A novel variable step-size normalized subband adaptive filter based on mixed error cost function

Pengwei Wen , Jiashu Zhang

PII: S0165-1684(17)30033-6
DOI: 10.1016/j.sigpro.2017.01.023
Reference: SIGPRO 6382

To appear in: *Signal Processing*

Received date: 22 November 2016
Revised date: 19 January 2017
Accepted date: 22 January 2017

Please cite this article as: Pengwei Wen , Jiashu Zhang , A novel variable step-size normalized subband adaptive filter based on mixed error cost function, *Signal Processing* (2017), doi: 10.1016/j.sigpro.2017.01.023

A novel variable step-size normalized subband adaptive filter based on mixed error cost function

Pengwei Wen and Jiashu Zhang*

***Abstract*—A novel variable step-size algorithm is proposed for normalized subband adaptive filter. The proposed algorithm is based on the mixed error cost function. By assuming the time-averaging estimate of the *priori* and *posteriori errors* equals the variance of subband noise, the step-size is obtained. Therefore, the proposed algorithm has more effective approach to the optimum solution. The power of noise-free subband *priori error* is obtained by using the shrinkage denoising method. Using the energy conservation method, the mean-square convergence performance analysis is presented. The analysis result shows this algorithm is stable and effective. The simulation results demonstrate the performance of proposed algorithm distinctly outperforms other conventional variable step-size algorithms in both steady-state error and abrupt tracking performance.**

***Index Terms*—Normalized subband adaptive filter, mixed error cost function, variable step-size.**

1. Introduction

As well known, the normalized least-mean-square (NLMS) algorithm is one of the popular algorithms because it is easy to implement and has low computational complexity. However, the performance of the NLMS algorithm will be degraded severely when the input signals are colored [1]. This problem is frequently encountered in a wide variety of situations, such as underwater acoustics, audio processing, broadband power line communications, robust multiuser detection, real time traffic prediction and low frequency atmospheric propagation [2].

To solve the problem, a normalized subband adaptive filtering (NSAF) algorithm has been developed and learned in [3]. The merit of NSAF is that it can decompose the signals into many almost mutually repulsive subband signals to whiten them [4]. Considering the property of the NSAF algorithm, a suitable choice of step-size is important because it controls the compromise between the convergence speed and the misalignment. The collide could be solved by using the variable step-size, and various ways have been presented [5–7]. By assuming that the l_2-norm of the *a posteriori error* is equal to the measurement noise variance in [5], a called variable step-size matrix NSAF (VSSM-NSAF) has been designed and is capable of tracking unknown system, however, exhibits a large steady-state error. Two kind of variable step-size NSAF algorithms were derived based on minimizing the mean-square deviation (MSD), which are VSS-NSAF [6] and individual VSS-NSAF (VISS-NSAF) [7]. The VSS-NSAF algorithm achieves a low steady-state error and fast convergence speed under stationary systems, its re-adaptation ability degrades in changed environment. The performance of VISS-NSAF outperforms the former proposed variable step-size algorithms. However, it still has a large steady-state estimation error.

In this paper, a novel variable step-size NSAF based on mixed error cost function is proposed. The optimum individual step-size is derived by assuming that the cross-correlation function of *priori and posteriori errors* is equal to the power of subband noise. And the shrinkage denoising method is used to obtain the power of noise-free subband *priori error*, this method has been detailed described in [8-11]. Then, the convergence performance analysis of the proposed algorithm is presented in this paper, which demonstrates the process of weight update is stable. The performance of the proposed algorithm is evaluated for system identification and compared with that of the VSS- NSAF, VSSM-NSAF and VISS-NSAF algorithms. The simulation results show that the proposed algorithm achieves a fast convergence rate at the instant and a low steady-state error at the steady-state.

This paper is organized as follows. Section 2 introduces the NSAF algorithm. Section 3 describes the proposed algorithm. Section 4 illustrates the convergence analysis of the proposed algorithm. Section 5 illustrates the simulation results obtained using the proposed algorithm, and Section 6 presents some conclusions.

2. Conventional NSAF algorithm

Fig. 1 displays the construction of the subband adaptive filter [12].Consider a desired signal

$$d\left(n\right)=\mathbf{u}^{T}\left(n\right)\mathbf{w}_{o}+\upsilon\left(n\right) \tag{1}$$

where $\mathbf{u}(n)=[u(n), u(n-1),\dots, u(i-M+1)]^T$ is the input signal, $\mathbf{w}_o$ and $\upsilon(n)$ denote the unknown weight vector with the length M and the background noise, respectively. The noise $\upsilon(n)$ and $\mathbf{u}(n)$ are statistical independence, and given to be stationary and zero mean. In Fig.1, the signals $\mathbf{u}(n)$ and $d(n)$ are decomposed into $\mathbf{u}_i(n)$and $\mathrm{d}_i(n)$ by the filters $H_i(z)(i=0 ,1\dots N-1)$. And the subband desired output signals $y_i(n)$ are acquired from $\mathbf{u}_i(n)$ filtered by $\hat{\mathbf{w}}(k)$. N is the number of subband. Notice that we use the variable n to index the primitive signal sequences, and k to index the decomposed orders. The signals $\mathrm{d}_i(n)$ and $\mathrm{y}_i(n)$ are decimated to $\mathrm{d}_{i,D}(k)$ and $\mathrm{y}_{i,D}(k)$ respectively. We can know $\mathrm{d}_{i,D}(k)=\mathbf{u}^T_i(k)\mathbf{w}_o+\upsilon_i(k)$. Then, the weight vector of the NSAF is expressed as

$$\hat{\mathbf{w}}\left(k+1\right)=\hat{\mathbf{w}}\left(k\right)+\mu\sum_{i=0}^{N-1}\frac{\mathbf{u}_{i}\left(k\right)}{\left\|\mathbf{u}_{i}\left(k\right)\right\|^{2}}e_{i,D}\left(k\right) \tag{2}$$

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*Corresponding author.

E-mail addresses: 623101594@qq.com(P. Wen), jszhang@home.swjtu.edu.cn (J. Zhang).