APPLYING THE PARTICLE SWARM OPTIMIZATION ALGORITHM (PSO) IN THE DESIGN OF THE ADAPTIVE FILTER

ỨNG DỤNG THUẬT TOÁN TỐI ƯU BẦY ĐÀN TRONG THIẾT KẾ BỘ LỌC THÍCH NGHI

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ABSTRACT

The paper has proposed an adaptive filter using particle swarm optimization algorithm (PSO) and its application to cancelled white noise. This is a new method to obtain signals with higher quality than previous adaptive filter methods such as Least Mean Squares (LMS) filter, Normalized Least Mean Square method (NLMS). The adaptive filter uses the swarm optimization algorithm that automatically updates the filter coefficients to match to the random and unknown change of the signal. The simulation results show that, in the case the filter coefficient increases, the proposed approach achieves higher accuracy than the LMS algorithm.

Keywords: *Filter, Least mean squares (LMS), Recursive least squares (RLS), PSO (Particle Swarm Optimization).*

TÓM TẮT

Bài báo trình bày đề xuất xây dựng bộ lọc thích nghi sử dụng thuật toán tối ưu bầy đàn (PSO) và ứng dụng của nó để khử nhiễu trắng. Đây là một phương pháp mới để thu được tín hiệu có chất lượng cao hơn các phương pháp lọc thích nghi trước đó như lọc bình phương tối thiểu (LMS), bình phương cực tiểu chuẩn hóa (NLMS). Giải pháp này tự động cập nhật hệ số lọc để phù hợp với các tính chất thay đổi ngẫu nhiên của tín hiệu và do đó cải thiện đáng kể hiệu quả lọc. Các kết quả mô phỏng cho thấy rằng, trong trường hợp hệ số bộ lọc tăng lên thì giải pháp đề xuất đạt được độ chính xác cao hơn so với thuật toán LMS.

Từ khóa: *Bộ lọc, bình phương tối thiểu (LMS), bình phương cực tiểu chuẩn hóa (NLMS), tối ưu bầy đàn (PSO).*

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1. INTRODUCTION

In communication system, the reception of clean signals (no-noise) is an important factor in assessing the quality of them. In fact, interference caused by environmental influences always exists in the transmission. The more social development, the more devices that serve human and social life, so interference signals appear in the transmission environment are more, because each device is a source of interference for special communication especially wireless communication. Noise cancellation is a technique that removes unwanted signals from being mixed in the original signal during transmission. The traditional method of noise removal is to use noise filters, which can be either stationary or adaptive filters. An adaptive filter is a filter capable of adjusting its own parameters depending on the received signal. There are many types of adaptive filters but the LMS filter NLMS filter and the RLS filter are used the most [1]. The LMS filter is the most commonly used adaptive filter today, the weights of this filter are updated based on the gradient of least mean square error. The LMS algorithm updates the filter weights as follows:

$$\omega(n+1) = \omega(n) + \mu u(n)e(n) \quad (1)$$

Where: μ is the step size that determines the stability and the convergence rate of the algorithm. The weight vector ω(n) is indicated by having an index n to show its value as a function of time, u(n) is input vector, e(n) is estimation error at time n [2].

The weight, which was calculated by the LMS algorithm, is difficult to achieve the optimal value because the exact value of expectation is not used but their convergence is possible in mean. The convergence of the algorithm is strictly dependent on the choice step size μ [1]. In order to reduce the dependence on the step size the NLMS algorithm was proposed in [1]. In NLMS, the step size was showed by equation (2):

$$\mu = \frac{E\left[\left|y(n) - \hat{y}(n)\right|^2\right]}{E\left[\left|e(n)\right|^2\right]} \quad (2)$$

These algorithms are not suitable for multimodal error surface, as they are likely to stick in local optima. The authors in [3] proposed PSO based acoustic noise cancellation method in frequency domain. Comparison to many other optimization algorithms, the PSO provides advantages of faster convergence rate, strong global search, simplicity of the algorithm, few adjustable parameters, and ease of implementation [3, 6-8]. In this paper, we propose to use the Particle Swarm Optimization (PSO) algorithm in calculating the weights of the adaptive filter in the time domain, which can handle the problems in selected step size for LMS filtering and remove the transition from time domain to frequency domain compared with the technique shown in [4, 9-10].

2. THE PROPOSED APPROACH

2.1. Adaptive filter

A block diagram of an adaptive filter is shown in Figure 1.

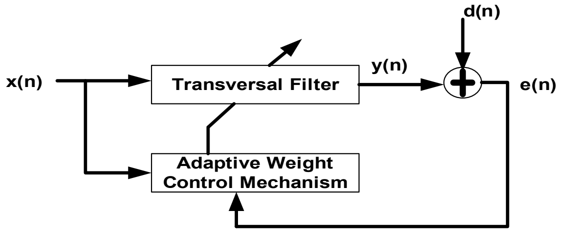

Figure 1. Adaptive filter

The parameters of the adaptive filter in figure 1 are x(n), H(z), d(n), W(z), y(n). In which x(n) is noise signal, H(z) is primary path transfer function, d(n) is primary noise signal at the error, W(z) is the weights of Adaptive Filter, which is calculated according to the PSO algorithm, and y(n) is output of adaptive filter that is calculated by equation (3):

$$y(n) = \sum_{i=0}^{M-1} w_i(n)x(n-i) \quad (3)$$

e(n) is modified error signal that is calculated by equation (4):

$$e(n) = d(n) - y(n) \quad (4)$$

2.2. PSO algorithm

Particle swarm optimization (PSO) is a population based stochastic optimization technique inspired by social behavior of bird flocking or fish schooling [5]. In PSO, each single solution is a particle, which is located $X(x_1, x_2, ..., x_n)$ in search n-dimensional space. Applied to the noise reduction problem, each position represents the weight of the adaptive filter. The best position (closest to prey) is the optimal set of weights for the adaptive filter. In essence, the position and velocity of a particle, xi and vi, respectively, can be updated as follows:

$$v_i^{n+1} = v_i^n + \alpha c_1(g^* - x_i^n) + \beta c_2(x_i^* - x_i^n) \quad (5)$$

$$x_i^{n+1} = x_i^n + v_i^{n+1} \quad (6)$$

Where c_1 and c_2 are two random vectors and with each entry taking the values between 0 and 1. The parameters α and β are the learning parameters or acceleration constants, which can typically be taken as, say, $\alpha \approx \beta \approx 2$.

g^* is the current global best solution and x^* is the individual best position [4].

In the proposed PSO based adaptive noise cancelling, objective function defined as follows:

$$obj = mean(\sqrt{e(n)^2} \quad (7)$$

3. SIMULATION RESULTS

In this section, we use Lenovo computer Core i3 processor, 6GB RAM, Matlab 2018a software to simulate the scenarios of the paper. Time of simulation is 57,218ms. Design a 10th order adaptive filter for sinusoidal noise filtering, at 100Hz, the weights of the filter are calculated based on the LMS algorithm with learning rate = 0.2 and the PSO algorithm with size. herd is 100 individuals; maximum number of repetitions is 50.

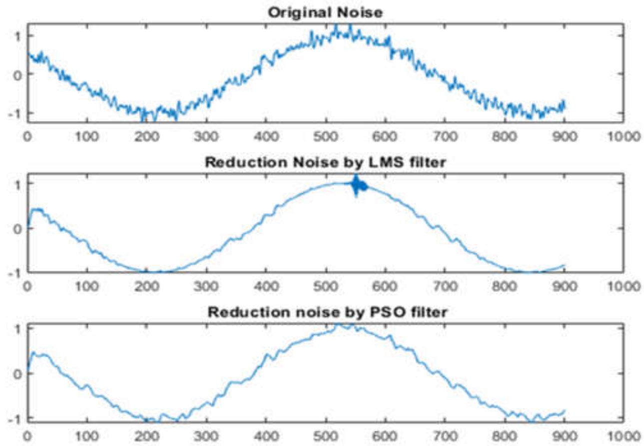

Figure 2. Input signal and output signal in LMS filter and PSO filter

Figure 2 shows the result by using LMS algorithm and PSO algorithm for reduced noise in a sin signal. Parameter μ was chosen as 0.2 with filter length of filter was 10. In the results obtained by both algorithms, the signal noise is reduced. However, at the sinusoidal peak of the LMS filter output signal local noise occurs. The reason is that the selected in step size parameter is large, while this error is corrected in PSO filter.

Figure 3 shows the effect of the step size parameter on the output SNR ratio using an LMS filter with the length of filter was 10. If the step size is small enough, the output SNR ratio of the LMS filter gives better results than the PSO filter, but the larger the step size, the lower the SNR to LMS ratio while the output SNR on PSO is almost unchanged.

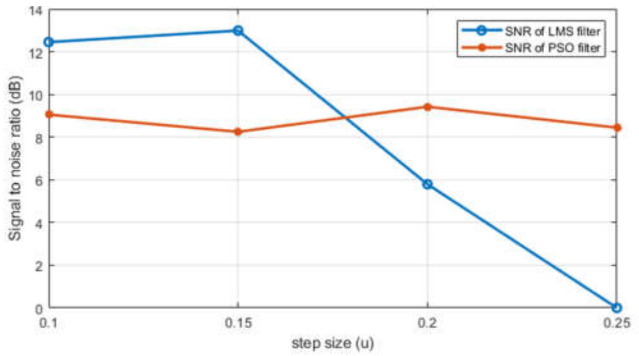

Figure 3. SNR with varying number of step size

In fact, when the order of the filter increases, the SNR ratio also increases. In the LMS algorithm, when the filter order reaches a certain threshold value the SNR will not increase, contrast to, in the proposed algorithm, the SNR still increase in the case the order of the filter increase. In Table 1, the LMS algorithm was not determine the weights of the filter when the filter order is greater than 11 and then the SNR is approximately zero, while the proposed algorithm was still determined the weights of the filter and the SNR values were almost not change.

Table 1. Comparison of the influence of the order of the filter on the signal-to-noise ratio in the different case

The number oforder filter	SNR of LMS filter (dB)	SNR of PSO filter (dB)
5	10.2278	-4.4299
6	11.4564	-2.4382
7	11.9485	-0.4600
8	12.3355	2.3062
9	13.9366	5.2466
10	5.7904	9.4221
11	0.0002	8.4445
12	0	8.4425

4. CONCLUSION

The paper presented PSO approach applied in the case cancel white Gaussian noise. When we increase the order of the filter, the noise filtering ability of the proposed approach was higher than LMS algorithm. In addition, the simulation results proved that the signal-to-noise ratio of the proposed algorithm was not affected as the filter order increases.

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THÔNG TIN TÁC GIẢ

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