A New Technique using GA style and LMS for Structure Adaptation

Sukesh Kumar Das and Nirmal Kumar Rout
School of Electronics Engineering
KIIT University, BHUBANESWAR, INDIA
skd_sentu@rediffmail.com
routnirmal@rediffmail.com

ABSTRACT-In this paper an adaptation technique using both *genetic algorithm* (GA) and *least mean square algorithm* (LMS) is proposed. The key control parameters tap-length and tap-weight are updated using the GA and the LMS algorithm respectively according to the value of mean square error (MSE). The proposed algorithm results optimal solutions very fast by reducing initialization and derivative problems. It can give good convergence than that of only LMS style algorithms. In this paper, LMS style adaptive algorithms where both tap-length and tap-weights are updated using the same algorithm, and its difficulties in application field are discussed. And effectiveness of the proposed adaptation technique using both the GA and the LMS is verified by its extensive simulations.

KEYWORDS: Adaptive filter, variable tap-length, LMS, GA.

I. INTRODUCTION

Adaptive signal processing is more useful in practical cases since it can adjust the system automatically with respect to the time-varying environment. It has the learning ability from data to change the filter parameters according to their needs. For multi objective adaptive system two things are to be considered: (a) errors in optimal cases and (b) the convergence speed. As tap-length and weights both get changed over times and they are the key parameters to control the error and convergence rate, both are required to be updated over times. So, the duo adaptation procedure is proposed in this paper. In the proposed algorithm tap-length and tap-weights are adapted using the GA and the LMS respectively, according to the MSE of corresponding tap-lengths and tap-weights of the linear FIR filter. The LMS based adaptation procedures and its probable demerits are discussed and thereafter the duo adaptation technique is used for simulation. Conventionally the LMS and recursive least square (RLS) are used to update the filter parameters [1]. Various LMS style algorithms have been introduced to update tap-weights, tap-length, and step-size. The LMS based algorithm is more famous because of its simplicity and robustness with moderate convergence rate towards optimal solutions whereas RLS is complex enough but has good convergence rate. The conventional LMS follows the following equation to update tap-weight vector.

$$W_k = W_{k-1} + 2\mu e_{k-1} X_{k-1} \qquad (1)$$

Where $W_k = \text{Tap} - \text{Weight vector in kth iteration}$, μ=Step-size,

e_k= error in k th iteration and X_k= Input vector

The LMS style algorithm may restrict itself in different applications due to adaptation noise, initialization problems, long training period and undesirable local minima during training phase. In variable length stochastic gradient (VLSG) algorithm [2], initially low dimension is considered for fast convergence and then increased dimension is considered for steady state performance. Still this style is not very practical as exact knowledge of input statistic is needed to implement. To speed up the convergence rate, variable step-size LMS (VSLMS) and variable length LMS (VLLMS) have been proposed [3], where step-size and tap-length are updated after a predetermined time constant. Here step-size is updated using the following equation:

$$\mu_K = a\mu_{K-1} + be_{K-1}^2 \qquad (2)$$

where *a* and *b* are constants satisfying 0<*a*<1, *b*>0;

It has the initialization problem of step-size (for *a* and *b*) and tap-length as well. In the case of LMS with gradient decent (GD) filter [4], filter length is changed dynamically and at the end weights are updated by conventional LMS. But it also has more computational complexity, low convergence rate, gradient noise problems. A novel variable tap-length algorithm [5] has been proposed to have good performance and to avoid adaptation noise. But optimum tap-length is achieved after truncation of pseudo tap-length and it is not also free from gradient noise and initialization problem. In segmented filter (SF) [6], the primary filter is partitioned into several segments and new tap-length is adjusted every time by one segment being either added or removed.

Though it has less computational complexity, its implementation is difficult as filter is needed to be divided. Fractional tap-length (FT) [6] is one of the best algorithms as it is a compromised one between the GD and the FT. But there is an initialization problem and a complex cost function is used for adaptation of tap-length. Recently, several GA based adaptation procedure have been introduced to update step-size or weight vector [10-13]. As step-size controls the convergence speed, adaptation of step-size in LMS is done with the help of evolutionary programming to achieve better convergence rate [10]. GA is used to update the filter weights in active sound and vibration control system [11], in volterra filter [12] and in the channel equalizer [13].Since fluctuating environment can change the tap-length of an unknown system resulting higher error signal, tap-length is needed to be controlled and it can be easily determined by GA according to the MSE. Basically, this optimization technique is based on evolution and random search considering the MSE. Tap-length with minimum mean square error (MMSE) is the fittest one and others are discarded. Here in this proposed procedure, random inputs and unknown linear FIR filter are considered for simplicity but it also can be extended for nonlinear system. Many real world systems like smart antenna, echo-canceller, and channel equalizer can be well designed using this process to perform very fast with less error.

The organization of the paper is as follows. Section II represents proposed technique for adaptation of tap-length using the GA and weights using the LMS. The simulation experiments and discussions are presented in section III. Section IV provides conclusion of the paper.

II. ADAPTATION OF TAP-LENGTH USING GA AND WEIGHTS USING LMS

For this type of adaptation, the adaptive filter structure is treated as a black box where it requires evaluation of the cost function involved in variable tap-length. The tap-length is one of the influential factors of an adaptive system.

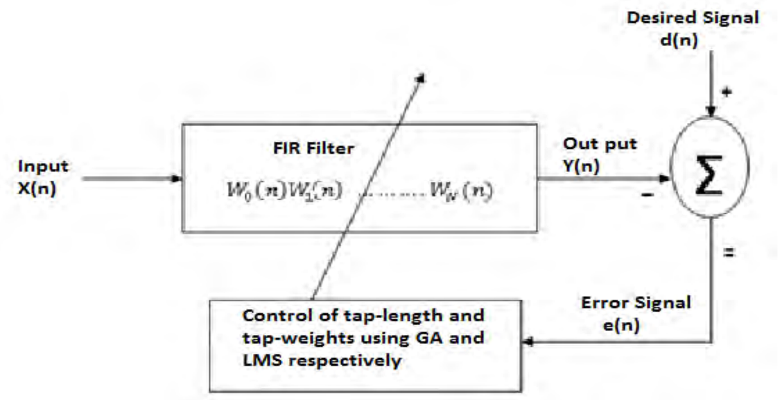

Fig. 1. Block diagram of adaptive structure.

Block diagram of the basic adaptive structure which is FIR in nature, is shown in Fig. 1. Here depending on the error signal adaptive algorithm controls the tap-length and tap-weights as well and determine the fittest one. This tap-length is updated using GA style algorithm and for every individual tap-length, tap-weights are updated using LMS algorithm. Generally both these parameters of a system are affected in a time varying environment. The proposed technique updates both parameters efficiently. In conventional GA, crossover and mutation are performed among fittest parent and new population always replace current population. Typical values of GA parameters are: population size=50, crossover rate=0.9, mutation rate=0.05. But in the proposed technique the conventional GA is modified as shown in the flow chart (Fig.2) to achieve better convergence and therefore named as GA style.

The flow chart of GA style algorithm for tap-length adaptation is shown in Fig.2. Here initially a pool of tap-lengths which are integers within a specific range is taken randomly. From the pool of tap-lengths two are taken randomly and encoded them into binary strings in representation phase. As the length of every decimal number in binary is not same, zero-padding is done to obtain equal length. First two point crossovers are performed in which the point is randomly determined. Mutation with probability 0.25 is then executed where the points are also randomly chosen. Crossover and mutation operation on the parent pair produce two offspring. Crossover does exchange the information of parent strings while mutation introduces randomness to obtain diversity in the offspring. Two child tap-lengths are then added to the parent pool. All the tap-lengths including the offspring are sorted in ascending order of their MSE. Last two tap-lengths are discarded as they are not fit and thereby population of tap-lengths is same throughout the generations. In every generation, it keeps the record of the best suited tap-length having low MSE. After production of predetermined number of generation, the execution of algorithm is stopped. Weights are updated here using the conventional LMS algorithm as per equation (1).

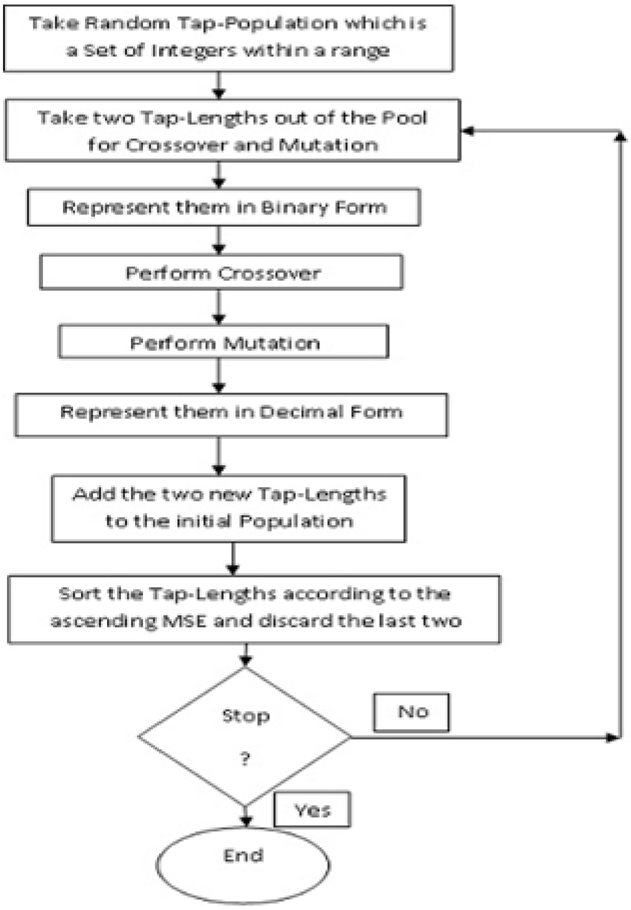

Fig. 2. GA algorithm for tap-length adaptation.

III. SIMULATION SETUP AND DISCUSSIONS

From the tap-length adaptation point of view, after several generations, the optimal tap-length is achieved and it gets the constant value. The performance of the proposed technique is validated by considering the unknown system function,$h = [1\ \ -2.5\ \ 5.25\ \ -2.5\ \ 1\ \ 0.9\ \ -1\ \ 0.5\ \ 1.5]$, input samples(taken as random vector)= 800, generations= 100. From each of these generations, one tap-length having least MSE is recorded. After hundred generations, hundred best suited tap-lengths have been plotted with corresponding MSE. While tap-length getting updated tap-weights also get updated by the LMS algorithm with step-size, μ=0.005 and for every individual tap-length the MSE is estimated taking the mean of MSE from last five hundred samples.

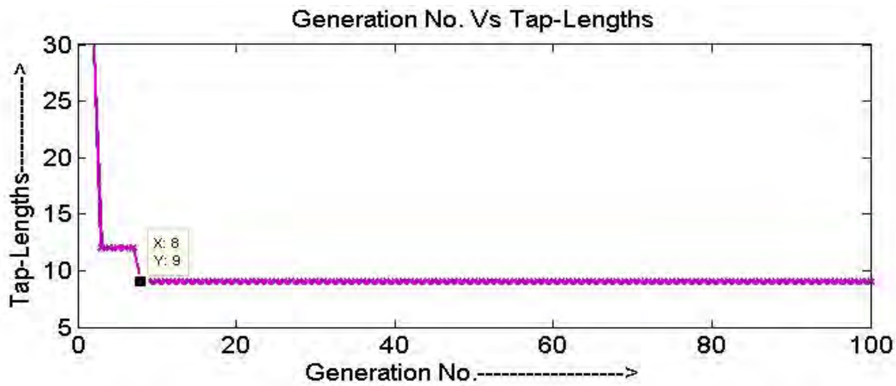

Fig. 3. Tap-Length learning curve with respect to corresponding generations.

Tap-lengths having least MSE from first generation to 100th generation are plotted in Fig.3. It shows that after 8^{th} generation tap-length gets constant value i.e. 9 which is exactly the same as that of the unknown system. It implies that the realized system with the proposed adaptation technique can work well in changing environments. The simulation result also implies that there is the most probability of getting optimal tap-length very fast i.e. convergence is good in terms of tap-length adaptation.

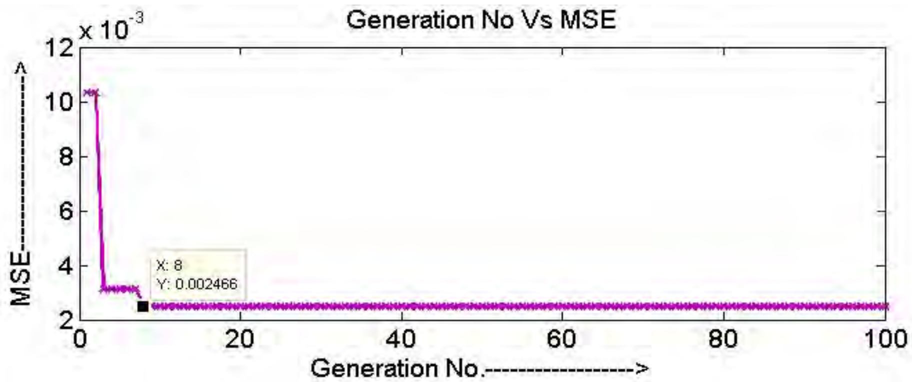

Fig. 4. MSE learning curve with respect to corresponding generations.

Mean of MSE taking from last five hundred samples for every individual tap-length are calculated and least MSE of every generation has plotted here in Fig.4. After 8th generation it gets least MSE i.e.0.002466 and thereafter it does not change until system is changed.

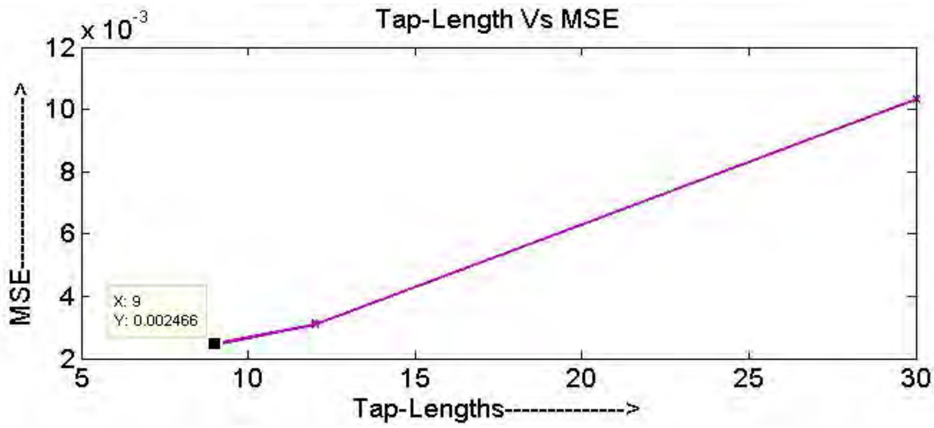

Fig. 5. MSE learning curve with respect to corresponding Tap-Length.

Fig.5 shows the MSE learning curve with corresponding tap-length. MSE is less when tap-length is nine and elsewhere it increases. So, here optimum tap-length is 9.

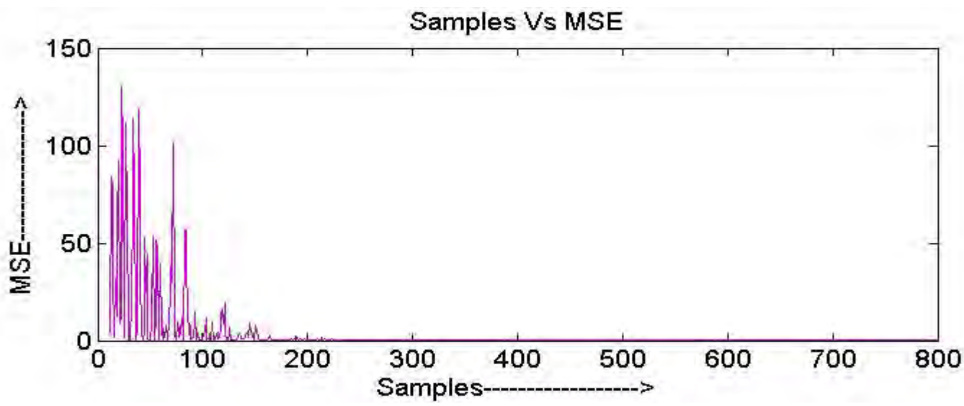

Fig. 6. MSE learning curve with respect to corresponding samples using LMS when μ=0.005.

Fig. 6 shows the MSE learning curve with respect to input samples when tap-length is 9 (optimum). Here tap-weights are updated using LMS with μ=0.005. This figure indicates that error curve converges very fast by updating tap-weight vector using LMS and it shows that MSEs are significantly less after 160 samples.

IV. CONCLUSION

This technique of adaptation gives better performance over only LMS based optimization as one of the important parameter tap-length is updated using GA while another parameter weight-vector is updated using LMS. If both parameters are updated using LMS, it will increase adaptive noise, initialization problem and slow down the convergence rate. Besides GA style variable tap-length can be applied to different engineering applications such as smart antenna, channel equalizer, echo canceller etc because it is easy to understand, has low adaptation noise and simple fitness function. These benefits may make it capable to lead recent research areas (adaptive) like optimization, optimal tap-length determination, control system design etc. In the LMS it requires large numbers of iterations to find optimal tap-length but using the GA it is easy to get the same very fast. So, it reduces the computational complexity which is desirable to be minimized in time varying environment as training phase is executed time to time. Also in LMS, tap-length learning curve may gets stuck in a local minima so optimum tap-length determination is not so easy. The GA introduces the principle of evolution that use “Good solution survives while bad one dies” and does not depend on derivatives and based on natural selection. Also, the GA with small solution size and high mutation rates give best solution. Hence proposed GA style algorithm for tap-length adaptation can take attention to determine optimal solution in adaptive system.

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