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Research Article

Implementation of Complementary Pair Least Mean Square (CP-LMS) algorithm in LabVIEW

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Abstract

In adaptive filtering, there is a trade off between convergence speed and steady state error both depends upon the same parameter, step size. This paper presents the designing of Complementary pair least mean square algorithm (CP-LMS) in LabVIEW using adaptive filter toolkit. The algorithm consists of two adaptive filters operating in parallel. User interface is designed in LabVIEW to generate learning curve of the CP-LMS algorithm. The results show that the CP-LMS algorithm provides faster convergence speed and small steady state error.

Keywords: *LabVIEW, Complementary pair least mean square (CPLMS) algorithm, mean square error, step size, learning curve.*

1. Introduction

There are various adaptive filtering algorithms are available based on either statistical or deterministic approach.

The Least mean square (LMS) algorithm is most commonly used in various applications due to its simple computational approach and predictable behaviour. The standard least mean square (LMS) algorithm is developed by Widrow and Hoff in 1976 which adjusts the filter parameters like step size μ to minimize the error between filter output signal and the desired signal.

By having fixed or variable step size convergence speed and steady state error varies accordingly. To obtain faster convergence speed, step size μ has to be relatively large but larger step size μ will cause large steady state error. To obtain small steady state error, step size μ has to be relatively small but smaller step size μ makes the convergence speed very slow.

To overcome this problem, many variable step size algorithms (Huang, B *et al* 2003; Casco-Sánchez *et al* 2011; Y. Ozbay *et al* 2010; K. Mayyas *et al* 2004; T. Aboulnasr *et al* 1997; K. Mayyas *et al* 2011) have been developed which tries to achieve both small steady state error and faster convergence speed. The performance of these algorithms is dependent upon the algorithm parameters which are selected without any specific rules. To have strictly controlled performance and to overcome the conflict of accuracy and the speed, a new adaptive filtering algorithm called Complementary pair least mean square (CP-LMS) algorithm is used.

2. Implementation of CP-LMS Algorithm in LabVIEW

The CP-LMS algorithm is proposed by Woo-Jin Song and Min-Soo Park (Min-Soo Park and Woo-Jin Song, 1998). The algorithm uses two adaptive filters operating in parallel with fixed step sizes. One filter has small step size, μ_1 known as accuracy filter and second filter has larger step size, μ_2 known as speed filter, i.e. $\mu_1 < \mu_2$.

The estimation errors of two adaptive filters are compared and the coefficient of one filter is used for re-initialisation of second filter to speed up the convergence speed.

The CP-LMS algorithm can be described as follows:

$$\widehat{h_2}(n+1)=\hat{h}_2(n)+2\mu_2 e_2(n)x(n) \quad (1)$$

$$\widehat{h_1}(n+1)=\begin{cases}\widehat{h_2}(n+1), & \begin{matrix} if & n(mod\,T)=0 \\ and & \prod_{i=1}^{L} Q(n-iT)=1\end{matrix} \\ \widehat{h_1}(n)+2\mu_1 e_1(n)x(n), & else\end{cases} \quad (2)$$

where $\widehat{h_1}$ is the vector of accuracy filter coefficients, $\widehat{h_2}$ is the vector of the speed filter coefficients, $x(n)$ is the vector of input, $e_1(n)$and $e_2(n)$ are the output errors, T is the length of comparison interval and L is the number of comparisons.

$$e_1(n)=y(n)-y_1(n)+w(n) \quad (3)$$

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$$e_2(n) = y(n) - y_2(n) + w(n) \qquad (4)$$

where $w(n)$ is the output noise.

Two valued function $Q(m)$ is defined as:

$$Q(m) = \begin{cases} 1 & if\ \sum_{i=m}^{m+T} e^2 1(i) > \sum_{i=m}^{m+T} e^2 2(i) \\ 0 & otherwise \end{cases} \qquad (5)$$

The Virtual Instrument (VI) for the algorithm is designed in LabVIEW. The Virtual Instrument is a graphical program by selecting various icons from toolkits available in LabVIEW and joined together to make the algorithm (Kaur, Rashpinder 2012). It resembles with physical instruments but exists only virtually so it is known as virtual instrument.

The following steps are used to implement the equations of complementary pair least mean square algorithm.

- The Complementary pair least mean square algorithm is implemented using two AFT (adaptive filter toolkit) create FIR (Finite impulse response) LMS VI's, the step size are given as input to both the AFT create FIR LMS VI's (National Instruments, "Adaptive filter toolkit").
- The coefficients of CPLMS filter is updated using AFT filter and update coefficients VI.
- The unknown system VI is taken to give stimulus and response signals to both update coefficients VI.
- The square of error signals of speed filter and accuracy filters is taken by using square function of LabVIEW.
- Then both error signals are compared by using less? (Comparison mode) function and given as selector input to case structure in which two case are taken for Q (m) for two values of 0 and 1.
- The modulus of interval length M is taken by using quotient and remainder function.
- To implement second condition of equation 2, For loop is taken and its will executes Q(m) for J times.
- The iteration terminal of main For loop is combined with modulus of M using multiply function.
- Now both conditions of first part of equation 2 are applied to logic AND gate function and given as selector input to another case structure.
- Inside the case structure, for true case, the vector of speed filter coefficients will be equal to updated accuracy filter coefficients and for false case, the vector of updated speed filter coefficients are equal to updated accuracy filter coefficients.
- The difference between filter output of speed coefficient vector and updated accuracy filter coefficient is taken by using subtracter function and given as input to mean square error VI.
- The learning curve is displayed by using waveform graph and it is output of mean square error VI.

The block diagram of implementation of Complementary pair least mean square (CP-LMS) algorithm is shown below in Fig.1.

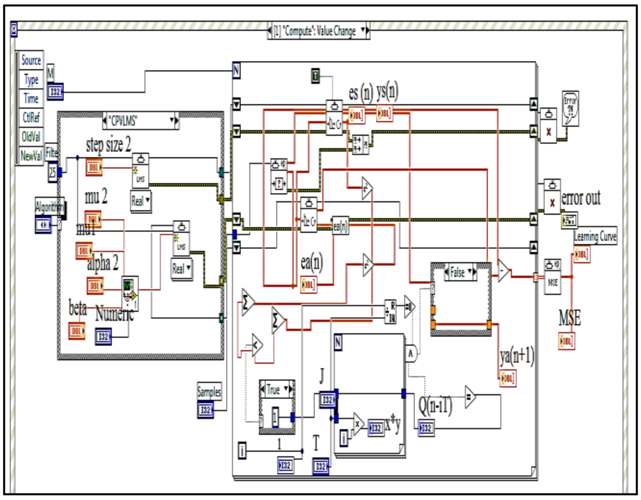

Fig.1 Block Diagram of CPLMS algorithm in LabVIEW

3. Simulation Experiments

The performance of adaptive filter is analysed by measuring convergence speed. Adaptive filter has fast convergence if it takes less time to calculate appropriate coefficients to minimize the power of the error signal (National Instruments, "Analyzing Adaptive Filter Performance").

The MSE of the error signal will be calculated with the following equation:

$$MSE = \frac{\sum_{k=1}^{T} e_k^2(n)}{T} \qquad (6)$$

where T is the number of times you execute the filter and $e_k(n)$ is the error signal at k^{th} trial. The values of parameters $\alpha = 0.6$, $\beta = 50$, M = 100 and J = 3 are taken to perform simulation experiments. The simulation of complementary pair least mean square algorithm is done by plotting learning curve between mean square error (MSE) and number of iterations for different step sizes (H. Kaur *et al* 2012).

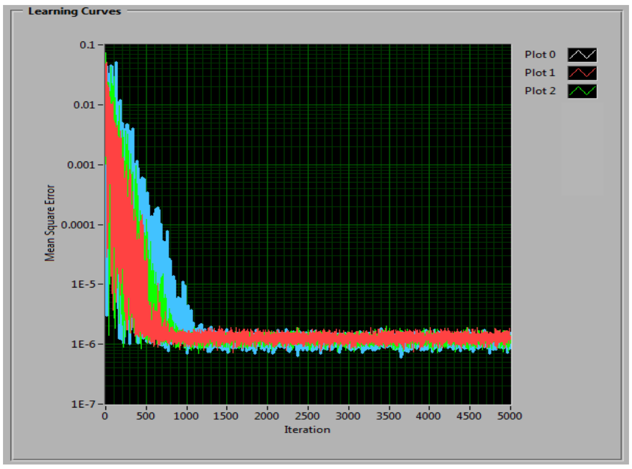

Fig.2 Learning Curve of CPLMS algorithm for three different step sizes

The Fig.2 shows that red curve with step size $\mu_1 = 0.03\ and\ \mu_2 = 0.009$ converge faster and achieve steady state error at 500th iteration, while the green curve with step size $\mu_1 = 0.04\ and\ \mu_2 = 0.007$ converges and achieve steady state error at 800th iteration and the blue curve with step size $\mu_1 = 0.05\ and\ \mu_2 = 0.005$ converges slowly and achieve steady state error at 1000th iteration. The step size of accuracy filter and speed filter both are used to obtain learning curve and mean square error obtained is given in Table 1.

Table1 Different Step Size and Mean Square Error of CPLMS

S. No.	Step size of Accuracy filter	Step size of Speed filter	Mean Square Error (MSE)
1	0.03	0.009	0.0013
2	0.04	0.007	0.0026
3	0.05	0.005	0.0052

Conclusions

The complementary pair least mean square algorithm is implemented using LabVIEW. By implementing two adaptive filters with different update step sizes operating in parallel, the CPLMS algorithm has both small mean square error and faster convergence speed. The results shows that accuracy filter with smaller step size and speed filter with larger step size will have smaller mean square error and faster convergence speed whereas accuracy filter with larger step size and speed filter with small step size will have larger mean square error and slower convergence speed.

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References

Casco-Sánchez, F.M.; Medina-Ramírez, R.C. and López-Guerrero, M. (2011), "A New Variable Step-Size NLMS Algorithm and its Performance Evaluation in Echo Cancelling Applications", *Journal of Applied Research and Technology*, vol.9, no.3, pp. 302-313

Y. Ozbay, A. R. Kavsoaglu (2010), "An optimum algorithm for adaptive filtering on acoustic echo cancelling using TMS320C6713 DSP," *Elsevier publication on Signal Processing*, vol.20, pp. 133-148.

K. Mayyas (2004), "A transform domain LMS algorithm with an adaptive size equation", *IEEE Proc.4th International Symposium on Signal Processing and Information Technology*, Irbid, Jordan, pp. 22-25.

T. Aboulnasr, K. Mayyas (1997), "A robust variable step size LMS type algorithm: analysis and simulations", *IEEE Trans. on Signal Process.*, vol.45, no.3, pp. 1633-1642.

K. Mayyas, F. Momani (2011), "An LMS adaptive algorithm with a new step size control equation," *Journal of Franklin Institute*, vol. 348, pp. 589-605.

Min-Soo Park and Woo-Jin Song (1998), "A complementary pair LMS algorithm for adaptive filtering", *IEICE Trans. Fundamentals*, vol. E81-A, no. 7, pp. 1493-1496.

Kaur, Rashpinder; Singh, Gurjinder; Dhaliwal, B.S and Gill, S.S (2012), "Implementation of Modified Variable step Size Least Mean Square Algorithm in LabVIEW", Proceedings of the *IEEE International Conference on Computational Intelligence and Computing Research, Coimbatore*, pp. 102-105.

National Instruments, "Adaptive filter toolkit", available at http://www.ni.com/labs

National Instruments, "Analyzing Adaptive Filter Performance (Adaptive Filter Toolkit)", available at http://www.ni.com/part number 372357A-01.

H. Kaur, R. Malhotra, A. Patki (2012), "Performance analysis of gradient adaptive LMS algorithm," *International Journal of Scientific and Research Publications*, vol.2, issue 1, pp. 1-4.