Review on System Identification using Adaptive Filters

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Abstract— System identification is one of the most important applications for adaptive filters, mainly for the typical Least Mean Square (LMS) algorithm, due to its ease in calculations and the ability to withstand or overcome any conditions. Based on the error signal (difference signal), the adaptive systems weights are evolved and corrected, until the output signal of the unknown and adaptive system are equal. This application helps to develop, do some research and create an opportunity for automatic prediction and correction.

Keywords- System Identification, Adaptive Filter, LMS, NLMS, RLS.

1. INTRODUCTION

System Identification is the concept of modelling systems that are dynamic from experimental results (i.e., the patterns of input/output). The main objective is to obtain the digital model and estimate the Transfer Function of given unknown circuit using Adaptive Filter System Identification approach. Adaptive Filtering technique is successfully applied in communication systems like Noise cancellation, sonar, video and audio processing, interference cancellation, channel equalization challenges, echo cancellation similar to noise cancellation and many others. In this technique signal processing in real time is used to identify the model of unknown systems that might vary over time. There are various adaptive filtering structures (i.e., LMS, NLMS and RLS). Least mean Square algorithm is also called as stochastic gradient algorithm. It is popular and widely used because of the fact that it is very easy to implement. The main job of LMS adaptive filter is to adapt or update the newly received information for desired applications as shown in Figure 1. The idea is to provide a linear model to the unknown system using adaptive filter that represents the best possible representation to the system to be identified, i.e. find the approximate weights of response (h[k]) of that particular system to impulse input.

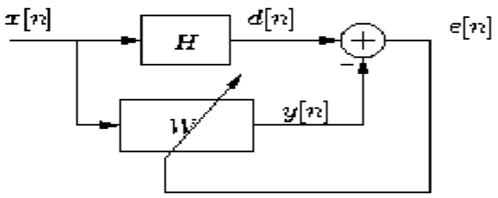

Figure 1. Generalized Block diagram of LMS algorithm used for System Identification.

2. LITERATURE REVIEW

Irina Dorean et.al. [1] presents identification of a system using stochastic gradient algorithm, which is known as least mean square algorithm. These filters are implemented using digital signal processing (DSP), for increasing performance these are implemented using ASICs or FPGA. The main logic here is taking gradient descent for estimating a time varying signal. This will find min value and by way of taking increasing steps in negative direction of gradient. It is done in order to reduce error signal value.

Basically, using these two equations the unknown system is identified using LMS algorithm.

$$e[n] = d[n] - y[n] \quad (1)$$

$$c[n+1] = c[n] + \mu\, e[n]\, x[n] \qquad (2)$$

μ is the main parameter which decides the efficiency of the adaptive output signal. We should make sure to keep it to desired value so that it will converge properly. The main reason for using LMS algorithm is that it is comparatively very simple to implement in both hardware as well software as it is computationally simple and efficiently uses memory.

Sajjad Ahmed Ghauri et.al. [2] compares the three commonly used adaptive filtering algorithms in System identification is they are Least mean square (LMS), recursive least square (RLS) and Normalized least mean square (NLMS) algorithms. LMS is computationally simple than the other two, NLMS is its normalized form and RLS is a complex but efficient algorithm.

The LMS adaptive filter updating equations are similar to the above paper, in NLMS the major challenge in finding the appropriate value of the step size is overcome by normalizing the input and its updating equation is as shown,

$$C[n+1]= c[n] +((\mu/||x(n)||^2) * e^*(n)*x(n) \qquad (3)$$

The RLS is a recursive algorithm which has good convergence but computationally complex moreover, it requires predefined conditions and information to update the estimation.

Ibraheem Kasim Ibraheemthe [3] has presented that LMS algorithm is improved by a approach called LMS-GA. The genetic searching methodology is integrated with LMS algorithm to speed the process and reduce time in this algorithm.This algorithm also preserves the simplicity of LMS algorithm , has fewer computation and has fast convergence rate.The LMS-GA algorithm out performs the basic LMS algorithm

Tang Jia et.al. [4] have presented a method to overcome the problem of decrease in performance when signal to interference ratio (SIR) is low this overcome by the use of varing step size Least mean square method.It provides a different non linear relationship between step factor and error of adaptive system. New expression is written as

$$\mu(n) = \beta\, [\, (1/(1+\exp\,(-\alpha\, |e(n)|)) -0.5] \qquad (4)$$

This algorithm is not sensitive to interference and has better performance when compared to the commonly used LMS algorithm when the SNR is less.

Yilun Chen et.al. [5] have proposed an adaptive filtering method when the system is scattered. This method applies l1 relaxation, to enhance LMS type adaptive filters performances two new algorithms are introduced, they are the zero-attracting least mean square (ZA-LMS) and the reweighted zero-attracting least mean square (RZA-LMS). By combining a l1 norm penalty in the coefficients into the quadratic Least mean square cost function ZA-LMS can be obtained. To better the filtering ability further RZA-LMS is designed utilizing a re-weighted ZA, numerically RZA-LMS's performance is better than ZA-LMS. Both algorithms are compared in performance with the typical LMS algorithm which results in improved ZA-LMS and RA-LMS in comparison to the typical LMS both in steady-state performance and transient performance when the system is scattered, it also shows the reduced MSE from ZA-LMS algorithm.

Li Xiao-bo et.al. [6] have presented LMS algorithm with variable step size along with a functional relationship between the difference signal and step-size which is nonlinear in nature. A hop parameter (αn) is used in this algorithm to remove the disturbances of independent noise by varying the step-size. This algorithm also presents a similar method that is based on the Sigmoid function (SVSLMS) whose size of step is high although the difference signal is approximately to zero.

The system formula of SVSLMS algorithm is given by

$$\mu(n) = \beta(\frac{1}{1+\exp(\alpha|e(n)|)} * 0.5) \qquad (5)$$

The simulation results run on a Computer confirms that the method is better compared to the previous algorithms in performance, the convergence properties are better at the beginning of adaptation while establishing very less eventual miss-adjustment.

Rongshan Yu et.al. [7] propose two new versatile adaptive calculation methods, in particular Prominent subspace least mean square (PS-LMS) and PS-LMS+. This helps for quicker estimation of unknown models, which are scattered in transfer domain. PS-LMS calculations are valuable for quick recognizable proof of varying unknown systems and furthermore enhances the union speed of standard Least mean square calculation if the system to be found is scattered and has long impulse response. To decrease the error PS-LMS+ adaptive method was introduced as shown in Figure 2. Performances of PS-LMS and PS-LMS+ algorithms are compared with typical algorithms such as LMS, RLS, PN-LMS, µ-law PN-LMS adaptive methods by conducting experiments. The outcome furnishes a quicker speed of convergence with compromise of marginally higher computational intricacy compared to typical LMS algorithm.

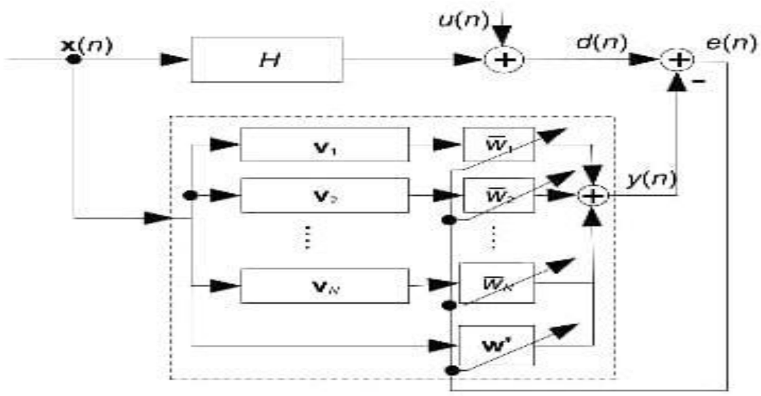

Figure 2. Realization of PS-LMS+ utilizing equal PS-LMS and LMS adaptive algorithm

Ching-An Lai [8] has explained NLMS (normalized least mean square) algorithm whose behaviour is same as that of Least mean square-SAS algorithm. In NLMS algorithm the gradient estimation error is used, which will be present in normal adaptive process, this acts as perturbing noise. NLMS algorithm is easy and simple, which increases the computational speed in comparison to LMS algorithm which has comparatively small step size. In LMS-SAS Edmonson uses estimated gradient vector for finding perturbing noise. Author has shown that NLMS is better when compared to LMS-SAS algorithm. And efficiency is greater compare to GLMS algorithm because it does not require any cooling schedule.

Gokhan Akgun et.al. [9] have compared different methods to find the unknown system and other distinct PI controllers are developed to identify response of system. To identify the existence of different model parameters several system identification models are utilized and accuracy of the model is most vital step to design efficiently.

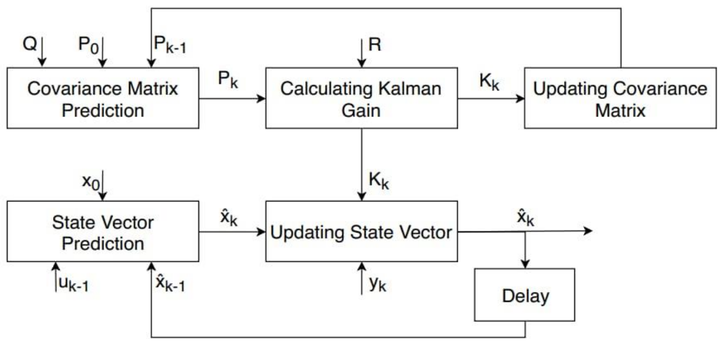

Figure 3. Typical EKF algorithm block diagram

The states of the linear system can be estimated using the Kalman filter (KF), it comprises of two major steps first prediction step and then correction steps. Non-linearity in the state space model can be seen as a result of extension and Extended Kalman Filter (EKF) is used for this identification, which is shown in Figure 3. Parameters of the system and its internal states can be estimated efficiently using extended Kalman filter.

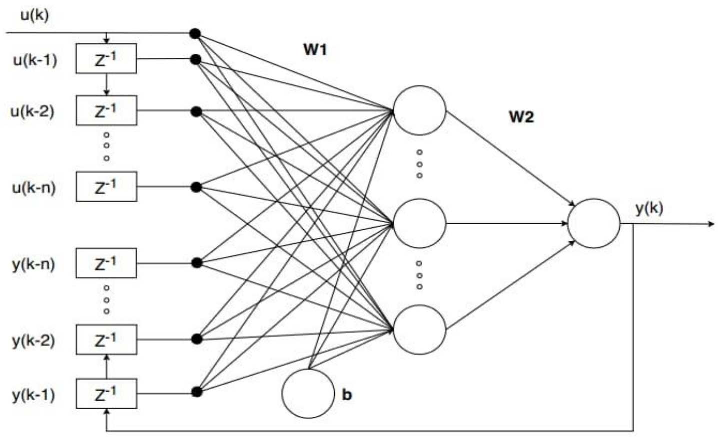

Figure 4. NARX neural network's typical block diagram

Nonlinear Autoregressive Exogenous Model (NARX) is a multi-layer recurrent perceptron neural system network, which can be utilized as a black-box identifying technique. Both parallel and series-parallel architecture can be seen in NARX. The simple block diagram is shown in Figure 4. The major benefit of this estimation method is that, it is not necessary to have information about the system to be found and it is effective for both linear and nonlinear systems. A high convergence rate can be obtained in all the other methods other than the LMS. The MSE comparison between LMS and NARX gives mid accuracy in comparison to RLS and EKF. Highest precision can be realized using EKF but this results in increase in cost and complexity.

Ibraheem Kasim Ibraheem [10] proposed a simple way of using adaptive IIR filter in system identification. The improved genetic search approach of Least Mean Square (LMS) algorithm that is Least Mean Square-Genetic Algorithm (LMS-GA) helps in searching the multi-model error surface of the IIR filter. This helps in avoiding local minima and in finding the optimal weight vector. Genetic Algorithm (GA) is an optimization approach used in applications of vast, nonlinear and potentially discrete systems. In GA, a population of strings called chromosomes which represent the candidate solutions to an optimization problem is evolved to a better population. GA as the maximization of fitness function is given by,

$$F(t) = \frac{1}{1+f(t)} \quad (6)$$

here the cost function to be minimized is represented as f(t). The cost function f(t) is taken as the Mean Square Error (MSE) in adaptive filtering which is given by

$$f(t) = \varepsilon_{j^2} = \frac{1}{t_e}\sum_{i=1}^{t_e}[d(n) - y_j(n)]^2 \quad (7)$$

here t_e represents the size of window along which errors are accumulated and $y_j\ (n)$ is the estimated output for the j^{th} set of estimated parameters. Graph of MSE versus Iterations is shown in below Figure 5.

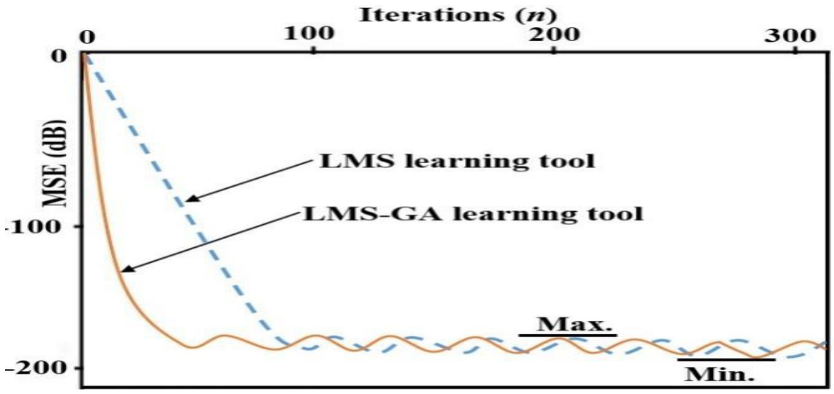

Figure 5. The LMS-GA convergence performance for adaptive IIR filter.

To understand parameters of the digital filters (FIR and IIR) and to minimize error signal the adaptive algorithms LMS and LMS-GA are adopted. The characteristics and the simplicity of the standard LMS learning algorithm can be preserved with comparatively fewer computations and fast convergence rate using LMS-GA algorithm.

Conclusion

There are a lot of different adaptive techniques of filtering that can be realized in order to estimate the unknown function with each of them having their own advantages and disadvantages. The most simple in implementation and computations involved is the LMS algorithm, but it not the most accurate and takes some time, in order to overcome this NLMS algorithm in which the input is normalized, LMS-GA which uses a genetic search approach, LMS with varying step size and other such algorithms have been developed. RLS is another algorithm, which is computationally complex but the estimate is more accurate to the unknown system. Hence the choice of algorithm can be made based on the application, for example for an application involving the estimate to be highly accurate with cost and computationally complexity not being an issue RLS algorithm can be used, but for applications where approximate result is sufficient keeping the complexity simple then LMS algorithm is preferred. Therefore, for laboratory application where the accuracy is not an issue and simplicity is also required LMS algorithm is used.

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