Adaptive Noise Cancellation

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Abstract

This project focuses on the study of the principle of Adaptive Noise Cancellation (ANC) using a Adaptive Noise Canceller. Adaptive Noise Cancellation is an alternative technique of estimating signals corrupted by additive noise and interference. Its advantageous as it doesn't require any apriori estimate of the noise or signal and it is possible to attain the levels of noise rejection which would be difficult using any other signal processing methods of removing noise. This method requires two input, one is the primary signal and the other is a reference noise uncorrelated with the signal but somewhat correlated with the noise associated with the primary signal. The reference is adaptively filtered and subtracted from the primary input to estimate the signal.

1 Introduction

1.1 Background

The typical method of estimating a signal corrupted with additive noise is to pass the corrupted signal through a filter that would suppress the noise while leaving signal relatively unchanged also known as direct filtering as shown in figure 1. The design of such filters come under the domain of optimal filtering, filters being used for direct filtering are fixed filters and adaptive filters.

Fixed Filters - The design of the fixed filters requires the prior knowledge of both the signal and the noise. The filter is so designed to pass the frequencies present in the signal and reject the frequency band contained by the noise.

Adaptive Filters - The design of adaptive filter on the other hand has the ability to adjust their impulse response to filter out the correlated signal present in the input, very little or no a prior information of the signal or the noise is

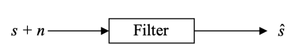

Figure 1: Basic Filter

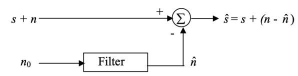

Figure 2: Noise Cancellation

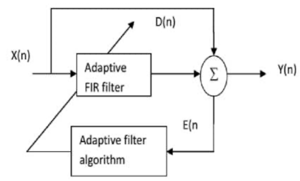

Figure 3: Adaptive Noise Cancellation

required. Also, the adaptive filter has the ability to adaptively track the signal under non-stationary conditions.

Noise cancellation is a alteration of optimal filtering which involves estimating the noise by filtering the reference input and than subtracting the estimated noise from the primary input which contain both the signal and noise as shown in figure 2.

1.2 Terminologies

Adaptive Filter - A filter which could regulate its impulse response according to some optimization criteria. The filter coefficients are updated at every iteration until the convergence criteria is met and a well-established signal is obtained. In case of non-stationary signals, the filter is expected to track the time versions and accordingly adjust its filter coefficients, correspondingly in a stationary signals the filter is expected to converge to a Weiner Filter.

There are a few types of adaptive algorithms being used but in this work, Least Mean Square (LMS) algorithm is being used. Figure 3 shows the use of adaptive noise canceller which cause to subtract the noise from the output response in an adaptively controlled manner so as to boost the signal to noise ratio, x(n) denote the input signal includiing noise, d(n) denote the desired signal, e(n) denote the error signal and y(n) denote the desired output signal.

Least Mean Square (LMS) Algorithm - LMS algorithm as discussed earlier is a category of adaptive filter, used to structure a desired filter by finding the filter coefficients which could minimize the least mean squares of error signal. Figure 4 shows the flow chart of an LMS Adaptive filter with x(n) as the input signal, d(n) is the desired output, w(n) represents the weights and e(n) represents the error. The weights are updated using the following rule w(n+1) = w(n) + 2*step_size*e(n)*x(n) The weights are being updated until the convergence criteria is met.

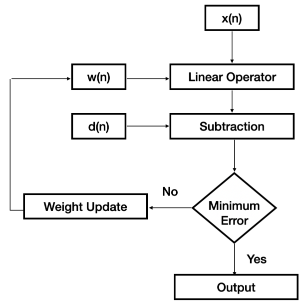

Figure 4: Flow chart of LMS Adaptive Filter

1.3 Organization

Section 1 discusses the introduction to adaptive noise cancellation and the overview of the methodology being used then in section 2 we discuss the literature then in section 3 we will discuss about the methodology and in section 4 will contain the conclusion of the work.

2 Literature

The concept of noise cancellation was recently got more attentation due to the increase in the number of application and is widely considered a virtual method to eliminate noise from useful signals [1]. As the noise from the surrounding severely decreases the quality of the signal, it becomes very important to suppress the noise and enhance the signal.

2.1 Previous methods

The most accepted way of estimating a signal corrupted with additive noise is to pass the signal though a filter that would suppress the noise leaving the signal relatively unchanged. The design these filters come under the domain of optimal filtering which originated with the pioneer work of Weiner and was extended and enhanced by the work of Kalman, Bucy and others [2, 3]. But as previously mentioned, fixed filters are mostly not applicable in case of noise cancellation as the correlation and cross correlation function of the primary and the reference input are unknown and often variable in time. But adaptive noise cancellation learns the statistics on their own, one of the earliest work of adaptive noise cancellation was performed by Howells and Applebaum and their colleagues, a system for antenna sidelobe cancellation was build where they used a reference input derived from an auxillary antenna and a simple two-weighted adaptive filter [4]. Since then, adaptive noise cancelling are being successfully applied to a numerous problems, including elimination of periodic interference in general [5], and to cancelling echos over long distance transmission lines [6].

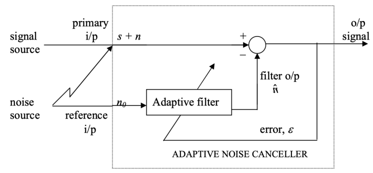

Figure 5: Adaptive Noise Canceller with reference input

2.2 Proposed Method

The basic concept of Adaptive Noise Canceller (ANC) is that it removes or suppresses noise from a signal using adaptive filters which was first introduced by Widrow [7]. Due to long impulse responses, the computational requirements of adaptive filters are very high especially during implementation on digital signal processors. Where as in case of non-stationary environments, the convergence becomes very slow if the adaptive filter receives a signal with high spectral dynamic range. To overcome this problem various approaches have been proposed over the years. For example, the Kalman filter and the Wiener filter, Recursive-Least-Square (RLS) algorithm, were proposed to achieve the optimum performance of adaptive filters. Amongst these the Least Mean Square (LMS) algorithm is most frequently used because of its simplicity and robustness. In this project, an Adaptive Noise Canceller using Least Mean Square (LMS) algorithm is proposed.

3 Methodology

3.1 Algorithm

As shown in figure 5, an adaptive noise canceller has 2 inputs the primary input and the reference input. The primary input receives the signal s which is corrupted by noise n uncorrelated with the signal. The reference input receives a noise no uncorrelated with the signal but correlated in some way with the noise n. The noise is made to pass through the filter n$\hat{}$that is a close estimate of primary input noise. The noise estimate is then subtracted from the corrupted signal to produce an estimate of the signal s, that is the Adaptive Noise Canceller.

In noise cancelling system the primary objective is to produce a system output s$\hat{=}$ s + n - n$\hat{}$that best fits the least square sense of the signal s. The objective is achieved by feeding the system output back to adaptive filter and adjusting the filter weights through an LMS adaptive algorithm to minimize the total system power. Consequently the system output serves as the error for adaptive process.

It is assumed that s, n, no and y are statistically stationary and have zero means. The signal s is uncorrelated with n and no but n is correlated with noise no

$$s' = s + n - n'$$

Taking square on both the sides,

$$s' = s'^2 = s^2 + (n - n')^2 - 2s(n - n')$$

Taking expectation both the sides and realizing that s is uncorrelated with no and n'

$$E[s'^2] = E[s^2] + E[(n - n')^2] + 2E[s(n - n')]$$
$$E[s'^2] = E[s^2] + E[(n - n')^2]$$

The signal power $E[s^2]$ will be unaffected as the filter is adjusted to minimize $E[s'^2]$

$$minE[s'^2] = E[s^2] + minE[(n - n')^2]$$

Thus, when the filter is adjusted to minimize the output power $E[s'^2]$, the output noise power $E[(n-n')^2]$ is also minimized. Since the signal at the output remains constant, hence minimizing the total power maximized the signal to noise ratio.

Since,

$$(s' - s) = (n - n')$$

It is equivalent to causing the output śto be a best least square estimate of the signal s.

3.2 Plots tables and outputs

For this project, the reference inputs were used as gaussian noise and Sinusoidal Noise. Figure 6 shows the output of the adaptive noise canceller with Gaussian Noise as reference input and figure 7 shows the output of the adaptive noise canceller with sinusoidal signal.

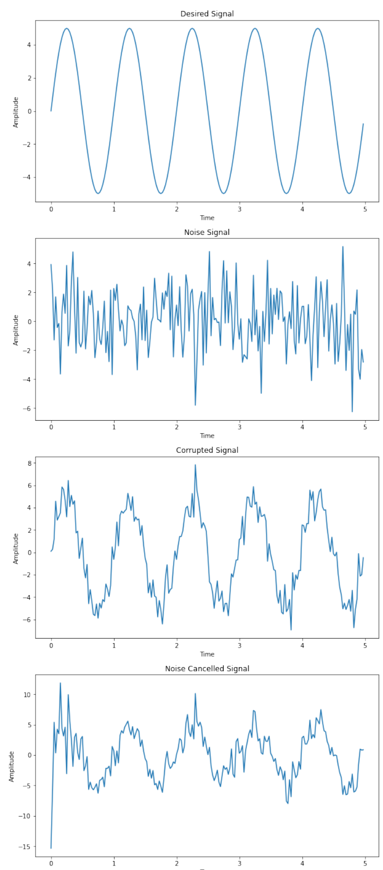

Figure 6: Adaptive Noise Canceller Output with reference input as Gaussian Noise

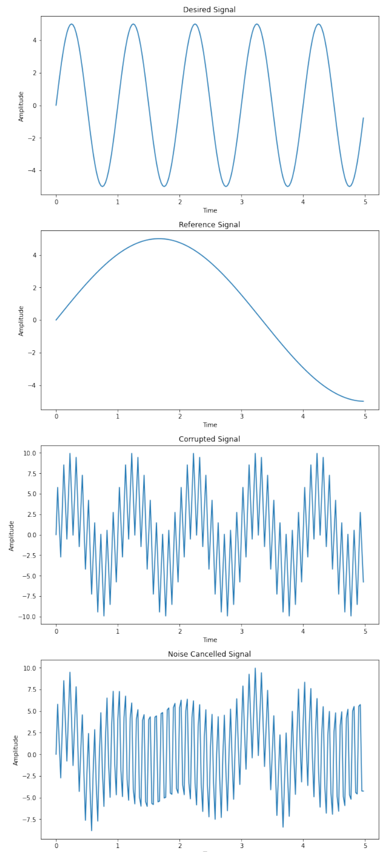

Figure 7: Adaptive Noise Canceller Output with reference input as Sinusoidal Signal

Here, it could be noted that despite ANC being a correlation canceller, when it is applied with a reference input of sinusoidal signal it performs well with maximum noise cancellation and minimal loss of signal and it;s subsequent properties.

4 Conclusions

Adaptive Noise Cancellation is an alternative way of canceling noise present in a corrupted signal. The principal advantage of the method are its adaptive capability, its low output noise, and its low signal distortion. The adaptive capability allows the processing of inputs whose properties are unknown and in some cases non-stationary. Output noise and signal distortion are generally lower than can be achieved with conventional optimal filter configurations.

This Project indicates the implementation and shows us the possibilities and effectiveness of Adaptive Noise Canceling and how it can be used. The simulation results verify the advantages of adaptive noise cancellation, canceling was accomplished with little signal distortion even though the frequencies of the signal and interference overlapped. Thus it establishes the usefulness of adaptive noise cancellation techniques and its wide range of applications.

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