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Application of Affine Projection Algorithm in Adaptive Noise Cancellation

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Abstract

This paper presents the application of two classes of Affine Projection Algorithm (APA) for Adaptive Noise Cancellation. The output results are compared on the basis of signal to noise ratio (SNR) and frequency spectrum of the filtered signal. The two classes of Affine Projection Algorithm used to adapt the noise, involve Conventional APA and Adaptive Step Size APA. Computer Simulations for various classes of APA are carried out using Matlab. For colored input and correlated data, APA family is suitable to accelerate the convergence of Least Mean Squares (LMS) Algorithm at a computational cost. In adaptive step size APA, step size is adapted on the basis of absolute mean value of error vector.

Keywords – APA , adaptive filter, adaptive step size, performance.

1. Introduction

Adaptive Noise Cancellation is a technique of estimating additive noise or interference through an Adaptive Filter and then subtracting this estimated noise from the corrupted signal to get the actual signal. In Adaptive filters an impulse response or transfer function can be adjusted or changed over time according to an optimizing algorithm to match desired system characteristics. They do not require complete a priori knowledge of the statistics of the signals to be filtered. In this paper we present various classes of APA as optimizing algorithm for adaptive filter.

APA is a useful family of adaptive filters whose main purpose is to speed the convergence of LMS-type filters, especially for correlated data, at a computational cost that is still comparable so that of LMS [1]. APA is a generalization of the well known normalized least mean square (NLMS) adaptive filtering algorithm. Under this interpretation, each tap weight vector update of NLMS is viewed as a one dimensional affine projection. In APA the projections are made in multiple dimensions [2]. The APA class of algorithms provides an improvement in convergence rate over NLMS, especially for colored input signals. The APA provides a way to increase the convergence rate without compromising too much on misadjustment [3]. The difference between the normalized LMS (NLMS) and the APA is that the NLMS updates the weights based only on the current regressor, while the APA updates the weights based on the K most recent regressors and observations [4].

An APA with a constant step-size parameter has to compromise between the performance's criteria of fast convergence rate, and low misadjustment. Therefore, a variable step-size APA represents a more reliable solution [5]. Adjusting step size instead of fixed step size has a powerful effect on the performance of the system and the structure of the adaptive filter will not be changed, also this technique requires fewer overheads in computations [6].

Here, in this brief, noise of a corrupted frequency varying sinusoidal signal is cancelled using the two classes of APA in adaptive filter. SNR of the output signal for the both algorithms are compared by varying number of iterations and projection order.

This paper is organized as follows. Section 2 describes the model of adaptive noise canceller used throughout the paper. Various classes of APA are discussed in section 3. Simulation results are given in section 4 and conclusion is in section 5.

2. System Model

The system model used for adaptive noise cancellation throughout this paper is as shown in figure 1.

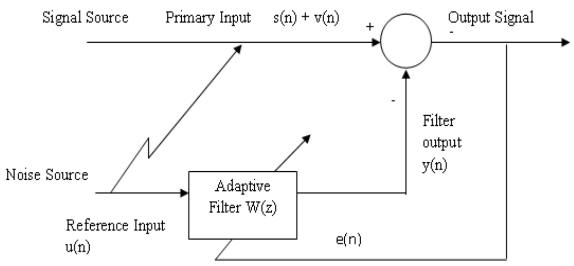

Figure 1. System Model

This model can be described as follows:

- **s**(n) is the actual signal from the signal source at the primary input. In this paper a sinusoidal signal of varying frequency is taken as actual signal.
- v(n) is the noise signal at primary input. Here, it is taken as white guassian noise passed through an autoregressive process.
- This noise signal v(n) is added to the **s**(n) resulting in a desired signal **d**(n).
- **u**(n) is a noise at the reference input correlated with v(n) applied as an excitation to the adaptive filer. In this brief, it is taken as a white guassian noise passed through a moving average process.
- Both the noises are uncorrelated with s(n), so that,
  $E[s(n)v(n)] = 0$ (1)
  and
  $E[s(n)u(n)] = 0$ (2)
- **w**(z) is the tap weight vector of adaptive filter.
- y(n) is the output of adaptive filter.
- This output is subtracted from desired signal resulting in an error signal **e**(n).

3. Affine Projection Algorithm

APA is used to maintain the rate of convergence constant, independently of the angle between the input vector **u**(n) & unit delayed vector **u**(n-1). It is based on affine projections of most recent K data vectors, and is the basis for the algorithm that converge rapidly for autoregressive (AR) processes of order less than or equal to K. The instantaneous error of APA is a vector.
APA variables are defined as follows:

- The excitation noise signal matrix for adaptive filter, **A(n) ,** is L by N and has the structure,
  A(n) = [**u**(n),**u**(n-1),....,**u**(n-K+1)] (3)
  Where, again **u(n)** = $[u(n),....,u(n-L+1)]^T$ is the excitation vector.
- The adaptive tap weight vector is **w**(n) = $[w_0(n),.....,w_{L-1}(n-1)]^T$, where $w_i(n)$ is the i^{th} coefficient at sample period n.
- **e**(n) = $[\mathbf{e}_0(n),\mathbf{e}_1(n),.....\mathbf{e}_{K-1}(n)]^T$ is the K length vector consisting of signal and residual noise.
- The N length desired response vector, **d**(n) = $[d(n),d(n-1),.......,d(n-K+1)]^T$, where, d(n) = **s**(n)+**v**(n) consisting of actual signal and unknown noise .
- K defines the rank of affine projections in the solution space and it is called as the projection order of APA.
- L is the length of the adaptive filter.
- **I** is K by K identity matrix. Here, the delta is employed to avoid the inversion of possibly rank deficient matrix $\mathbf{A}^T(n)\mathbf{A}(n)$. Moreover, it plays an important role in the convergence rate and the steady state misalignment of the conventional APA.
- μ is adaptation constant in the range $0 \leq \mu \leq 1$ and δ is the regularization factor (delta).
- Filter structure is taken as finite impulse response (FIR).

These variables are used for both the classes of APA throughout this brief.

3.1 Conventional APA

The main purpose of APA is to speed the convergence especially for correlated data. The flowchart for APA is as shown below:

In APA the projection order (K), the step size μ ($0< \mu \leq 1$) and delta govern the rate of convergence and the steady state misalignment i.e. performance of the conventional APA.

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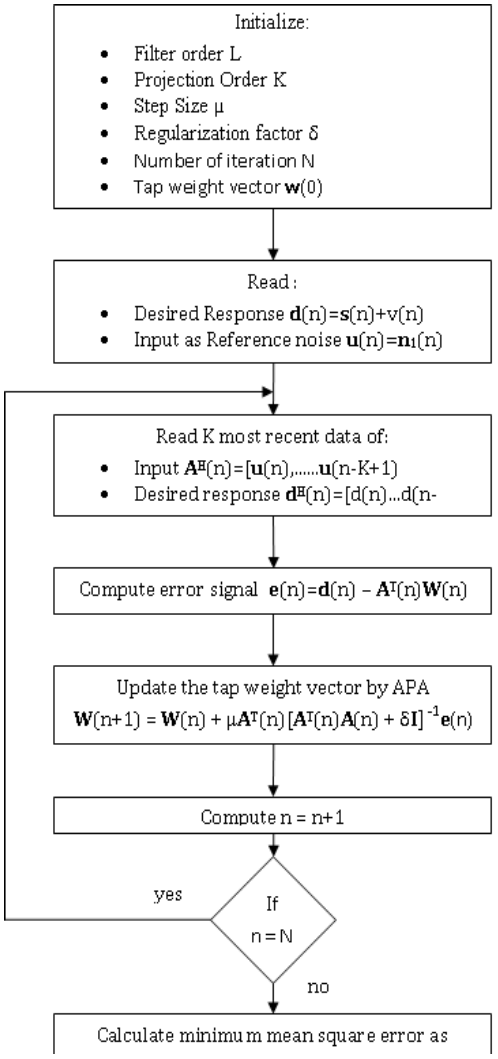
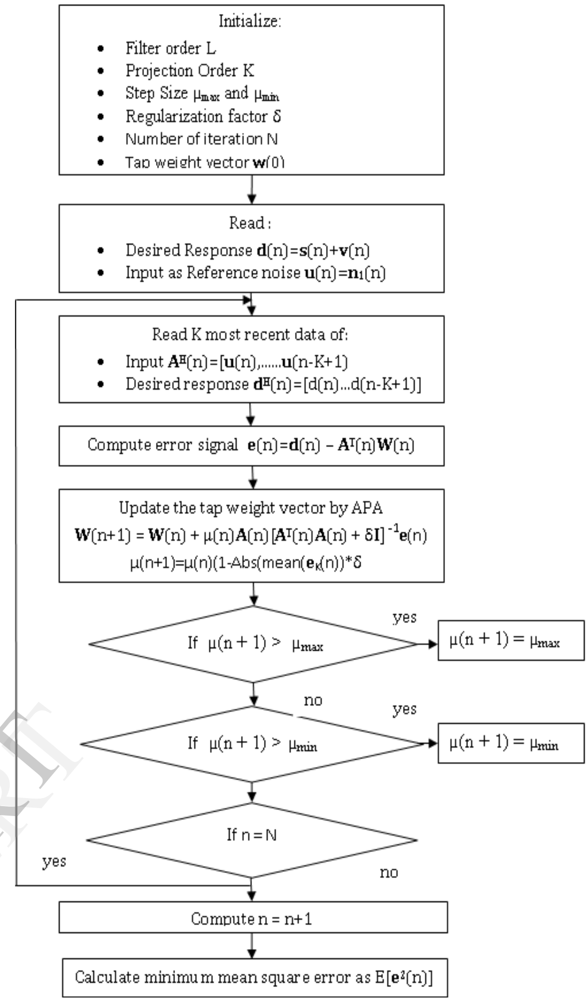


Flowchart 1. Affine Projection Algorithm

3.2 Adaptive Step Size APA

Instead of fixed value in this algorithm at the beginning, step size takes a large value and then decays gradually until it reaches a selected minimum value in the rest of the iterations. The time varying step size is adjusted according to absolute mean value of the current and the previous estimation error's vector. Current value of step size also depends on its previous value. Flowchart for the algorithm is as follows:



Flowchart 2. Adaptive Step Size APA

Here, $\mu(1)$ is taken as μ_{max} and $0 < \delta < 1$.

4. Simulation Results

Both the APA algorithms are simulated using Matlab software and results are shown in graphical and tabular form.

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4.1 APA

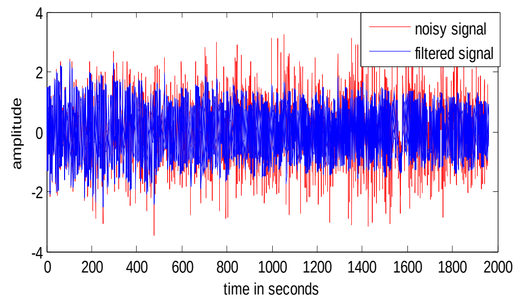

Figure 1. Time Response of noisy and filtered signal

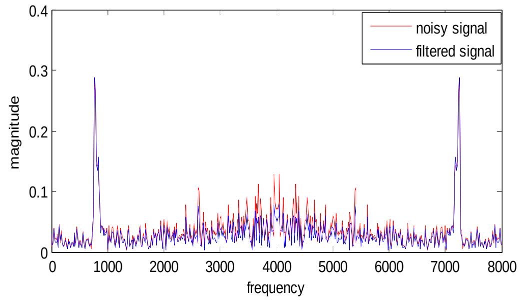

Figure 2. Freq. Response of noisy and filtered signal

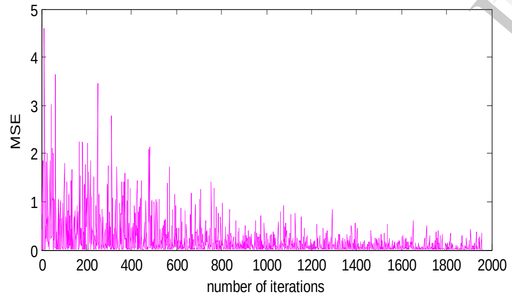

Figure 3. MSE v/s no. of iterations

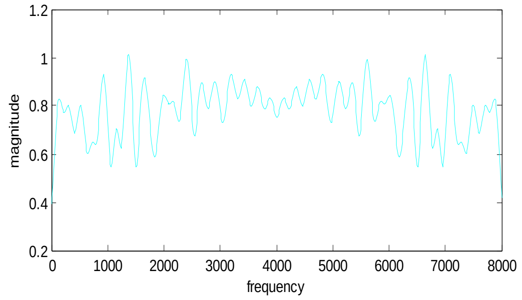

Figure 4. Freq. Response of Adaptive Filter

Table 1. Data for Conventional APA

N	μ	δ	K	L	SNR in dB		Gain (b)-(a)
					I/P (a)	O/P (b)	
2000	.01	.001	04	40	-1.99	4.18	6.17
2000	.01	.001	04	20	-1.99	3.93	5.93
2000	.1	.001	04	40	-1.99	4.18	6.17
2000	.1	.0001	08	40	-1.99	1.78	3.77
2000	.1	.0001	08	20	-1.99	1.17	3.16
2000	.01	.0001	08	20	-1.99	6.41	8.39
2000	.01	.001	08	20	-1.99	6.40	8.40
1000	0.1	.0001	04	40	-1.71	4.09	5.80
1000	0.1	.0001	08	20	-1.71	1.25	2.96

4.2 Adaptive Step Size APA

Value of delta and μ_{max} is initialized at 0.001 and 0.01 respectively..

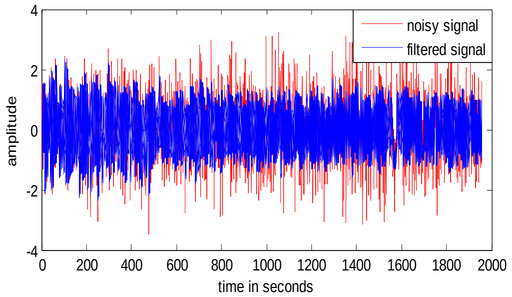

Figure 5. Time Response of noisy and filtered signal

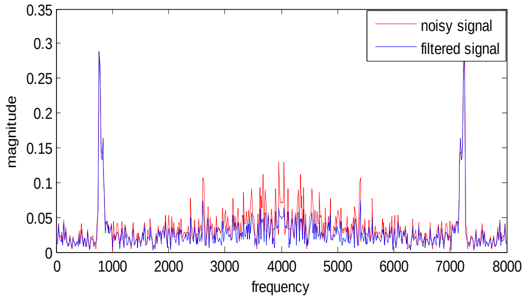

Figure 6. Freq. Response of noisy and filtered signal

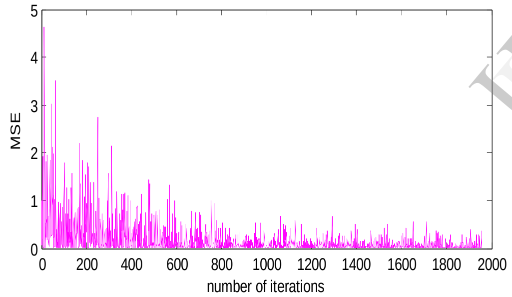

Figure 7. MSE v/s no. of iterations

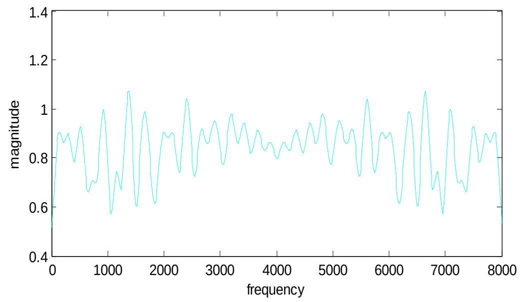

Figure 8. Freq. Response of Adaptive Filter

Table 2. Data For Adaptive Step Size APA

N	Final µ	K	L	SNR in dB		Gain (b)-(a)
				I/P (a)	O/P (b)	
2000	0.007	06	40	-1.99	5.01	7.01
2000	0.007	04	40	-1.99	3.64	5.63
2000	0.0074	08	40	-1.99	5.57	7.57
2000	0.0075	08	20	-1.99	6.54	8.53
2000	0.0070	04	20	-1.99	5.91	7.90
1000	0.0070	04	20	-1.71	3.92	5.63
1000	0.0070	04	40	-1.71	1.76	3.47
1000	0.0087	08	40	-1.71	3.82	5.53
1000	0.0087	08	20	-1.71	5.36	7.07

4. Conclusions

Table 1 shows that K, µ and δ govern the convergence rate of APA. The noise components are more suppressed in adaptive step size APA (fig. 2 & 6). Table 2 concludes that by controlling step size better SNR can be obtained. The mean square error in figure 7 is reduced for less number of iterations resulting in increased speed of convergence. Hence the overall performance and stability of adaptive filter using ASSAPA is improved.

5. References

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