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Performance Analysis Of Wavelet Transform Based Image Denoising For Real Time Communication System

V.Lavanya & M Laxmi Prasanna Rani
[1]Dept.of ECE, MVGR College of Engineering, Vizianagaram, Andhra Pradesh, India, lavanyavadda@gmail.com
[2]Dept.of ECE, MVGR College of Engineering, Vizianagaram, Andhra Pradesh, India, prassugowtham@gmail.com

Abstract:

One of the most important advantages of the digital transmission systems for voice, data, and video communications is that they are highly reliable. But the major obstacle to higher reliability and high data transmission rate is noisy channel. By this noise, the quality of the images can be reduced and diagnosis becomes critical in case of medical images. In this paper, different test and medical images are transmitted through an channel and the noisy images are denoised by using different wavelet transform techniques (Haar, Daubechies, Coiflet, Symmlet, bi-orthogonal). From the results it is found that the bi-orthogonal wavelet transform technique performs better in terms of the performance metrics like PSNR, MSE and SSIM compared to other wavelet transforms.

Keywords: Wavelet, Image Denoising, PSNR, MSE and SSIM.

Introduction

Now a day's digital images play a vital role in day today life and also in different areas of research and technology. Noise is unwanted information that interferes with the original image and it degrades its visual quality. There are different sources of noise in digital images such as imperfect instruments, data acquisition process, interference, transmission and compression. The images can be distorted when they are acquired or transmitted through a channel. By this, noise is introduced and the quality of the images can be reduced. So it is necessary to reduce this noise to get error free images for better analysis without reducing the essence of the image. Image denoising is removal of noise from digital image to maintain visual quality. In case of medical Images, denoising is a crucial step for accurate diagnosis of critical diseases.

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Thus, it is necessary to design some effective techniques for denoising of digital images. There are conventional techniques of spatial domain and transform techniques like frequency and wavelet domain are used for denoising of images. The spatial domain techniques used to reduce noise in an image are filtering like median filters, mean filters and etc. The transform techniques of image denoising are DFT, DCT, DWT and etc. The techniques of image denoising have been developed after a lot of research and mainly based on thresholding Discrete Wavelet Transform (DWT) coefficients of the image [1]. For denoising of high noise density images, image preprocessing toolkit has to be applied to these images so that essence of the image is retained.

In this paper different digital images are transmitted through channel. The received image is a noisy image which consists of Gaussian noise. This noisy image is denoised using different wavelet transforms with non adaptive universal threshold method. This paper is organized as follows: section II about communication system model to transmit and receive image. Section III about the process of denoising this received image from a communication system, section IV about results and discussion.

II. Communication system model:

The communication system model considering channel is shown below. Different images are considered and these images are transmitted through the channel. For this image is converted into data and then the data is grey coded and it is modulated using different modulation techniques. Here QPSK modulation technique is considered. As the image is transmitted through channel, Gaussian noise is added to it. Gaussian noise is uniformly distributed over the image. Each pixel of image noise is the sum value of true pixel and a value of Gaussian noise randomly distributed. The probability density function [PDF] of the Gaussian noise follows normal distribution and is known as the Gaussian distribution.

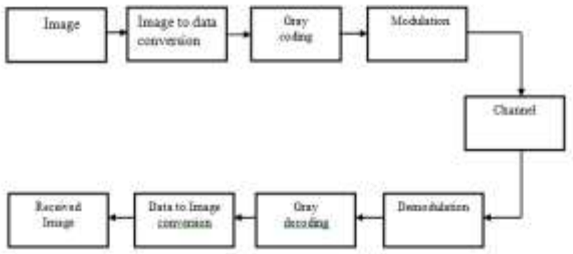

Fig.1. Communication system model

Channel is clearly more favourable than the Rayleigh fading channel since there is a large performance degradation experienced in the Rayleigh channel. Still channel introduces some noise to the data or image transmitted through it. Noise modeling depends on several factors such as data collection instruments, transmission media, and Image quantification discrete radiation sources. Depending on the noise model, different algorithms can be used. Various noises have their own characteristics and are inherent in the images of different ways. At the receiver side demodulation, decoding and data to image reconversion takes place.

III. Process of denoising the received image from a communication system

The received noisy image is denoised by implementing different wavelet transforms. The block diagram for process of denoising the received noisy image using wavelet transform is as follows.

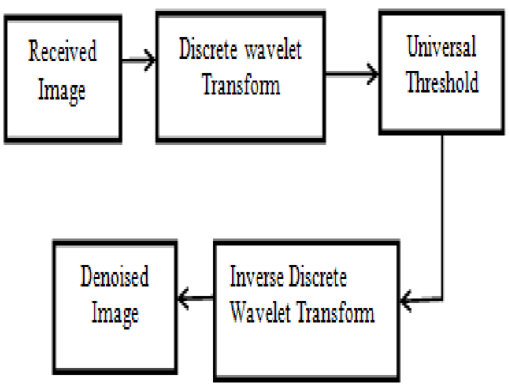

Fig 2: Block diagram of Image Denoising using universal thresholding.

Wavelet Transform (WT):

The wavelet transform is a powerful tool to de-noise an image. The wavelet transform of a noisy image is a combination of the wavelet transform of the image and noise and this noise is spread among all the wavelet coefficients. The aim of noise reduction is to approximate the original image by reducing the value of Mean Square Error (MSE).The wavelet transform basis functions are compact in time compared to Fourier sine and cosine functions. So the wavelet transform provides time information about a signal in addition to frequency information.

Using DWT the image is decomposed into 4 sub bands; HH, HL, LH, and LL [3]. The diagonal coefficients of the image are given by the sub band HH, the horizontal details are given by sub band HL and the vertical coefficients are given by the sub band LH. The LL sub band is the approximation coefficients of low frequency components and this sub band is further divided into different sub bands in higher levels of decomposition.

There are an infinite number of possible wavelets, out of these common ones are the Haar wavelet (Daubechies order 2 wavelet), the Daubechies order 8 wavelet, the Coiflet order 5 wavelet, and the Symmlet order 8 wavelet and biorthogonal wavelets of order 3.5 and 3.7. The smoothness of the wavelet is indicated by the order of the wavelet. As the order of the wavelet increases it provides better smoothness but it also means less compactness in time. The selection of type and order of the wavelet depends on the dominant features of the image.

Wavelet Thresholding:

Thresholding technique for image denoising has been proposed in the wavelet domain by Donoho and Johnstone [6, 7]. Image denoising using wavelet threshold is based on the comparison of transform domain coefficients with threshold value. Wavelet coefficients of the image have strong correlation at the corresponding positions, while the coefficients of the noise are weak. In the fixed threshold denoising method, it will not change with the wavelet coefficients, which leads the inevitably error on the part of the wavelet coefficients. When the threshold is properly selected, most error coefficients will appear in the neighborhood of threshold. There will be less error wavelet coefficients in the adjacent region of the threshold. So the selection of threshold becomes crucial to get denoised image. The thresholding techniques are of two types i.e., soft thresholding and hard thresholding with different thresholding of non-adaptive and adaptive.

The hard and soft thresholding functions are shown in figure. 3.

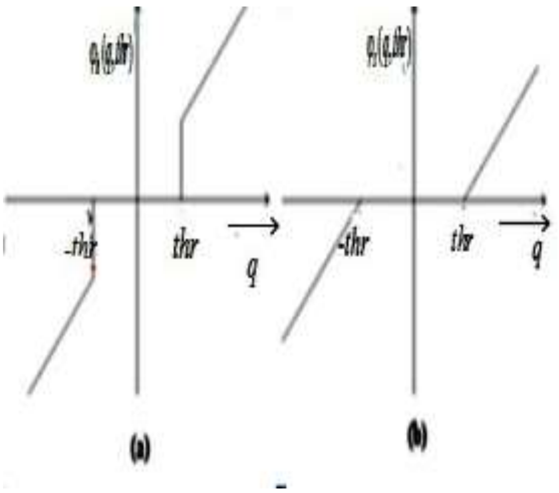

Fig 3: (a) Hard thresholding function. (b) Soft thresholding functions

Image Denoising Using Non adaptive Universal Thresholding

For image denoising, using the technique of non-adaptive thresholding, the selection of a particular threshold is the important. The reconstructed image will remain noisy, if the value of threshold is too less. On the other hand, details of image will distort, if the threshold value is too large. So the selection of threshold value is important to get accurate results.

The steps involved in the method of universal threshold [1] for image denoising are explained below.

1. Discrete Wavelet Transform is applied to the received image from a communication system which is passing through channel and get the approximation, vertical, horizontal and diagonal coefficients by process of Wavelet Decomposition.
2. Universal threshold is applied to all detail coefficients of horizontal, vertical and diagonal coefficients, where universal threshold is

   $$universal\ threshold\ th = \sigma\sqrt{2logN}$$

   Where $\sigma = \frac{median(|x|)}{0.6745}$

   Where N is the number of pixels in an image; σ is standard deviation of noisy image and x is the detail coefficients of an image.
3. Apply the Inverse Discrete Wavelet Transform to the all the threshold coefficients and get an denoised image.

In the wavelet domain only few coefficients contain the energy of an image and all the coefficients have the noise energy. This is the fundamental idea of the wavelet thresholding. Therefore, non-linear wavelet soft thresholding is used to reduce the noise coefficients to zero and get larger coefficients representing the image.

IV. Performance Metrics:

The performance of denoising of image non adaptive universal threshold technique can be obtained by calculating PSNR (Peak Signal to Noise Ratio), MSE (Mean Squared Error) and SSIM (Structural Similarity Index Measurement.

MSE is another parameter that measures the excellence of the image by estimating the difference between original and reconstructed images [7].

$$MSE = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}((p(x,y)-s(x,y))^2) \tag{1}$$

Where *p(x,y)*, *s(x,y)*are original and reconstructed images with size of *MXN.*

The excellence of the image can be determined by the value of PSNR. High PSNR value resembles that the reconstructed image quality is high and low PSNR value gives that reconstructed image quality is low.

$$PSNR = 10\log_{10}\left(\frac{I^2_{max}}{MSE}\right) \quad (2)$$

Where I_{max} is the maximum possible pixel values of the image.

SSIM considers image degradation as perceived change in structural information, while the luminance masking and contrast masking terms are also considered. Structural information gives strong inter-dependencies of pixels when they are spatially close. These dependencies give important information about the structure of the objects in the visual scene. The phenomenon of image distortions tend to be less visible in bright regions is called Luminance masking, while contrast masking is a phenomenon where there is significant activity or "texture" in the image, distortions become less visible.

The Structural Similarity (SSIM) Index quality assessment index is based on the computation of three terms, namely the luminance term, the contrast term and the structural term. The overall index is a multiplicative combination of the three terms.

$$SSIM(x,y) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[s(x.y)]^{\gamma} \quad (3)$$

Where

$$l(x,y) = \frac{2\mu_x\mu_y + C_1}{\mu_x{}^2 + \mu_y{}^2 + C_1}$$

$$c(x,y) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x{}^2 + \sigma_y{}^2 + C_2}$$

$$s(x,y) = \frac{\sigma_{xy} + C_3}{\sigma_x\,\sigma_y + C_3}$$

Where μ_x, μ_y, σ_x,σ_y, and σ_{xy} are the local means, standard deviations, and cross-covariance for images *x*, *y*. If $\alpha = \beta = \gamma = 1$ (the default for Exponents), and $C_3 = C_2/2$ (default selection of C_3) the index simplifies to:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

IV. Results and discussions:

This paper presents non adaptive universal thresholding technique of different wavelet transforms. The thresholding is applied to the medical images like MRI of brain, X-ray images and a test image of lena and cameraman processed through a channel. This technique is implemented with the wavelets of the Haar, Daubechies order 8 wavelet, the Coiflet order 5, Symmlet order 8 and biorthogonal wavelets of order 3.5 and 3.7. Performance of this thresholding technique with wavelet

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transforms is evaluated using the parameters of Peak Signal to Noise Ratio (PSNR), Mean Squared Error (MSE) and SSIM. The following are Original, noisy and denoised images of MRI of brain, ultrasound image, lena and cameraman.

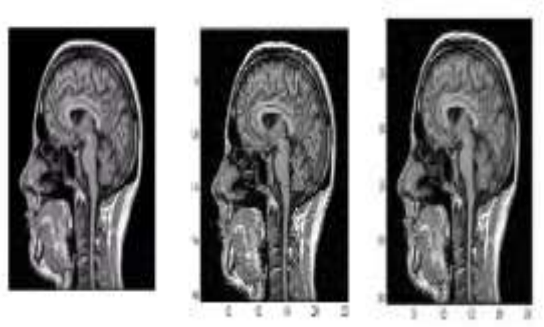

Fig 4: original, noisy, denoised of MRI of brain image

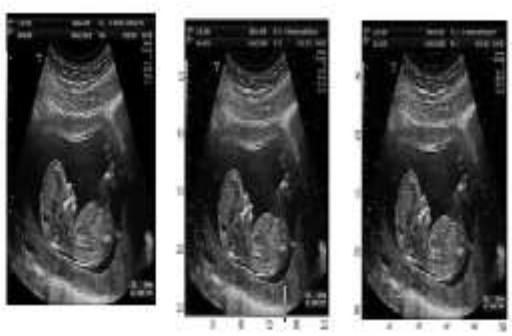

Fig 5: original, noisy, denoised of ultra sound image

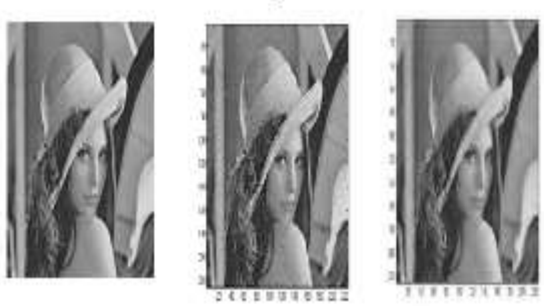

Fig 6: original, noisy, denoised of lena image

Fig 7: original, noisy, denoised of cameraman image

The performance metrics of above images using different wavelet transform techniques are tabulated as follows

Table1. MSE, PSNR and SSIM of MRI IMAGE using different wavelet transforms

Wavelet	MSE	PSNR	SSIM
dB1(haar)	37.6281	32.3757	0.8414
Db8	20.2193	35.0731	0.9327
Boir 3.5	2.2130	44.6809	0.9922
Boir 3.7	0.0347	62.7277	0.9999
symlet	0.8820	48.6761	0.9955
Coif5	0.5491	50.7343	0.9970

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Table 2 MSE, PSNR and SSIM of Ultrasound Image using different wavelet transforms.

Wavelet	MSE	PSNR	SSIM
dB1(haar)	37.6281	32.3757	0.8414
Db8	20.2193	35.0731	0.9327
Boir 3.5	1.9901	45.1420	0.9892
Boir 3.7	0.0414	61.9563	0.9998
symlet	1.0759	47.8131	0.9932
Coif5	0.6669	49.8901	0.9956

Table 3: MSE, PSNR and SSIM of Test image (Lena) using different wavelet transforms.

Wavelet	MSE	PSNR	SSIM
dB1(haar)	34.0559	32.8089	0.8029
Db8	25.7980	34.0150	0.8737
Boir 3.5	6.8166	39.7951	0.9681
Boir 3.7	0.3879	52.2435	0.9976
symlet	3.0620	43.2707	0.9820
coif	1.3900	46.7006	0.9913

Table 4: MSE, PSNR and SSIM of Test image(Cameraman) using different wavelet transforms.

Wavelet	MSE	PSNR	SSIM
dB1(haar)	18.1223	35.5487	0.8829
Db8	15.6461	36.1868	0.9024
Boir 3.5	2.6067	43.9699	0.9819
Boir 3.7	0.0675	59.8404	0.9994
symlet	0.9217	48.4848	0.9920
coif	0.5332	50.8615	0.9952

Conclusions:

This paper progressed with non adaptive universal thresholding technique of different wavelet transforms of Haar, Daubechies order 8, Coiflet order 5, Symmlet order 8 and biorthogonal wavelets of order 3.5 and 3.7. The values of PSNR , MSE and SSIM are compared for different images with different wavelet transforms. From these results biorthogonal wavelet exhibits better less MSE, more PSNR and better SSIM values for medical images compared to test images which in turn reconstructs the original image without reducing the image quality. From the testing outcomes, it could be concluded that the this technique is successful and capable than prevailing strategies in phrases of PSNR, MSE and SSIM with biorthogonal wavelet tranform.

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