

2 Goals

The typical IoT device will have limited access to energy, and should therefore employ highly energy-efficient algorithms for learning the conditions in its environment. While several methods for reducing the computational complexity (number of operations) in adaptive filters have been proposed in the last decade or two, such as set-membership or subband adaptive filters, there have been fewer efforts for the design of algorithms that work well under short-wordlength conditions. One of these approaches is the sums-of-powers-of-two (SOPOT) scheme, used with LMS-type adaptive filters, and cooperative learning algorithms based on filter differences. The main goal of this Ph.D. research will be to devise algorithms that combine the advantages of these various approaches, and extend their application to faster-converging RLS algorithms based on DCD iterations (which are numerically robust methods especially designed for low-cost hardware implementations). Another goal of this research will be to study the effect of different analog-to-digital (A/D) conversion strategies (for example, $\Sigma - \Delta$ conversion with different oversampling and feedback choices) and their resulting delay on filter performance; and the use of cooperative learning to reduce the impact of rough quantization at the input signals.

3 Methods

The student will initially perform a literature review in the subjects of adaptive filtering and online estimation, with emphasis on low-complexity and energy-efficient algorithms, and algorithms designed especially for IoT applications. During the initial phase, the student will also take courses on stochastic processes, statistical signal processing, sensor networks, adaptive filtering and hardware design. These two tasks will be completed during the first year of work. At the beginning of the second year the student will take the qualifying exam, and start the

research in earnest, first implementing known algorithms in simulations that takes into account the particularities of the IoT environment. At the end of the second year, the student should propose the first new algorithms for energy-efficient estimation, trying to derive methods that allow using shorter wordlengths in coefficients and in the input A/D conversion, while sacrificing as little of the performance as possible. In the third and fourth years, the student will work on developing theoretical models for the designed algorithms, on using these models to devise improved algorithms, and on writing papers and the dissertation. We expect that the research will result in two or three conference and two journal papers.