Abstract of Ph.D. Thesis

NEW PROPORTIONATE TYPE ADAPTIVE ALGORITHMS FOR IDENTIFYING SPARSE SYSTEMS WITH VARIABLE SPARSITY

RAJIB LOCHAN DAS

Supervisor: PROF. MRITYUNJOY CHAKRABORTY

ELECTRONICS & ELECTRICAL COMMUNICATION ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR, INDIA

In practice, one often encounters systems that have a sparse impulse response, with the degree of sparseness varying with time and context. During the last decade or so, several adaptive algorithms have been proposed to identify such systems that achieve significantly improved performance as compared to conventional adaptive filters like the LMS and the NLMS by clever exploitation of the system sparseness. Of all the algorithms proposed so far, the Proportionate Normalized Least Mean Square (PNLMS) algorithm and its variants constitute the most popular class of algorithms.

The primary concern of this thesis is to present new analyses of the PNLMS class of algorithms that provide new insights into their workings. Subsequently, based on these analyses, it develops new proportionate type adaptive filters that overcome some of the commonly known shortcomings of these algorithms. Towards these, we first present a new convergence analysis of the PNLMS algorithm, where we evaluate the steady state excess mean square error (EMSE) and also conditions for stability of the EMSE without imposing any whiteness assumption on the input. The analysis relies on a transform domain model of the PNLMS algorithm and brings out certain new convergence features not reported earlier. In particular, it shows that the mean square deviation (MSD) of each tap weight is directly proportional to the corresponding gain factor of that tap.

Next, we propose a sparse adaptive algorithm by introducing a suitable weighted l_1 norm penalty of the filter weight vector to the cost function of the classical PNLMS algorithm. Minimization of the cost function w.r.t the filter weights leads to the introduction of certain zero attracting terms in the corresponding update equations, which act as an additional force to pull the inactive taps towards zero. This helps in arresting the sluggishness of the convergence speed of the PNLMS algorithm observed at a later stage of the adaptation process and also in bringing down its steady state MSD simultaneously. A detailed first and second order convergence analyses of the proposed algorithm is then carried out, which, however, reveals that the steady state MSD of the PNLMS algorithm can not be reduced significantly by the zero attractors alone, especially for less sparse systems. To counter this, a variable step size mechanism is introduced in the proposed algorithm which yields both faster convergence rate and lesser steady state MSD simultaneously.

Finally, we present a new robust adaptive algorithm for identifying sparse systems where the sparsity may vary over a wide range, i.e., from highly sparse to non-sparse or fully dispersive systems. The proposed approach uses two adaptive filters - one based on the sparsity agnostic NLMS and other based on the sparsity aware PNLMS, which run in parallel under a novel cooperative learning framework. The proposed collaborative framework results in transfer of weight information from the constituent filter with lesser output MSE to the other one, leading to mutual refinement of each one's convergence performance. Both the

PNLMS and the NLMS algorithms under the proposed arrangements provide uniformly good performance at all levels of system sparsity and outperform existing robust sparse adaptive filters.

Keywords: Sparse system, normalized least mean square, proportionate normalized least mean square, excess mean square error, mean square deviation, l_1 norm, convergence rate, steady state.