AFFINE PROJECTION ALGORITHMS: EVOLUTION TO SMART AND FAST ALGORITHMS AND APPLICATIONS

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ABSTRACT

Affine projection algorithm encompasses a family of configurable algorithms designed to improve the performance of other adaptive algorithms, mainly LMS based ones, especially when input data is highly correlated. The computational cost of the affine projection algorithm depends largely on the projection order, which in turn conditions the speed of convergence, thus high speed of convergence implies usually high computational cost. Some real-time applications (especially multichannel) using the affine projection algorithm can not be implemented in the existing general-purpose hardware, because of this several improvements of the affine projection algorithm have been proposed to make it more computationally efficient and more versatile in terms of performance. This paper outlines the evolution of the affine projection algorithm and its variants, in order to get an efficient and self-reconfigurable algorithm. Furthermore new improvements over the existing low cost and variable step size and projection order versions are proposed to give examples of the new generation of affine projection algorithms.

1. INTRODUCTION

Originally affine projection (AP) algorithms emerged to improve speed of convergence of gradient based algorithms when the input signals did not exhibit flat spectrum, since the speed of convergence of these algorithms decreased substantially in this cases [1].

A common feature that encompasses all AP algorithms is the filter update equation, which uses N (called projection order) vectors of the input signal instead of a single vector as the NLMS algorithm. Therefore, these algorithms could be understood as an extension of the algorithm NLMS, or more generally, as a minimization problem with constraints that can be expressed mathematically as follows.

Let (1) be the change of the L adaptive filter coefficients between successive algorithm iterations,

$$\Delta \mathbf{w}_L[n] = \mathbf{w}_L[n] - \mathbf{w}_L[n-1]. \tag{1}$$

To develop the algorithm the expression (2) has to be minimized under N constraints given by (3):

$$\|\Delta \mathbf{w}_L[n]\|^2 = \Delta \mathbf{w}_L^T[n] \Delta \mathbf{w}_L[n], \tag{2}$$

$$\mathbf{w}_L^T[n]\mathbf{x}_L[n-k] = d[n-k] \quad \text{para } k = 0, 1, \ldots, N-1. \tag{3}$$

$\mathbf{x}_L[n]$ is a vector that comprises the last L samples of the input vector and $d[n]$ represent the desired signal as it is illustrated in Fig. 1.

Figure 1: Adaptive scheme and signals involved using the affine projection algorithm.

The solution of the presented problem leads to the AP update equation given by

$$\mathbf{w}_L[n] = \mathbf{w}_L[n-1] + \mathbf{A}^T[n](\mathbf{A}[n]\mathbf{A}^T[n])^{-1}\mathbf{e}_N[n], \tag{4}$$

where

$$\mathbf{A}[n] = (\mathbf{x}_L[n], \mathbf{x}_L[n-1], \ldots, \mathbf{x}_L[n-N+1])^T, \tag{5}$$

$\mathbf{e}_N(n)$ is a vector of size $N \times 1$ given by

$$\mathbf{e}_N[n] = \mathbf{d}_N[n] - \mathbf{A}[n]\mathbf{w}_L[n-1], \tag{6}$$

and $\mathbf{d}_N[n]$ represents the desired signal vector of size $N \times 1$

$$\mathbf{d}_N^T[n] = (d[n], d[n-1], \ldots, d[n-N+1]). \tag{7}$$

Equation (4) can be expressed by a general form, see expression. (8), which includes the entire affine projection family.

$$\begin{aligned}\mathbf{w}_L[n] &= \mathbf{w}_L[n-1-\alpha(N-1)] \\ &+ \mu \mathbf{A}_\tau^T[n](\mathbf{A}_\tau[n]\mathbf{A}_\tau^T[n] + \delta \mathbf{I})^{-1}\mathbf{e}_{N\tau}[n]\end{aligned} \tag{8}$$

with $\mathbf{e}_{N\tau}[n] = \mathbf{d}_{N\tau}[n] - \mathbf{A}_\tau \mathbf{w}_L[n-1-\alpha(N-1)]$,

$$\mathbf{A}_\tau[n] = (\mathbf{x}_L[n], \mathbf{x}_L[n-\tau], \ldots, \mathbf{x}_L[n-(N-1)\tau])^T \tag{9}$$

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