Determination of Optimum Step Size of LMS Algorithm in De-noising of Image

This Major project in partial fulfillment for the award of the degree of
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In
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DECLARATION

We hereby declare that we carried out the work reported in this project in the Department ofElectronics and Communications Engineering, East West University, under the supervision of**Dr. Mohamed Ruhul Amin and Dr. Md. Imdadul Islam**. We solemnly declare that to the best of our knowledge, no part of this report has been submitted elsewhere for award of a degree. All sources of knowledge usedhave been duly acknowledged.

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ABSTRACT

If the source of noise of an image is known then we consider that the noise is correlated with one portion of the noisy image. In this case the noisy of the signal or image is removed using adaptive algorithm. In this project work we removed noise from noisy images using LMS(Least Mean Square) algorithm then similarity between original and recovered images is measured using cross-correlation efficient. The step size of the algorithm is varied to get maximum value of cross-correlation co-efficient to achieve optimum step size.

CONTENTS

Determination of Optimum Step Size of LMS Algorithm in De-noising of Image

Chapter-1

INTRODUCTION

Most widely used applications of adaptive filter are: de-noising of images, speech signal, echo-cancellation of communications, noise and interference elimination, bio-medical signal (for example ECG, EEG), adaptive beam-forming of wireless communication etc.

In [1] authors used adaptive algorithm in de-noising of ECG signal. The basic theories of adaptive algorithms are given where authors used only LMS algorithm and low frequency power-line signal is considered as the source of interference. The original ECG signal, sinusoidal wave of power-line, contaminated ECG signal and de-noised ECG signal are shown in the result sector of the paper. Similar work is also done in [2] but the authors proposed NLMS algorithm for converting a noisy ECG signal into noise-free ECG signal.

On the basis of FFT (Fast Fourier Transform), in [3], authors introduced an advanced adaptive algorithm in order to eliminate power-line interference of ECG signal which is examined by usingMIT-BIH ECG signals database.A comparison among LMS, NLMS, RLS and proposed algorithm in respect of SNR (Signal-to-Noise Ratio) and step size is shown in the result part of the paper to prove the effectiveness of the proposed adaptive algorithm. Same type of comparison is also done in [4] but the authors compared adaptivealgorithms in terms of MSE, complexity and stability.

In [5], authors proposed a Kalman based LMS algorithm which is termed as KLMS algorithm to efficiently diminish ECG signal noises. Convergence characteristics of various algorithms (such as LMS, NLMS, KLMS, IKLMS, SKLMS) and SNR of different algorithms for different noise sources (such as EM artifact, BW artifact, MA artifact) is demonstrated in the result unit.

For de-noising of both audio and sinusoidal signal adaptive LMS filter is implemented in [6]. The authors conducted experiment over an FPGA (field-programmable gate arrays) Spartan 3 from Xilinx, using MATLAB and System Generator. Generation of simulink block for the LMS algorithm, implementation of JTAG of the algorithm in FPGA for audio de-noising, original audio signal, contaminated audio signal and output error signal is presented in the result segment.In [7], authors showed that at the time of de-noising speech signal, WAF (Wavelet based Adaptive Filtering) method produces less RMSE (Root Mean Square Error) compared to WBT and adaptive LMS filter. Speech signal, corrupted speech signal, de-noised speech signal using WAF and performance measures (such as RMSE, SNR, PSNR, PDR) for speech signal under different noise environments (such as vehicle noise, airport noise, exhibition noise) using MDWT is shown in the result zone of the paper.

In [8], authors focused on basic adaptive noise cancellation technique using LMS, RLS and wavelet transform. Performance parameters (such as SNR, RMSE, MAE) of adaptive filter without wavelet transform and with Haar wavelet transform is demonstrated in the result and discussion zone of the paper. The authors came to a conclusion that wavelet transforms are appropriate for making a signal noise-free but adaptive algorithms are the finest for the retrieval of fading signals of wireless communication. Comparison is also shown in [9] between Wavelet, STFT, LMS and RLS on the basis of mean error, maximum error, variance, CPU time and practical implementation but in the paper, Vuvuzela is considered as the noise source.

In [10], authors researched on de-noising of PCG (Phonocardiogram) signal by using different adaptive algorithms. Murmurs (noise that is generated due to turbulent blood flow) are taken as the source of noise. The de-noising processes of PCG signal via different adaptive systems such as LMS, NLMS, DLMS, RLS and QRDRLS adaptive system are presented in the result area of the paper.

In order to eradicateocular artifact (eye blinking noise) from EEG (Electroencephalogram) signals, in [11], authors used adaptive noise cancelation system on the basis of thresholding method in DWT (Discrete Wavelet Transform). OA (Ocular Artifact) region is taken as the noise source and adaptive noise cancellation method is demonstrated. Comparison of MSE and MAE values for different methods (EMD, DWT with simple LMS and DWT with normalize LMS),recorded EEG signal, EOG signals, DWT corrected EOG and corrected EEG signal is presented in the result segment.

This project will show that it is indeed possible to achieve state-of-the-art de-noising performance with an adaptive LMS filter that maps noisy images onto noise-free ones in real time.

The project report is organized as: chapter2 provides the basic theory of adaptive filter along with algorithm of image de noising, chapter 3 provides results based on analysis of chapter 2 and chapter 3 concludes entire analysis with some recommendation about future work.

Chapter-2

ADAPTIVE FILTER IN DE-NOISING OF IMAGE

2.1 Overview

The computational scheme that challenges to model the relationship between two signals in real time in an iterative manner is known as an adaptive filter. Conferring to an adaptive algorithm, an adaptive filter self-adjusts the filter coefficients.

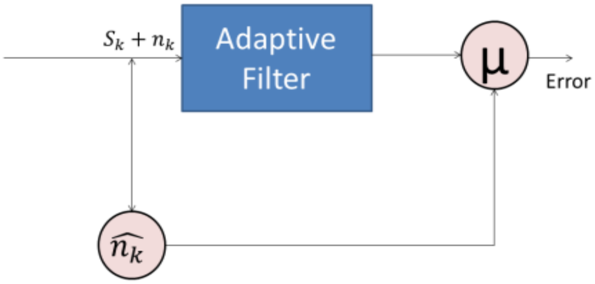


Fig 2.1: Adaptive Filter

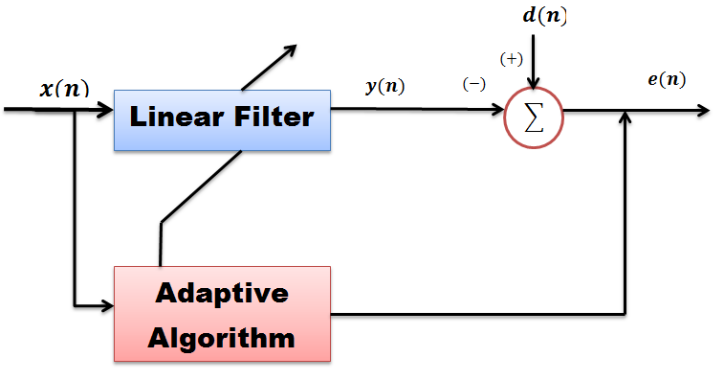


Fig 2.2: Adaptive Filter

Where **x(n)**is the input signal to a linear filter at time*n*

y(n)is the corresponding output signal

d(n)is an additional input signal to the adaptive filter

e(n) is the error signal that denotes the difference between d(n) and y(n).

There are four types of adaptive filtering configuration:Adaptive system identification, Adaptive noise cancellation, Adaptive linear prediction, Adaptive inverse system.

Though all of the systems are analogous in the implementation of the algorithm, they are different in system configuration.

2.2 Wiener Filter

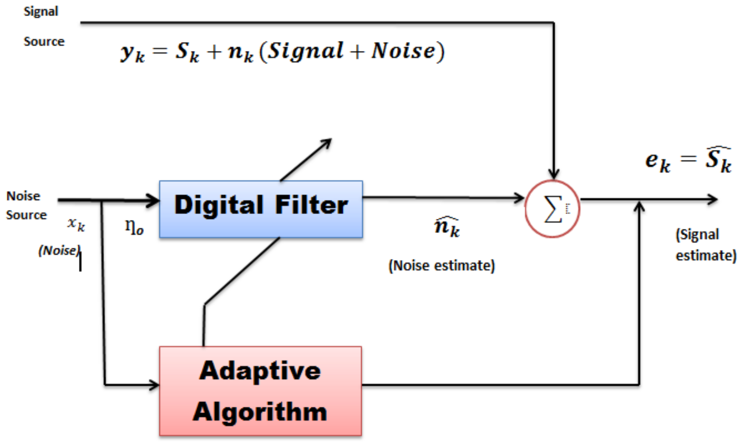


Fig 2.3: Block diagram of an adaptive filter as a noise canceller

An Adaptive filter as a noise canceller has two parts: a digital filter with adjustable coefficients and an adaptive algorithm which is used to adjust or modify the coefficients of the filter. The ANC (Adaptive Noise Canceller) has two inputs:- primary and reference.

The primary input receives a signal S from the signal source that is corrupted by the presence of noise n uncorrelated with the signal. The reference input receives a noise which is not uncorrelated with the signal but correlated in some way with noise n. The noise n_o passes through a filter to produce an output $\widehat{n_k}$ that is a close estimate of primary input noise. The noise estimate is subtracted from the corrupted signal to produce an estimate of the signal at $\widehat{S_k}$, the adaptive filter as a noise canceller system output.

In noise cancelling system, the main objective is to produce a system output,

$$\widehat{S_k} = y_k - \widehat{n_k}$$

$\widehat{S_k} = S_k + n_k - \widehat{n_k}$

$\Rightarrow e_k = \ y_k - n_k$

$\Rightarrow e_k = y_k - \sum_{i=0}^{N-1} w(i)x_{k-i}$

$\Rightarrow e_k = y_k - \{w(0)x_k + w(1)x_{k-1} + w(2)x_{k-2} + \cdots \cdots \cdots + w(N-1)x_{k-N+1}\}$

Using matrix,

$$e_k = y_k - \begin{bmatrix} x_k & x_{k-1} & \cdots & x_{k-N+1} \end{bmatrix} \begin{bmatrix} w(0) \\ w(1) \\ \vdots \\ w(N-1) \end{bmatrix}$$

$e_k = y_k - \boldsymbol{X_k^T W}$

$e_k = y_k - \{w(0)x_k + w(1)x_{k-1} + w(2)x_{k-2} + \cdots \cdots \cdots + w(N-1)x_{k-N+1}\}$

$$e_k = y_k - \begin{bmatrix} w(0) & w(1) & \cdots & w(N-1) \end{bmatrix} \begin{bmatrix} x_k(0) \\ x_{k-1}(1) \\ \vdots \\ x_{k-N+1}(N-1) \end{bmatrix}$$

$e_k = y_k - \boldsymbol{W^T X_k}$

Where the weighty vector, $\boldsymbol{W} = \begin{bmatrix} w(0) \\ w(1) \\ \vdots \\ \vdots \\ \vdots \\ w(N-1) \end{bmatrix}$

And the signal vector, $\boldsymbol{X_k} = \begin{bmatrix} x_k \\ x_{k-1} \\ \vdots \\ \vdots \\ \vdots \\ x_{k-(N-1)} \end{bmatrix}$

The square of error,

$e_k^2 = (y_k - \boldsymbol{W^T X_k})^2$

$= y_k^2 - 2y_k \boldsymbol{X_k^T W} + \boldsymbol{W^T X_k X_k^T W}$

The Mean Square Error (MSE),

$y = E[e_k^2]$

y= $E[y_k^2] - 2E\left[y_k \boldsymbol{X_k^T W}\right] + E\left[\boldsymbol{W^T X_k X_k^T}\right]$

Let, $R = E\left[\boldsymbol{X_k X_k^T}\right]$

$$= E\left\{\begin{bmatrix} x_k \\ x_{k-1} \\ x_{k-2} \\ \vdots \\ x_{k-N+1} \end{bmatrix}\begin{bmatrix} x_k & x_{k-1} & x_{k-2} & \cdots & x_{k-n+1} \end{bmatrix}k\right\}$$

$$= E\begin{bmatrix} x_k^2 & x_k x_{k-1} & x_k x_{k-2} & \cdots & x_k x_{k-N+1} \\ x_k x_{k-1} & x_{k-1}^2 & x_{k-1} x_{k-2} & \cdots & x_{k-1} x_{k-N+1} \\ \vdots & \ddots & \ddots & \ddots & \ddots \\ x_{k-N+1} x_k & x_{k-N+1} x_{k-1} & x_{k-N+1} x_{k-2} & \cdots & x_{k-N+1}^2 \end{bmatrix}$$

It is called auto-correlation matrix of dimension of *N x N*

$P = \boldsymbol{E}[y_k \boldsymbol{X}_k^T]$is the cross-correlation vector of *1 x N*

$\therefore y = \boldsymbol{E}[y_k^2] - 2P\boldsymbol{W} + \boldsymbol{W}^T R \boldsymbol{W}$ --***(1)***

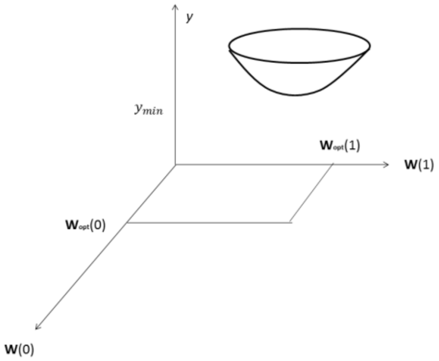


Fig 2.4: Error minimizing by wiener filter

Taking gradient of (1), $\frac{dy}{d\boldsymbol{W}} = \Delta\hat{y} = 0 - 2P - 2\boldsymbol{W}R = 0$

$$\boldsymbol{W}R = P$$

$$\boldsymbol{W}_{opt} = R^{-1}P$$

$\therefore$ the minimum error, $y_{min} = \boldsymbol{E}[y_k^2] - 2PR^{-1}P + (R^{-1}P)^T R(R^{-1}P)$

2.3 LMS Algorithm

The least mean squares (LMS) algorithms adjust the filter coefficients to minimize the cost function. The LMS algorithm performs the following operations to update the coefficients of an adaptive filter:

Let us consider the adaptive filter of size N,

Step-01: Initialize the weighty vector of sampling instant K as,

$$\boldsymbol{W}_{\mathrm{k}} = [\mathrm{w}_{\mathrm{k}}\,(\mathbf{0})\mathrm{w}_{\mathrm{k}}(\mathbf{1})\ \ldots\ldots\ldots\ldots\ldots..\,\mathrm{w}_{\mathrm{k}}(\boldsymbol{N}-\mathbf{1})]$$

Step-02: The output of the adaptive filter,

$$\hat{\boldsymbol{\eta}}_{\boldsymbol{k}} = [\mathrm{w}_{\mathrm{k}}\,(\mathbf{0})\mathrm{w}_{\mathrm{k}}(\mathbf{1})\ \ldots\ldots\ldots\ldots\ldots..\,\mathrm{w}_{\mathrm{k}}(\boldsymbol{N}-\mathbf{1})]\begin{bmatrix} x_k \\ x_{k-1} \\ \vdots \\ \vdots \\ x_{k-N+1} \end{bmatrix}$$

Step-03: The numerical value of error,

$$\mathrm{e}_{\mathrm{k}} = \mathrm{y}_{\mathrm{k}} - \hat{\eta}_{\mathrm{k}}$$

Step-04: The weighty factor at sampling instant k+1 will be updated as,

$$\mathrm{w}_{k+1} = \mathrm{w}_{\mathrm{k}}(\mathrm{i}) + \Delta\mathrm{w}$$

$$= \mathrm{w}_{\mathrm{k}}(\mathrm{i}) + 2\mu\mathrm{e}_{\mathrm{k}}\,\mathrm{x}_{\mathrm{k}-1}$$

Where, µ is called the step size of LMS algorithm.

2.4 Algorithm on De-noising of Image

Steps of de-noising technique:

1. Read an RGB image.
2. Convert it into gray scale image, Ig.
3. Convert the NxM matrix of gray scale image into a vector of $1xNM$.
4. Add noise to the vector of step-3.
5. De-noise the vector using LMS algorithm.
6. Convert the de-noised vector into NxM image.
7. Compare the original and recovered image.

Chapter-3

RESULTS and DISCUSSION

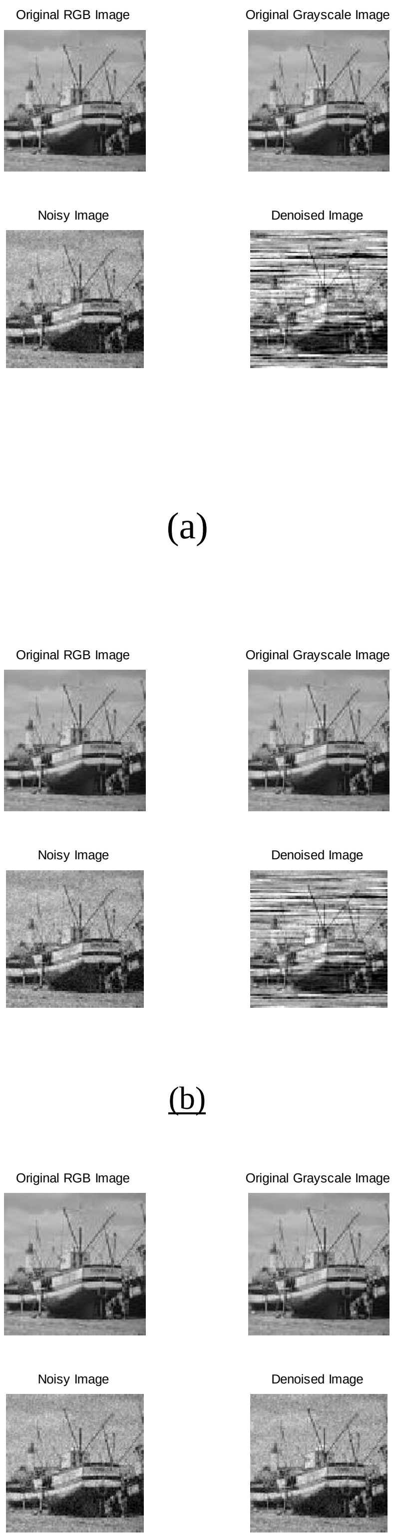
First of all we take 8 images (Barbara, Boat, Lena, Autumn, Peppers, Fabric, Football, Gantry crane) then noise is added with them, then we de-noise them using LMS algorithm. The original, noisy and de-noised images are shown in fig 3.1 to 3.8. For each image, three different step size is used and the variation of performance is established.

(a)

(b)

(c)

Fig.3.1: De-noising of image (Barbara) for 3 different step size

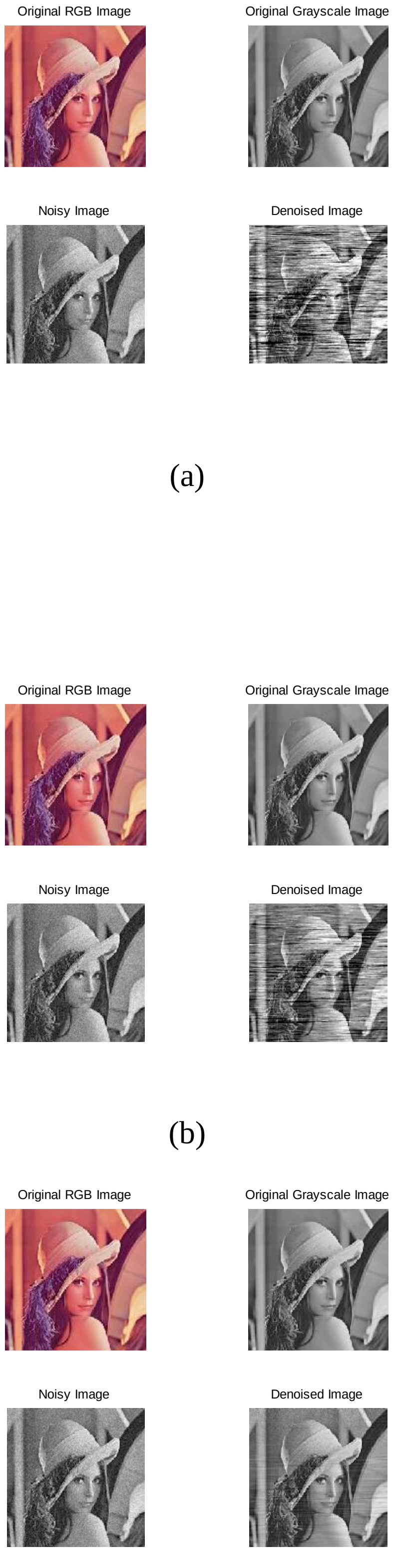


(a)

(b)

(c)

Fig.3.2: De-noising of image (Boat) for 3 different step size

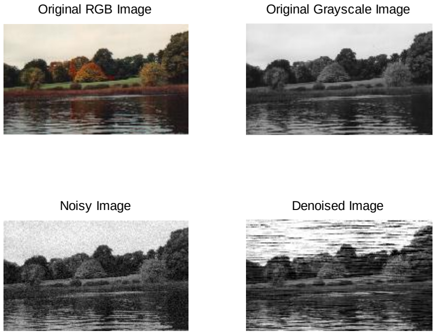


(a)

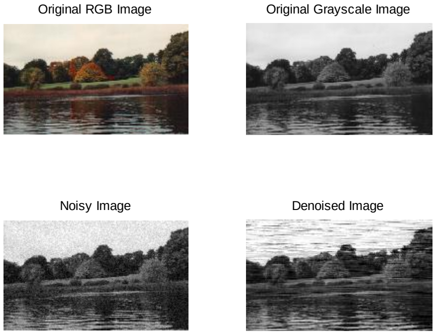
(b)

(c)

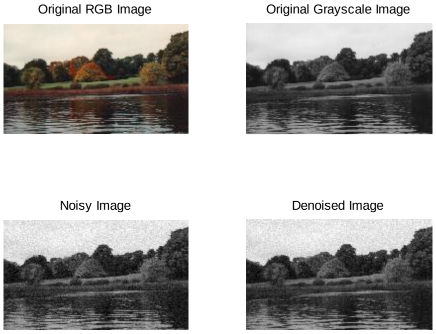
Fig.3.3: De-noising of image (Lena) for 3 different step size



(a)

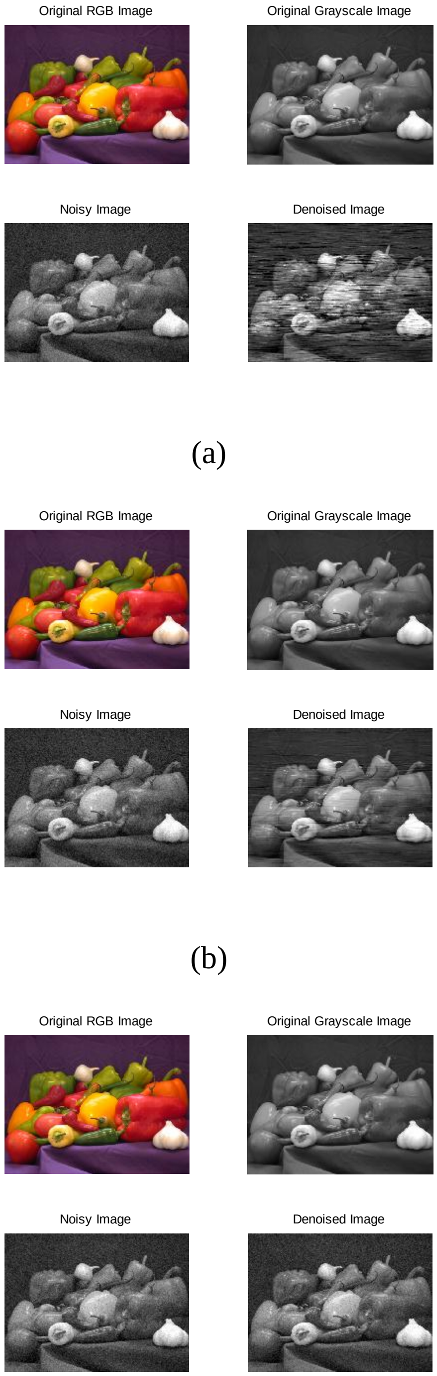


(b)



(c)

Fig.3.4: De-noising of image (nature) for 3 different step size

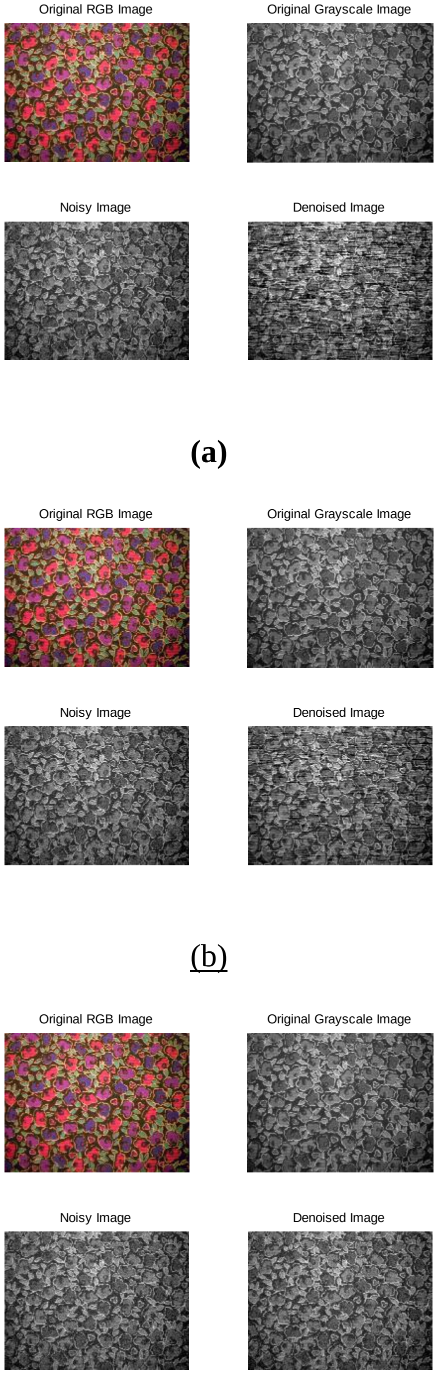


(a)

(b)

(c)

Fig.3.5: De-noising of image (peppers) for 3 different step size

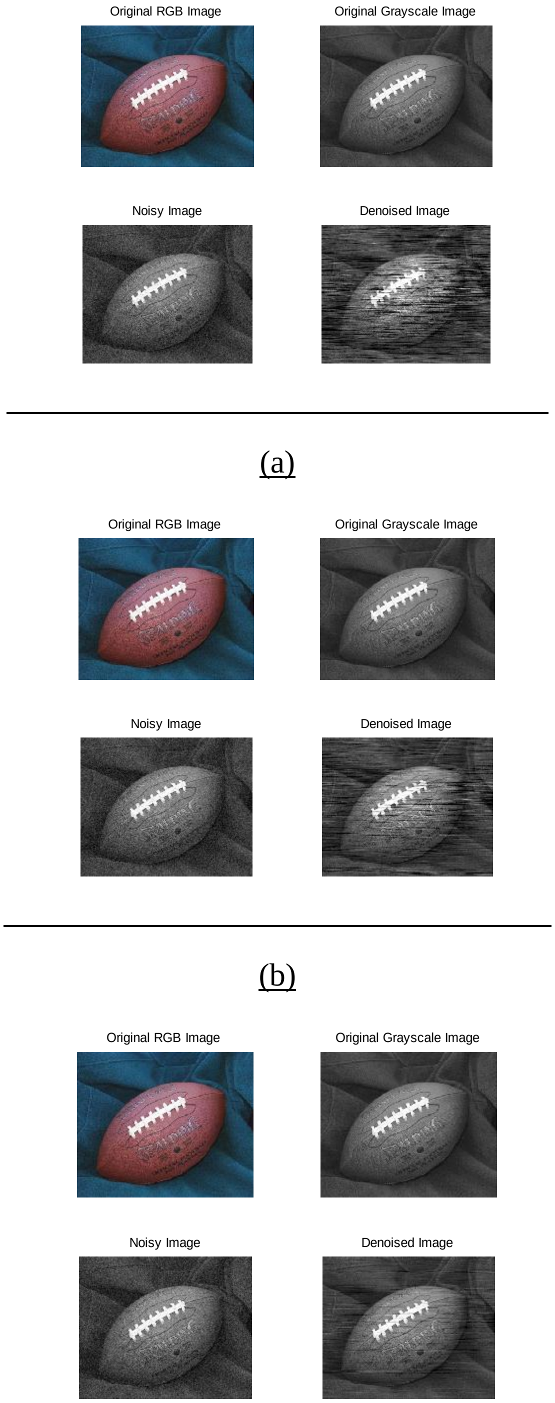


(a)

(b)

(c)

Fig.3.6: De-noising of image (fabric) for 3 different step size

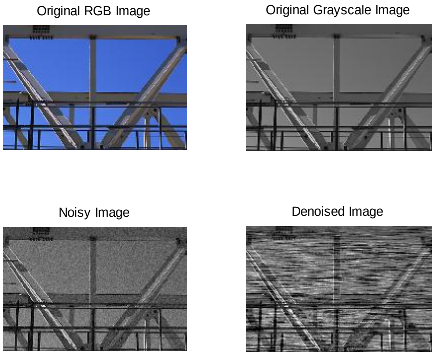


(a)

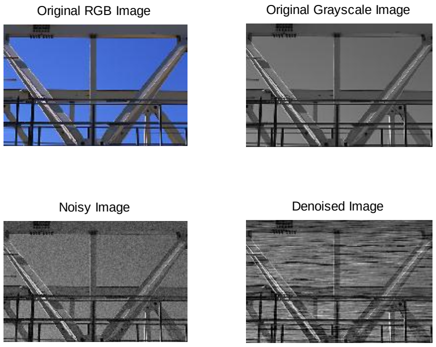
(b)

(c)

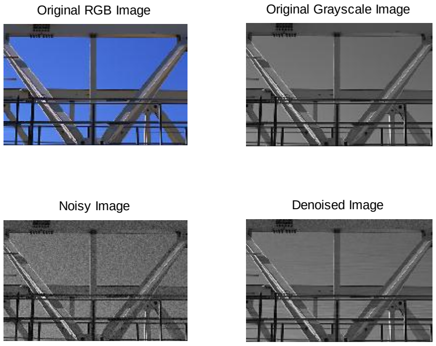
Fig.3.7: De-noising of image (football) for 3 different step size



(a)



(b)



(c)

Fig.3.8: De-noising of image (Gantrycrane) for 3 different step size

TABLE –I: Cross-correlation Coefficient Versus Step Size

Step size, μ	**Cross-correlation Coefficient of Different Image**							
	Barbara	**Boat**	**Lena**	**Autumn**	**Peppers**	**Fabric**	**Football**	**Gantry crane**
0.95	0.6896	0.6773	0.7312	0.8637	0.8314	0.7611	0.8179	0.6899
0.55	0.8467	0.8390	0.8152	0.9072	0.8787	0.8430	0.8687	0.7940
0.25	0.9082	0.8987	0.8994	0.9555	0.9312	0.9193	0.9260	0.8955
0.10	0.9641	0.9692	0.9526	0.9801	0.9740	0.9627	0.9745	0.9452
0.095	0.9662	0.9264	0.9565	0.9845	0.9776	0.9654	0.9761	0.9534
0.075	0.9712	0.9577	0.9662	0.9896	0.9811	0.9711	0.9720	0.9556
0.05	0.9818	0.9794	0.9732	0.9924	0.9883	0.9809	0.9795	0.9734
0.01	0.9819	0.9858	0.9885	0.9979	0.9971	0.9958	0.9945	0.9922
0.0097	0.9796	0.9834	0.9950	0.9922	0.9967	0.9944	0.9908	0.9805
0.001	0.9700	0.9770	0.9809	0.9939	0.9910	0.9919	0.9747	0.9730
0.00001	0.9677	0.9753	0.9722	0.9895	0.9711	0.9634	0.9559	0.9464

At first we have taken some RGB images and converted them into gray scale image. By adding 0.09dB AWGN (Additive white Gaussian noise) with gray scale image, we have transformed them into noisy image. Then we have de-noised them by using LMS algorithm against different step size (µ). After that we have cross-correlated the gray scale images with the de-noised image and found different cross-correlation coefficients for different step sizes (µ). If the step size is 0.01, then we get the de-noised image which is 99.39% similar with the original gray scale image. If we take any value of step size that is larger than 0.01, then we get a smaller cross-correlation coefficient. We know that smaller step size is better for the recovery of image. But in this research, we have seen that if we take step size (µ) smaller than 0.01, then the value of cross-correlation coefficient becomes smaller than that of when µ =0.01 (Table-I). So, µ=0.01 the optimal step size in LMS algorithm for the recovery of image.

Chapter-4

CONCLUSION

4.1 Conclusion

In this project work we removed AWGN noise from a noise image and compared the de-noised image with the original one. The optimum step size of LMS algorithm is determined to get the maximum similarly between two images (original and recovered). The project work is applicable in image communication through a AWGN wireless channel.

4.2 Future Work Scope

Still we have scope to use other adaptive algorithms: RLS, FDAE and Kalman filter. Similar job will be done in future using speech signals.

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