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Image Denoising using DWT Hybrid Thresholding and Intensity Transform

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ABSTRACT

Digital images have been a major form of transmission of visual information, but due to the presence of noise, the image gets corrupted. Thus, processing of the received image needs to be done before being used in an application. Denoising of image involves data manipulation in order to produce a good quality image. This paper introduces a new technique that is formed by hybridizing the thresholding techniques of the image decomposed using discrete wavelet transform along with the transformation of intensity to obtain a noise free, high quality denoised image. The hybridization of the Bayes and the Neigh Shrink is done to obtain the threshold that provides improved results after the denoising in comparison to when these techniques are used separately. This approach finds its application in denoising of images that are distorted with random Gaussian noise. Quantitative measures have been used to show the improvement in the quality of the restored image by the use of the proposed technique in comparison with the conventional thresholding techniques by the use of parameters mainly, PSNR, MSE and SSIM. The decomposition of the image using the discrete wavelet transform is done iteratively to obtain the best possible results. The most appropriate combination of wavelets is considered for decomposition and reconstruction of the images along with the hybridized thresholding.

Key Words: Image denoising, DWT, Thresholding

INTRODUCTION

Image processing requires the denoising of image as one of its most vital part. As the data we deal with consists of noise. Many great studies have been done in this field. The newest one being the wavelet transform which can be applied for digital signal and image processing for denoising and compression of data. Image restoration plays a very important role in the digital image processing. Restoration of image is reduction or removal of the distortions produced when the image is being obtained. Distortions in an image exist due to noise as well as blurring [1]. A distortion in an image due to noise is produced when the image is transmitted over a noisy channel, certain errors occur in the process. Hence, the image somehow degraded needs to be upgraded to a certain level before being printed.

In case of removal of noise, the success of the wavelet theory based techniques are used which have an ability to obtain a de-correlated image (noise and useful information signal being separated). Each technique for denoising of image, based on wavelet initially follows the classical technique which has 3 steps: Computation of discrete wavelet transform, the filtration of wavelet domain and computing the related inverse wavelet transform.

The concept of denoising of images is applicable to the areas of astronomy where severe limitations in resolution exist, in forensic sciences where the photographic evidence may be in extremely bad condition and in medical imaging where high quality imaging is required for analyzing images that are extracted using rays that penetrate human body leading to degraded low quality image.

The basic concept behind this study is to obtain an estimate uncorrupted image from a degraded low quality noisy image and this is often referred to as “Image Denoising”. Various techniques are available for this purpose but selection of an appropriate technique plays an important role in extraction of the desired cleaned image. Thresholding techniques [2][3] have been used for this purpose but their does not exist any generalized method for denoising of images. A highly efficient cleaned image could be obtained by enhancing or modifying these pre-existing denosing techniques.

PREVIOUS WORK

Thresholding of sub-bands is a popular approach for removal of noise because of simplicity. This technique operates over an orthogonal wavelet domain, in which each of the coefficient is thresholded by making a comparison with a threshold; in case the coefficient is smaller as compared to the threshold then it is set to zero, or else it is kept or is modified. The theory of thresholding was mainly developed by Donoho and Johnstone[4][5]. They defined two rules for thresholding known as the hard- thresholding (“keep or kill”) and the soft- thresholding (“shrink or kill”). The soft thresholding is used as the base for the proposed technique that uses two types of shrinkage techniques, namely Bayes Shrink and Neigh Shrink.

BAYES SHRINK

With the use of this technique different threshold levels for each of the sub-bands are decided and the data is shrinked down in accordance with these threshold levels. When a degenerated image is considered corrupted with additive noise which may be expressed in the form

$$Y = X + V \qquad (1)$$

Y used here is wavelet transform of the noisy image, X being the original image’s wavelet transform and V is the noise component’s wavelet transform. On considering that the components of noise follow Gaussian distribution N (0, $\sigma_v^{\ 2}$). As X and V are mutually independent, σ_x^2, $\sigma_y^2$and σ_v^2 of X, Y, V are their variances, and their relation with each other can be given in the form

$$\sigma_y^2 = \sigma_x^2 + \sigma_v^2 \qquad (2)$$

Bayes shrinkage technique does soft thresholding, that is adaptive data driven, to obtain sub-band as well as level dependent near optimal threshold given as

$$T_{BS} = \sigma_v^2 / \sigma_x \quad \text{if } \sigma_y^2 > \sigma_v^2 \qquad (3)$$
$$\max\{|A_M|\} \quad \text{otherwise}$$

A_M represents the wavelet coefficients of sub-band that are being considered and the total number of wavelet coefficients in that sub-band is M.

NEIGH SHRINK

This shrinkage technique includes the use of neighboring coefficients. The threshold based upon this technique is obtained in accordance with the magnitude of squared sum of all its wavelet coefficients, which posses localized energy of the neighborhood window.

The window sizes used for the neighborhood window could vary being 3X3, 5X5, 7X7, 9X9, etc. amongst them 3X3 serves the best [6]. The shrinkage function using Neigh thresholding of arbitrary window with size 3X3 having center (i,j) is

$$T_{ij} = (1- (T_{ij}^2 / S_{ij}^2)) \qquad (4)$$

T here is the threshold value calculated using universal shrinkage technique but since this does not provide an optimal output, Sure shrinkage technique could be used and S_{ij}^2 being the squared sum of all its wavelet coefficients corresponding to the selected window.

PROPOSED TECHNIQUE

This paper is aimed to produce more efficient removal of the Gaussian noise from the image through the use of a combination of the Bayes Shrink and the Neigh Sure[7]. Neigh sure is preferred over the simple Neigh shrink[8][9] as the threshold used in it were universal and did not produce an optimal threshold and instead lead to the over smoothening of the signal. The Neigh Sure considers the Sure shrink threshold to determine the shrinkage factor. The combination of these two is expected to produce improved results mainly in terms of Peak signal to noise ratio, Mean square error and Structural similarity index metric.

In addition to the above said combination [10] a Gaussian filter edge detector has been added to preserve the edge details of the image and obtain an image that provides an improvement in intensity of clarity of the image. Moreover, it is expected to reduce the mean square error significantly.

Along with the combination of the thresholding[11],[12], a combination of wavelet transform has been used obtained iteratively from the study in order to obtain which wavelet and thresholding technique combination serves the best to provide an image with the more efficient results. Thus these combinations have been worked upon to obtain a generalized technique for denoising of the corrupted image.

ALGORITHM:

Input: The noisy image corrupted with the Gaussian noise.
Output: Denoised estimate of the original image.

The steps followed by the proposed technique are:

1. 2 Dimensional Discrete wavelet transform of the noisy input image is done for decomposition of the image into 4 sub-bands, namely, LL, LH, HL, HH using different wavelets iteratively. Namely, Haar, Duabechies, Symlets and Coiflets.
2. Thresholding is performed only on the detail coefficients of sub-bands at each level. Thus, the thresholding is performed in the HH, HL,LH sub-bands using
   a) Bayes Shrink
   b) Neigh Sure
3. Steps 1 and 2 are repeated till the pre-defined level of decomposition.
4. Reconstruct the denoised estimate images by using the inverse wavelet transform.
5. Combine the image estimates obtained for hybrid formation.
6. Apply the intensity transform (Gaussian filtering) for preservation of the details of the image that improves its intensity.

As seen from the figure 3 the natural image is initially converted to a noisy image that is decomposed using the discrete wavelet transform which yields 4 sub-bands, namely, LL, LH, HL, HH. Since high frequency signal gets corrupted, the thresholding is applied to each of the detail sub-band separately which leaves LL sub-band that is further decomposed up to 2 more levels in this case.

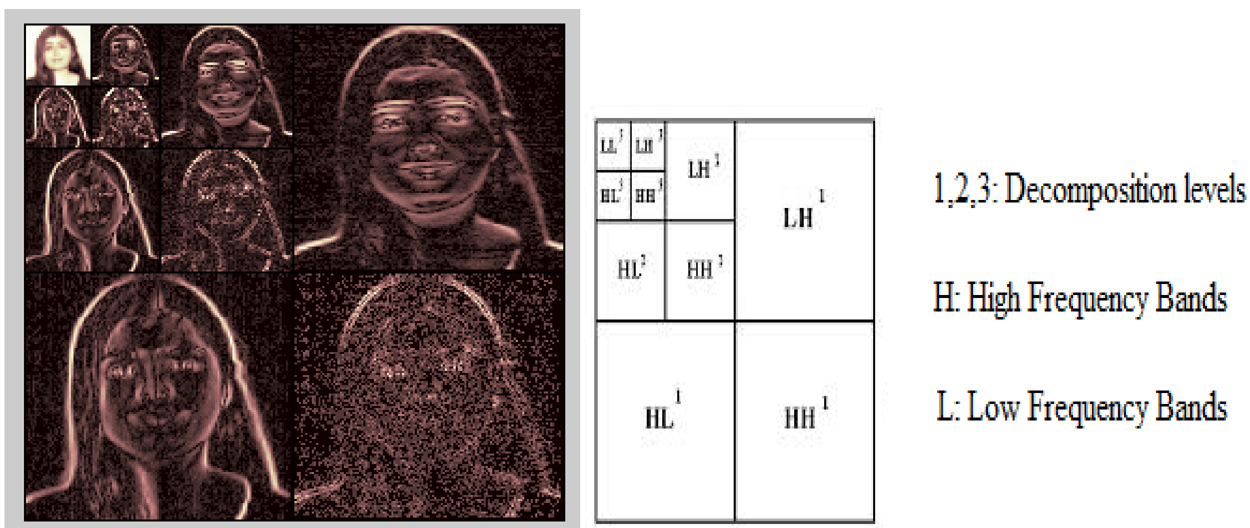

Fig 1: 3 level decomposition of (a) image of a girl (b) coefficients

Thus, forming ten sub-bands in total with three levels of decomposition out of which the thresholding is done of the nine subbands. The process of 3-level decomposition is shown in the figure 1.

The thresholding using Neigh and Bayes shrink are performed separately. The thresholded signals are reconstructed using their respective wavelet transforms which are then combined together to obtain the hybrid thresholded image. The combination of wavelets and thresholding technique is done iteratively in a manner to obtain optimum results.

1.

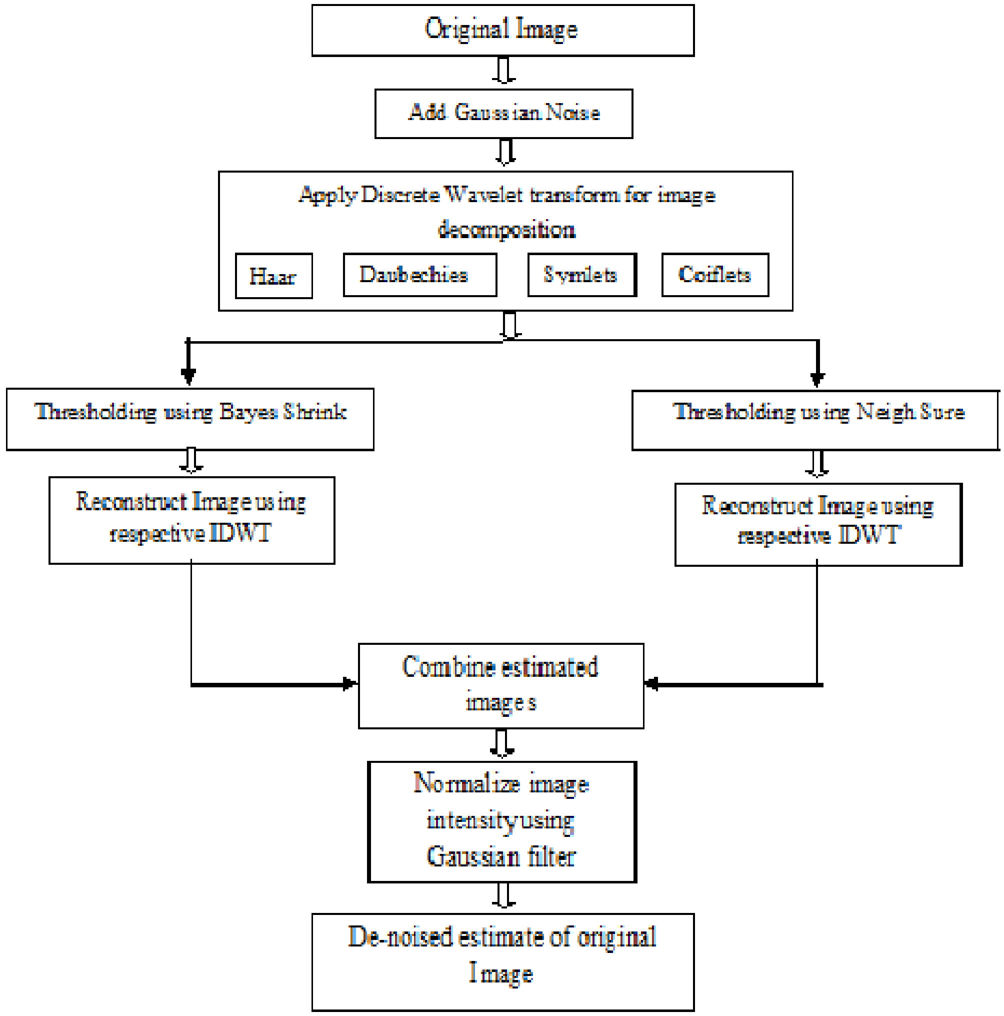

Fig 2: Flow chart of the proposed technique

This estimated image is then passed through a Gaussian low pass filter that will remove any high pass component present in the signal to normalize the intensity of the image for more efficient denoising of image.

The results obtained are compared with the noisy image parameters along with Bayes shrink and Neigh sure separately in order to prove the significance of the proposed technique in denoising of image.

RESULTS

Using matlab, the results are obtained on considering different images and by using different denoising techniques. The results when the denoising process is applied onto the images is shown in the figure (4,5,6) along with a table (1) showing the evaluated quality assessment metrics of which displays PSNR and SSIM whose values should get hiked and also displays SD and MSE whose values should be reduced.

The performance of the proposed technique has been evaluated with the help of the following quality metrics.

1. Mean Square Error (MSE)

It is an estimator that measures the average squares of the errors. The error being the difference between the denoised and the noisy image which is given by:

$$\text{Error} = (x(i,j) - n(i,j)) \qquad (5)$$

Here x(i,j) is the denoised image and n(i,j) is the noisy image. Thus, the mean square error can be expressed as

$$\text{MSE} = \sum_{ij} \frac{\text{error}^2}{M \times N} \quad \text{where i,j= 1,2…. M} \qquad (6)$$

Both the images should be of the same order, represented as MxN matrices. An MSE of zero means that the denoised image obtained is perfect in accuracy same as the original image. This is the ideal situation which is not practically possible.

2. Peak Signal to Noise Ratio (PSNR)

It is the ratio between the maximum signal power to the power of the corrupting noise. The PSNR of an image is given by:

$$\text{PSNR} = 10 \log_{10}({}^{\text{Max}_I^2}/_{\text{MSE}}) \qquad (7)$$

Where, Max_I is the maximum possible pixel value of the image. When the pixels are represented by using 8 bits per sample, which is 255.

3. Standard Deviation

It is the measure of the amount of variation or dispersion from the average. A low value of standard deviation shows that the data points tend to be very close to the mean also called the expected value while a high value of standard deviation shows that the data points are spread out over a large range of values.

4. Structural Similarity Index Metric

The Structural Similarity (SSIM) index is a method used for measurement of the similarity between two images. The SSIM index is a measure of quality of one image being compared to a reference original image of perfect quality. The SSIM can be expressed as:

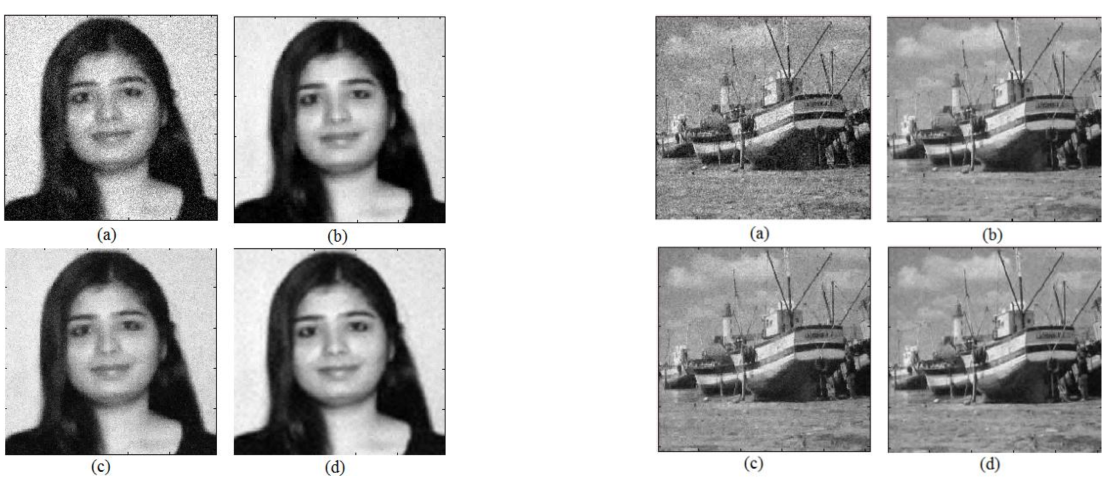

Fig 3: Girl and Boat: (a) Noisy Image (b) Bayes (c) Neigh (d) Proposed technique

Table 1: Observation table

	PSNR	SSIM	SD	MSE
Girl				
Noise value	20.721	0.5044	87.095	550.765
Bayes Shrink	27.032	0.8386	83.901	128.781
Neigh Sure	27.357	0.7786	83.305	119.488
Proposed	33.407	0.9092	83.874	29.679
Boat				
Noise value	20.104	0.6536	52.509	634.838
Bayes Shrink	24.361	0.7947	44.912	238.189
Neigh Sure	25.389	0.7963	45.588	188.003
Proposed	27.699	0.8475	44.603	110.431
House				
Noise value	20.068	0.4959	52.375	640.151
Bayes Shrink	26.289	0.7741	45.505	152.811
Neigh Sure	26.828	0.7396	46.344	134.978
Proposed	31.726	0.8407	45.487	43.698

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)} \qquad (8)$$

Where x and y are two signals with μ being their respective mean and σ being their respective standard deviation and C_1 and C_2 are the constants.

The software used for the simulation of the proposed technique is MATLAB.

It is observed the proposed technique produces the maximum improvement in the quality to image in terms of PSNR and SSIM when compared to the other techniques. However when standard deviation and mean square error are considered, although the result is optimum for the proposed technique but the value of the standard deviation is not minimum for the proposed technique but the difference between the lowest SD and the SD of the proposed technique is very minute.

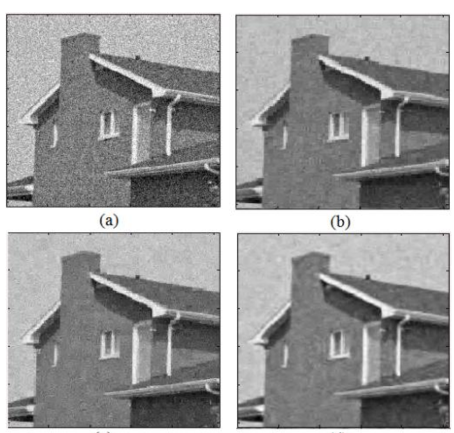

Fig 4: House : (a) Noisy Image (b) Bayes (c) Neigh (d) Proposed technique

Hence it can be said that the proposed technique is the most superior technique amongst the other studied techniques for the removal of noise from a corrupted image.

CONCLUSION AND FUTURE SCOPE

The experimental results lead to a conclusion that for removal of random Gaussian noise from a corrupted image there existed a need for a generalized technique that would result in an improvement in quality of denoised image. When different wavelets are iteratively considered for decomposition and reconstruction of the image while denoising, it is found that the coiflet 4 has the best output when Bayes shrink is used. When neigh shrink is used the symlet 5 serves to be the best wavelet for efficient output. When these combinations are used for hybridizing the thresholding techniques it yields the most significant improved output. The application of intensity transform mainly leads to a reduction in the mean square error to a great extent with some improvement in all other parameters. Since, the proposed technique yields the optimal result for all the considered images producing an almost perfectly cleaned image that is observed with the help of the assessment metrics, it can be said to be a generalized technique producing the most efficient and significantly improved denoised image.

As the field of denoising is very vast, the new techniques always need to be searched for. This could be done by using the multiwavelet functions instead of the wavelets and also amalgamation with the other techniques.

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