Noise Cancellation using Cascaded Combination of RLS Adaptive Filters

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***Abstract*-Adaptive filter is a kind of filter whose transfer function changes according to the requirement of the error signal.The linear adaptive filters are those that follow the principle of superposition when the parameters of the filter are kept fixed.The recursive least square algorithm involves the minimizing of the value of the squares of the difference in the estimating errors.It is based on the deterministic and time parameter approach.The adaptive filters used in this method has parameters that depend on the total number of inputs used in the process of computation.**

Keywords: Recursive Least Square algorithm,step size,Least Square,Mean Square error.

I. INTRODUCTION

There are two approaches to the development of linear adaptive filters.One is the stochastic gradient approach and the other is the Least Square estimation approach.The Recursive Least Square algorithm is based on the latter.In this method , the cost function is minimized and the cost function is referred to as the sum of weighted error squares.The input data stream is arranged in the form of equal length blocks.The data is filtered on a block by block basis.

II. RLS ALGORITHM

Method of Least Squares does not keep into account the various assumptions on the inputs to the adaptive filter.This method involves minimizing the value of the squares of the differences of the estimating error .The method of Least Squares acts as an alternative option to the Wiener filters.Wiener filters work on the principle of ensemble averages.This results in the filter to be optimum in the statistical sense.The environmental conditions underlying are wide sense stationary.

The method of least squares is based on a deterministic approach.The method of Least Squares is based on a time parameter approach .The adaptive filter used in this method has parameters which depends on the total number of inputs used in the process of computation.This method of Least Squares uses a batch processing approach which implies that it involves the processing of a batch of data that acts as an input to the adaptive filter used in the method of Least Squares.The adaptive filter that is used in the method of Least Squares repeats the computation in the form of a block by block basis.This computation is more demanding than the Least Mean Square algorithm.[4]

$$\mathbf{d(i)} = \sum_{k=0}^{M-1} w^{*}\, \mathbf{u(i-k)} + \mathbf{e(i)}$$

Here, d(i) is the desired response,w* is the conjugate of the unknown model parametes and e(i) is the error of measurement.[4]

e(i) has zero mean and a constant value of the vatiance.It has to be introduced to take into account the inaccuracy and statistical variations in the output which deviate from the desired response.

$$e(i) = d(i) - y(i) \quad [4]$$

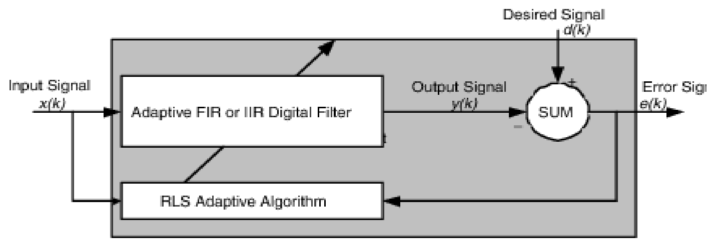
Here, d(i) is the desired response and y(i) is the adaptive filter output.e(i) represents the deviation of the output of the adaptive filter from the desired response that is optimum.

In the method of Least Squares, the tap weight vectors are chosen in such a manner that the cost function that is assigned to the adaptive filter is to be minimized.The cost function that is used in Least Square method consists of the sum of the various error squares.[4]

$$\in \mathbf{(i)} = \sum_{i=i1}^{i=i2} (|e(i)|)\ \hat{}\,2$$

Here, ∈ (i) represents the cost function of the filter.This sum can also be termed as error energy.The limits i1 and i2 are the limits of error minimization which means that these are the limits between which the minimization of the error takes place.

III. RLS ADAPTIVE FILTER



Recursive Least Square Adaptive Filter

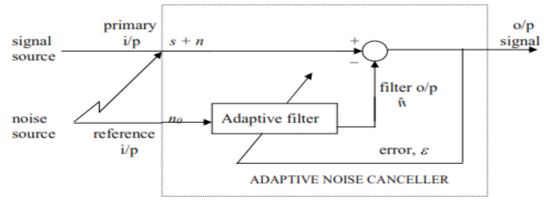
The initialization in the Recursive Least Square Algorithm is done by taking the least square estimate of the tap weight vector at iteration zero to be zero and the covariance matrix of the Recursive Least Square estimate of the tap weight vector to be equal to the product matrix of the identity matrix and the inverse matrix of a constant vector whose magnitude is small positive constant for a high value of signal to noise ratio and is a large constant for a low value of signal to noise ratio.Then in the next step the n-1(th) value of the covariance matrix of the tap weight vector is multiplied with the input vector u(n).The result obtained in the previous step is divided by the sum of the positive constant and the product of the value obtained in the previous step and the tap weight vector input.The error is calculated by subtracting the filter response from the desired response[4].The difference between the least square estimate of the tap weight vector at iteration n-1 and the least square estimate of the tap weight vector at iteration n is then computed as the product of the time varying gain vector and the tentative value of the estimation error at the time of the iteration n.

The covariance matrix of the Recursive Least Square estimate at the n(th) iteration is then computed to be the subtraction of the product of the inverse of the exponential weighting factor and the covariance matrix of the Recursive Least Square estimate at the n-1(th) iteration and the product of the time varying gain factor , the inverse of the exponential weighting factor,the updated tap input vector and the covariance matrix of the Recursive Least Square estimate at the n-1(th) iteration.[4]

The process of computation of the varying gain vector takes place in two steps:

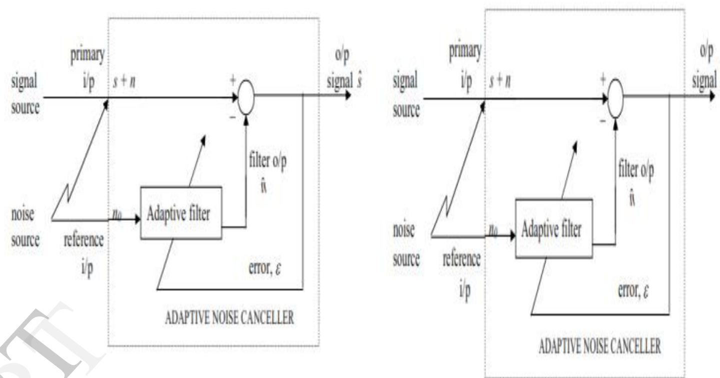
- An intermediate quantity is calculated.
- Then in the next step the intermediate quantity is used to calculate the varying gain vector.

The first step in the Recursive Least Square estimation process is the initialization of the initial weight vector and the initialization of the initial correlation matrix.



Adaptive noise canceller

IV. RESULTS



Cascaded adaptive filter design

Steps:[4]

Initialization

w (0) = 0

P (0) = δ^{-1} I

Computation at each time instant

$\pi\ (n)$ = P(n-1) u (n)

k (n) = $\pi\ (n)$ / (l + u (n) $\pi\ (n)$)

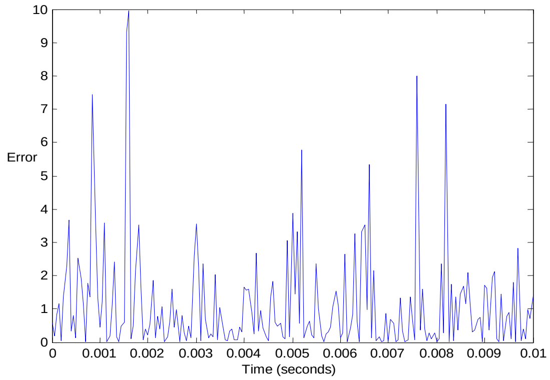
$\in\ (n)$ = d (n) – w (n-1) u(n)

w(n) = w(n-1) + k(n) $\in *\ (n)$

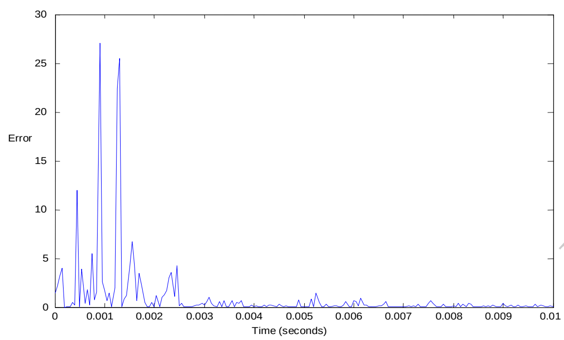
P(n) = l^{-1} P(n-1) - l^{-1}k(n) u(n) P(n-1)

K(n) is the time varying gain vector, $\pi\ (n)$ is an arbitrary quantity that needs to be calculated,P(n) is the covariance matrix of the Recursive Least Square

estimate. $\in\ (n)$ is the estimated error of the system,d(n) is the desired response,w(n) is the tap weight input at time instant n, l^{-1} is the inverse matrix of the exponential weighting factor. δ^{-1} is an arbitrary constant matrix.



Error minimization using RLS Algorithm



Error minimization using cascaded RLS algorithm

V. CONCLUSION

I have implemented the cascaded combination of adaptive filters using Recursive Least Square algorithm.The cascaded combination performs better noise cancellation than the single adaptive filter using Recursive Least Square algorithm.

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