Utilizing Wavelet Transform to Image De-Noising

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Abstract

Image de-noising and restoration represent basic problems in image processing with many different applications including engineering, reconstruction of missing data during their transmission and enhancement ..etc**.** this work is aimed at developing effective algorithm for denoising image using new strategy algorithm of wavelet techniques ,by applying two dimensions wavelet transform using Daubechies wavelet over the image and reordering all coefficient of 4 subimages in one row vector C (in each decomposition level) and thresholded this vector where the threshold value equal to STD of vector C. The Proposed method is verified for different data where applied for processing of various images ,different levels and different noises. The analysis results have indicated that the performance of suggested method is a good thresholdding strategy ,where the constructed images are good quality and less distorted. The Matlab programming environment has been used to realize the algorithms and to obtain the presented results.

الخلاصة:

إزالة الضوضاء وترميم الصور يمثلان مسائل أساسية في معالجة الصور في العديد من التطبيقات المختلفة والتي تتضمن الهندسية منها ،استرجاع البيانات المفقودة أثناء إرسالها ، وتحسينها...الخ . يهدف هذا العمل إلى تطوير كفاءة خوارزمية إزالة الضوضاء باستخدام إستراتيجية جديدة في التحويل المويجي وذلك بتطبيق التحويل المويجي ثنائي الأبعاد (2D) باستخدام تحويل دوبشيز لكامل الصورة و إعادة ترتيب جميع معاملات التحويل (للحزم الأربعة) في المتجه C (في كل مستوى تحليل) ثم إجراء تعتيب للمتجه بدالة عتبة تساوي الانحراف المعياري(STD) للمتجه C. أثبتت فعالية الطريقة المقترحة لقيم مختلفة من البيانات حيث طبقت على صور متنوعة بمستويات تحليل مختلفة ولأنواع مختلفة من الضوضاء .النتائج المنجزة تشير إلى فعالية الطريقة المقترحة كإستراتيجية تعتيب جيدة. حيث امتازت الصور المعالجة بجودة عالية وبأقل تشوه. استخدمت بيئة ماتلاب في انجاز الخوارزمية والحصول على النتائج الحالية.

1- Introduction

The goal of image restoration is the improvement of the visual quality of degraded image data. This subject has received a great deal of attention since there are many application areas such as medical thermography, satellite imagery and military target screening ...etc. A variety of techniques has been proposed and developed for removal of noise. Wavelet analysis represents a general tool for decomposition and reconstruction of multi-dimensional signals for their analysis, resolution enhancement and further processing [Newland1994,Pt´aˇcek et al 2002,Rioul&Vetterli1991,Strang1989**,** Prochazka et al **]** and it is very powerful and extremely useful for compressing and denoising data such as images and a lot of work has been done in the area of wavelet based image denoising [Chang et al 2000,Chang et al,Chang et al,Guleryuz2002, Donoho1995, Vaseghi2000, less2002]

Where Information about signals resulting from a selected process can be based upon signal decomposition by a given set of wavelet functions into separate levels or scales resulting in the set of wavelet transform coefficients. These values can be used for signal compression, signal analysis, segmentation and in the case that these coefficients are not modified they allow the following perfect signal reconstruction. In the case that only selected levels of signal decomposition are used or wavelet transform coefficients are processed it is possible to extract signal components or to reject its undesirable parts.

Wavelet analysis can be used to divide the information of an image into approximation and detail subsignals. The approximation subsignal shows the general trend of pixel values, and three detail subsignals show the vertical, horizontal and diagonal details or changes in the image(as noise). If these details are very small then they can be set to zero without significantly changing the image. The value below which details are considered small enough to be set to zero is known as the threshold [Prochazka et al,Strang1989].

In this paper presents algorithm of image(signal) decomposition enabling the following image(signal) denoising into selected levels using global threshold.

2- Wavelet transform in image processing

the approach of the 2D implementation of the discrete wavelet transform (DWT) is to perform the one dimensional DWT in row direction and it is followed by a one dimensional DWT in column direction, the Coefficients of Wavelet transform can be evaluated using Mallat decomposition tree presented in Fig. 1 for the two dimensional case and the first level of decomposition. At first each column of the image matrix is convolved with the highpass half-band filter (*Wavelet function*) and the complementary low-pass half-band filter (*Scaling function*) followed by downsampling. Then the same process is applied to all rows of the image matrix. Each step of the image *decomposition* results in four image matrices with the number of rows and columns reduced to the half of that of the original matrix . this process is considered a *decomposition process* of processed image where as the reverse operation ,i.e. reproducing the original image ,is referred to as a *reconstructed process* [Witwit2001,Prochazka et al]

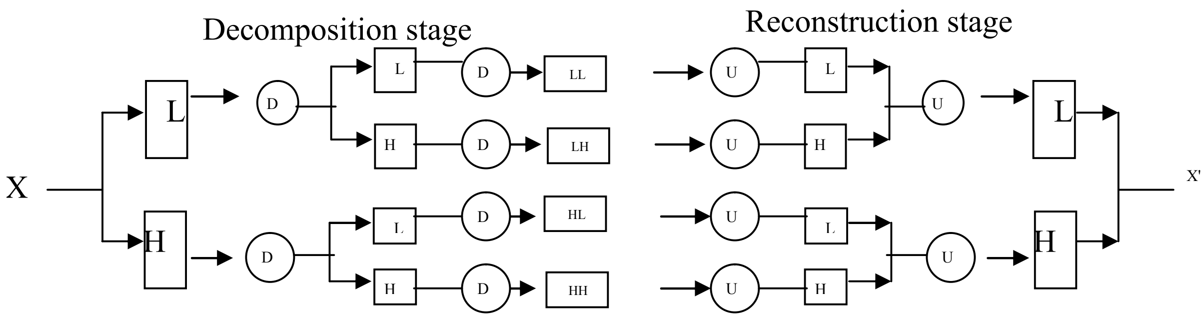


Figure 1: Image Wavelet decomposition tree using column and row two-dimensional signal decomposition with down sampling in each stage followed by image reconstruction, (for more details see [Prochazka et al,Witwit2001]).

Coefficients evaluated in image decomposition stage can be used for image analysis, feature extraction, image denoising, restoration or compression.

3. Image De-Noising

Using the threshold method introduced by [Donoho1995, Strang & Nguyen 1996] it is further possible to reject noise and to enlarge signal to noise ratio. The de-noising algorithm assumes that the signal contains low frequency components and it is corrupted by the additive Gaussian white noise with its power much lower than power of the analyzed signal. The whole method consists of the following steps:

- Signal decomposition using a chosen wavelet function up to the selected level and evaluation of wavelet transform coefficients
- The choice of threshold for decomposition level and modification of its coefficients
- Signal reconstruction from modified wavelet transform coefficients

Results of this process depend upon the proper choice of wavelet functions, selection of threshold and their use.[Patacek & Pprochazka]

4- Optimal Threshold

Chang et al [Chang et al2000,Chang et al, Chang et al 2] proposed a method of finding a near optimal threshold for image denoising and compressing that was adaptive to the image and each detail subband. The techniques used thresholding to filter additive Gaussian noise. It was explained that a threshold acts as an oracle which distinguishes between the insignificant coefficients likely due to noise, and the significant coefficients consisting of important signal structures'[Chang et al 2000]. These insignificant coefficients can be thought of as noise, or coefficients that can be removed during compression without significantly altering the energy of the image. It is interesting to note that thresholding can be used to simultaneously compress and denoise an image.Unlike Donoho and Johnstone, the thresholding strategy proposed by Chang et al was suited to images rather than 1D signals but the idea of filtering Gaussian noise was still used. In fact, the strategy used an observation that wavelet coefficients of any subband can be described by a generalised Gaussian distribution. and it's goal is to find the threshold that minimises the Bayesian risk [Chang et al 2000, Lees2002]. It was found that for each subband the near optimal threshold using soft thresholding was $T= \sigma^2/\sigma_f^2$ where σ^2 is the noise variance and σ_f^2 is the signal variance.σ^2 is the noise variance but this may be difficult to measure if there is no uncorrupted image or optimally compressed image to measure against.[Lees2002]
Thus ,the proposed method depend on the idea, The more energy that is contained within the approximation subband, and smaller amount of energy has to be retained by the detail coefficients, thresholding had an effect could change the energy retained and compression rates. Therefore when the investigation was carried out more attention was paid to choosing the wavelets, images and decomposition levels than the thresholding strategy. Using global thresholding is a perfectly valid solution to threshold ,because each detail subsignal had coefficients that it contained a little energy .Our assumption in this algorithm is that the transformation used to generate the wavelet transform coefficients mostly ensures that if vector **C** is hard-thresholded to zero with the threshold T equal to the STD of vectore C , then this procedure removes more noise than signal.

5- The Proposed Procedure:

The de-noising algorithm assumes that the signal contains low frequency components and it is corrupted by noise (additive Gaussian white noise or Poisson noise or salt and pepper noise) with its power much lower than power of the analyzed signal. The whole method consists of the following steps:

- Signal decomposition using a chosen wavelet function up to the selected level and evaluation of wavelet transform coefficients.

One step of the discrete Wavelet transform decomposition of an image provides coefficients that can be ordered in one row vector C containing column representation of 4 subimages in each decomposition level.

- calculate STD of vector C and sets as threshold for decomposition level and modification of its coefficients (set all the coefficients to zero except those whose magnitude is larger than STD of vector C).
- image reconstruction from modified wavelet transform coefficients by applying the corresponding inverse transform.
- Calculate PSNR values of different levels for corresponding reconstructed images
- The same process is repeated for various images and various noise.
- Display and compare the results

The PSNR (peak signal-to-noise ratio) and MSE (mean square error) have been chosen as a measure of similarity between two images together. The PSNR commonly used to measure the difference of two images has been evaluated by relation: [Witwit2001, Prochazka el al] $PSNR = 10 * \log_{10}(M / MSE)$ Where M is the largest value of the two dimensional signal , MSE is the mean square error of two images (original and restored) .

6- Experimental Results

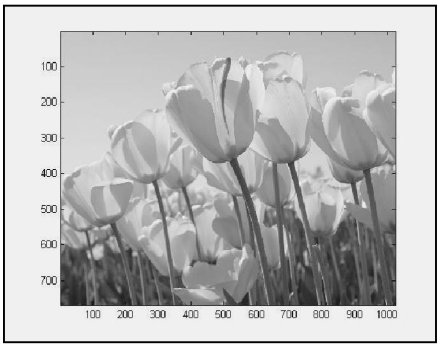
Different types of gray scale images (flowers, satellite and X-ray images) have been used to demonstrate the performance of proposed method**.** The Matlab programming environment has been used to realize the algorithms and to obtain the presented results. As the most efficient method of the image denoising the wavelet Daubechies of the 4th order has been used here for the decomposition into different levels. Coefficients in the wavelet domain have been modified by hard-thresholding before image reconst-ruction. The proposed algorithm has been applied to two types of images at different decomposition level using the Daubechies wavelet function of the 4th order. see figures (2) & (3) ,And repeated the same process for different types of noise and for various images. These results (original image ,noisy image ,and denoising) are presented in Figurs(4& 5)The quantitative measure values of adopting method (PSNR and MSE) has been listed in Tabel (1) &(2). The performance of proposed method has been illustrated in figures(2 and 3) for flowers and satellite image with different levels and in figure(4) for X-ray image with different noise and figure(5) for different images .

Table(1): Shows PSNR and MSE values using proposed method for different images (which degraded by Gaussian noise) at different levels.

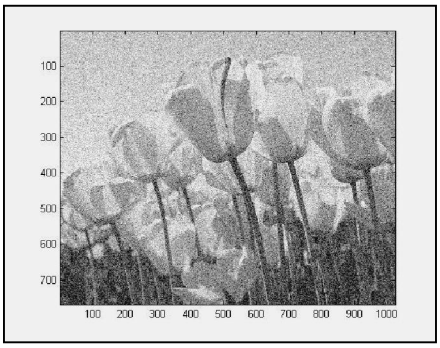
7	69.81	29.69
flowers image		
Level	**MSE**	**PSNR**
1	36.01	32.55
2	30.31	33.31
3	28.013	33.67
4	**26.914**	**33.83**
5	33.49	32.88
6	38.47	32.27
7	43.57	31.73
Satellite image		
1	68.15	29.79
2	42.82	31.81
3	38.90	32.23
4	**13.69**	**36.76**
5	15.29	36.28
6	16.38	35.98
7	20.85	34.93
X-ray image		
1	97.24	28.25
2	81.39	29.02
3	**45.04**	**31.59**
4	48.35	31.28
5	55.60	30.67
6	59.03	30.41

Table(2): Show PSNR and MSE values using proposed Method on medical image which degraded by different types of noise (at level -2).

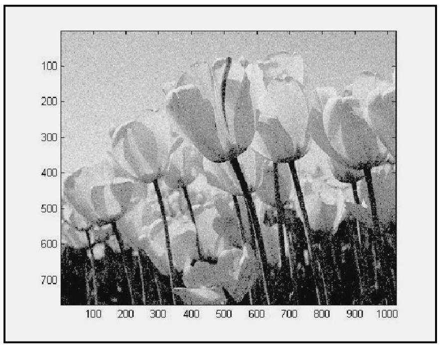
Medical image(X-ray) at Level-2 with different types of noise		
Type of noise	**MSE**	**PSNR**
Gaussian	**79.11**	**29.148**
Salt & pepper	**80.966**	**28.324**
Poisson	**79.18**	**29.144**



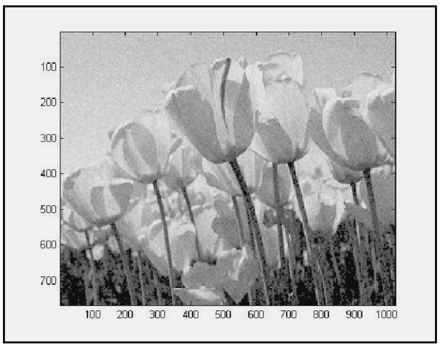
Original Image



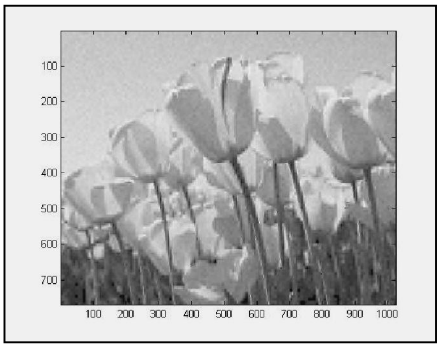
Noisy Image
(Gaussian noise)



Level-1
PSNR=32.55

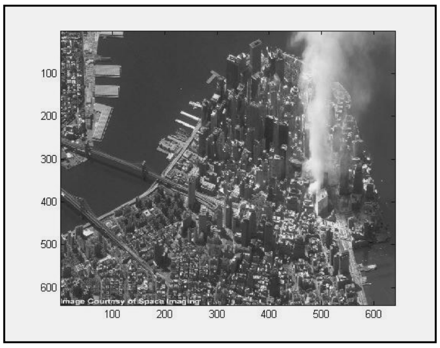


Level-2
PSNR=33.31

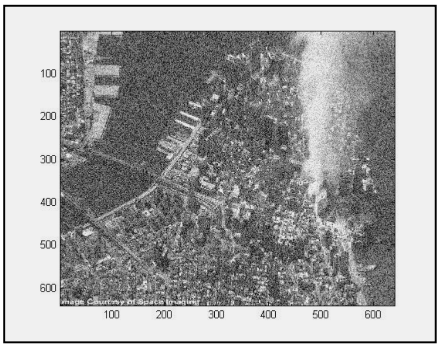


Level-3
PSNR=33.67

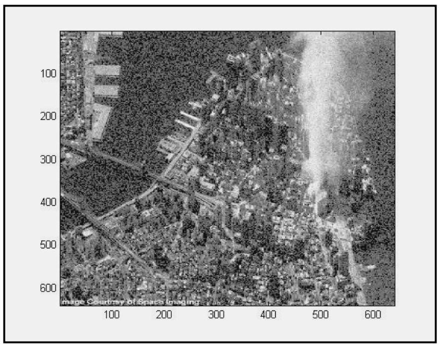
Figure (2): illustrate results of denoising flowers image at different levels using The modified Daubecheis Wavelet Transform .



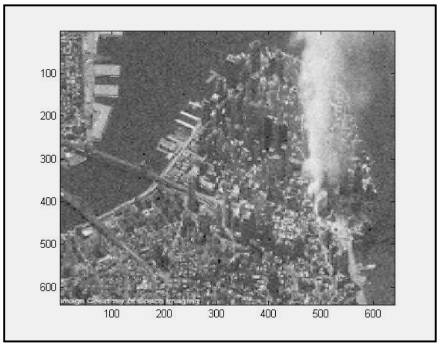
Original Image



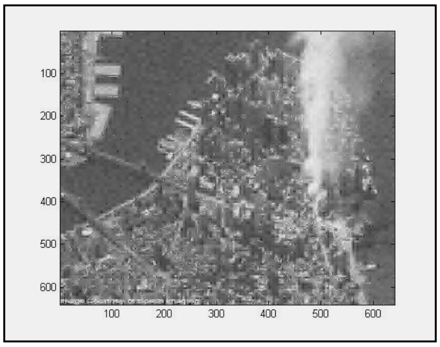
Noisy Image
(Gaussian noise)



Level-1
PSNR=29.79



Level-2
PSNR=31.81



Level-3
PSNR=32.23

Figure (3): illustrate results of denoising Satillite image at different levels using The modified Daubecheis Wavelet Transform .

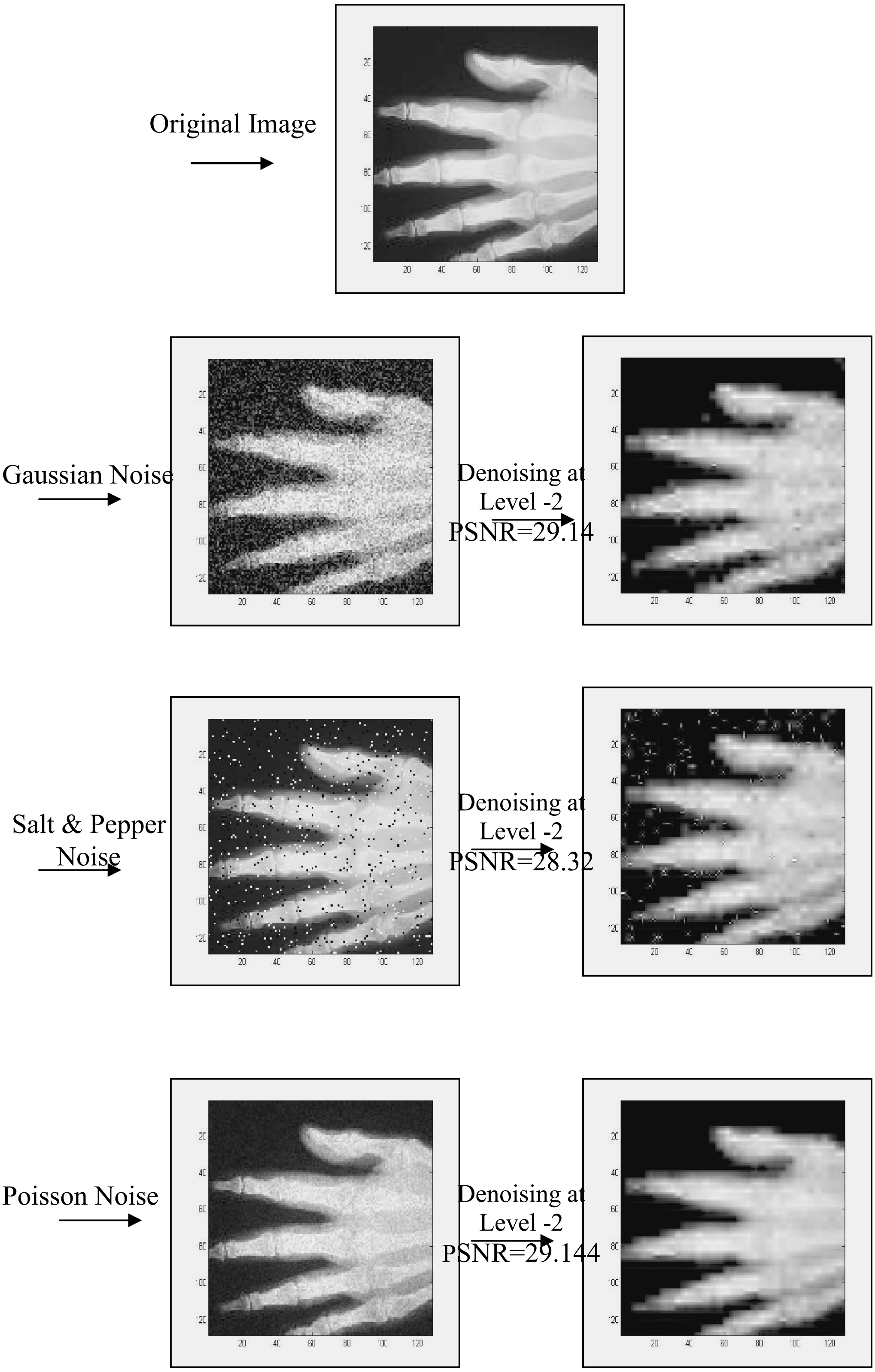
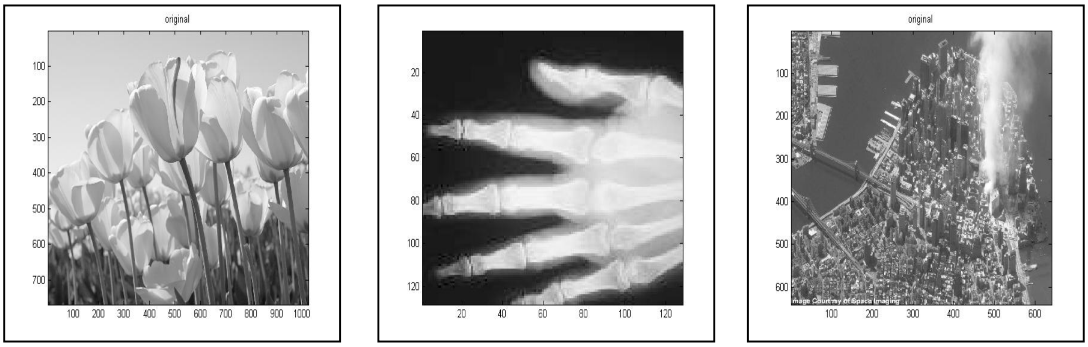
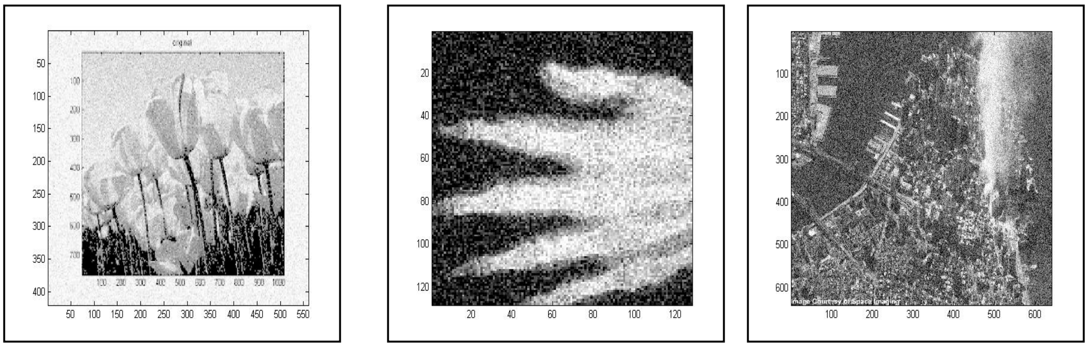


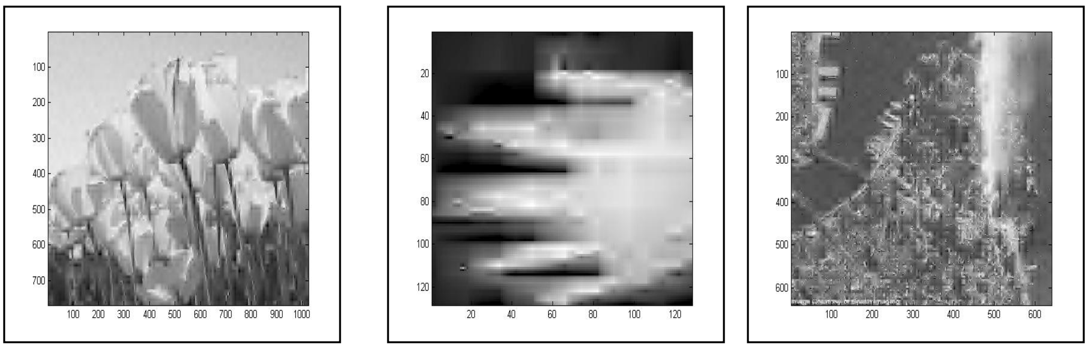
Figure (4): illustrate results of denoising X-ray image(at Level-2) degraded by different noise using The modified Daubecheis Wavelet Transform .



Original Image



Noisy Image
(Gaussian Noise)



PSNR=33.83 PSNR=31.28 PSNR=36.76

Restored Image at
Level -4

Figure(5): Applied proposed method on various image which had been degraded by Gaussian Noise (at level- 4)

7- Discussion and Conclusions

The obtained results from this work have been compared quatitatively, using set of the quantitative measures , and subjectively by demonstrating , visually , the output of each images.

1. The results calculated used global thresholding, These results set proved to be more useful in understanding the effects of decomposition levels, wavelets and images.
2. The different images will have different restoration quality (different PSNR and MSE), because the image itself has a dramatic effect on denoising, Where the changes between pixel values that determine the percentage of energy contained within the detail subsignals.
3. These results are substantially better for a satellite image than other utilized images ,where satellite image yielded higher PSNR values than others.
4. The results obtained concerning restored image quality as well as preservation of significant image details and remove noise .
5. We can conclude that the results which have been obtained from removeing Gaussian noise are better than those implementing on others types
6. The effects of number of decomposition was investigated by applying several values of level (1-7) as shown in table(1).
7. The experimental results for all utilized images shows that the four –level decomposition scheme is a good practical choice to attain a good quality of restored image, see table(1).
8. The PSNR values verify that the denoising images are better at relatively high levels than at low levels .
9. The wavelet divides the energy of an image into an approximation subsignal, and detail subsignals which containts noisy components. Wavelets that can compact the majority of energy into the approximation subsignal and a large number of coefficients contained within detailed subsignals can be safely set to zero, thus denoising the image.
10. Only one family of wavelets was used in the present work, the Daubechies wavelets. However there are many other wavelets that could be used such as Morlet , Meyer, and Coiflet.
11. There are many possible extensions to this project. These include finding the best thresholding strategy, finding the best wavelet for a given image, investigating other wavelet families.
12. Wavelets can be used for other signals such as audio signals.

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