FASTTRACKING CONJUGATE GRADIENT ALGORITHM

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ABSTRACT

This paper describes a novel Conjugate Gradient (CG) algorithm utilizing a noise-immunized forgetting factor in order to boost the tracking capability for time-varying parameters. The new algorithm is based on re-initializing the forgetting factor when it encounters an unexpected parameter change and has a noise-immunity property due to the cost-er logic function. Fast tracking and low parametric error variance properties are verified through computer simulation in a system identification problem. In addition, the convergence property is analysed by a Chebyshev polynomial approximation. It is shown that the convergence of the CG algorithm is speeded up by an acceleration term when compared to the Steepest Descent (SD) algorithm.

1. INTRODUCTION

The Conjugate Gradient (CG) algorithm has a much faster convergence rate than that of the Steepest Descent (SD) algorithm when the underlying process is stationary. The CG algorithm for adaptive filtering has been developed by G. K. Boray [1]. This algorithm has poor adaptation accuracy, especially when the gradient averaging window size is small. Recently, P-S Chang [2] modified the CG algorithm for the case of non-block processing. In [2], the covariance matrix is estimated with an exponentially decaying window from the input signal vector $x(n) \in \mathbb{R}^N$ as follows

$$\mathbf{R}(n) = g_f \mathbf{R}(n-1) + \mathbf{x}(n)\mathbf{x}^T(n) \qquad (1)$$

to minimize the quadratic cost function defined as

$$\min_{w(n)} \Phi[w(n)] = \frac{1}{2} \mathbf{w}^T(n)\mathbf{R}(n)\mathbf{w}(n) + \mathbf{b}^T(n)\mathbf{w}(n) \qquad (2)$$

where the matrix $\mathbf{R}(n) \in \mathbb{R}^{N \times N}$ is the Toeplitz-symmetric autocorrelation matrix of the input signal, $\mathbf{b}(n) \in \mathbb{R}^N$ is the cross-correlation vector between the desired signal and the input signal, $\mathbf{w}(n) \in \mathbb{R}^N$ is the coefficient to be updated adaptively, $\mathbf{x}(n) \in \mathbb{R}^N$ is an input signal vector, and g_f is the fixed forgetting factor with $g_f \in [0, 1]$.

In this paper, we present two results. Firstly, the convergence property is analysed using Chebyshev polynomials. It is shown that the convergence of the CG algorithm is speeded up by an acceleration term when compared to the Steepest Descent (SD) algorithm. Secondly, if the system parameters are changed abruptly as in a time-varying environment, the performance of the CG algorithm will be deteriorated noticeably. In other words, the CG algorithm may not be suitable for tracking time-varying parameters in some situations. To circumvent this problem, we propose the CG algorithm with a noise-immunized forgetting factor. This approach has not been previously considered in the literature.

2. CONVERGENCE PROPERTY OF THE CONJUGATE GRADIENT ALGORITHM

We first investigate the convergence properties of the CG algorithm. It is shown that convergence constant of the CG algorithm is less than that of the SD algorithm. In [4], this property was analysed by the partial conjugate gradient method. The result derived in this paper shows that the convergence constant has an acceleration term which improves the convergence rate. Let us consider a general approach for solving the quadratic minimization problem. Given an arbitrary starting point $w(0)$, let

$$\mathbf{w}(n+1) = \mathbf{w}(0) + \mathbf{P}_n(\mathbf{R})\mathbf{g}(0) \qquad (3)$$

where $\mathbf{P}_n(\mathbf{R})$ is a polynomial of degree n, $g(0)$ is the initial gradient vector and $\mathbf{R}(n)$ is assumed equal to $\mathbf{R}$.

The selection of a set of coefficients for each of the polynomials $\mathbf{P}_n$ determines a sequence of $w(n)$'s.

$$\mathbf{w}(n+1) - \mathbf{w}^*$$
$$= [\mathbf{w}(0) - \mathbf{w}^*] + \mathbf{P}_n(\mathbf{R})\mathbf{R}[\mathbf{w}(0) - \mathbf{w}^*]$$
$$= [\mathbf{I} + \mathbf{R}\mathbf{P}_n(\mathbf{R})][\mathbf{w}(0) - \mathbf{w}^*] \qquad (4)$$

where $\mathbf{w}(0)$ and $\mathbf{w}^*$ are initial and optimal weight vectors, and hence we may select the polynomial $\mathbf{P}_n$ in such a way as to minimize $\Phi[\mathbf{w}(n+1)] - \Phi[\mathbf{w}^*]$ with respect to all possible polynomials of degree of n. The point $\mathbf{w}(n+1)$ generated by the CG method satisfies

$$\|E[w(n+1)]\|_{\mathbf{R}}^2$$
$$= [\mathbf{w}(n+1) - \mathbf{w}^*]^T \mathbf{R}[\mathbf{w}(n+1) - \mathbf{w}^*]$$
$$= \min_{\mathbf{P}_n} \frac{1}{2}[\mathbf{w}(0) - \mathbf{w}^*]^T \mathbf{R}[\mathbf{I} + \mathbf{R}\mathbf{P}_n(\mathbf{R})]^2$$
$$\cdot [\mathbf{w}(0) - \mathbf{w}^*] \qquad (5)$$

where the minimum is taken with respect to all polynomials $\mathbf{P}_n$ of degree n and $\|E[w(n+1)]\|_{\mathbf{R}}^2$ defines an energy norm as a cost function.

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Table of Contents A Conjugate Gradient Algorithm For Analysis Of Variance

1. Understanding the eBook A Conjugate Gradient Algorithm For Analysis Of Variance
    - The Rise of Digital Reading A Conjugate Gradient Algorithm For Analysis Of Variance
    - Advantages of eBooks Over Traditional Books
2. Identifying A Conjugate Gradient Algorithm For Analysis Of Variance
    - Exploring Different Genres
    - Considering Fiction vs. Non-Fiction
    - Determining Your Reading Goals
3. Choosing the Right eBook Platform
    - Popular eBook Platforms
    - Features to Look for in an A Conjugate Gradient Algorithm For Analysis Of Variance
    - User-Friendly Interface
4. Exploring eBook Recommendations from A Conjugate Gradient Algorithm For Analysis Of Variance
    - Personalized Recommendations
    - A Conjugate Gradient Algorithm For Analysis Of Variance User Reviews and Ratings
    - A Conjugate Gradient Algorithm For Analysis Of Variance and Bestseller Lists

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