Image Denoising With Wavelet Thresholding Method for Different Level of Decomposition

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Abstract- The search for an efficient techniques for denoising of images is a valid challenge in the field of image and signal processing. The most important requirement for an effective image denoising model is the complete removal of the noise along with the preservation of edges. Denoising of images is basically done to obtain an estimate of the original image by suppression of noises present in a noise-infected image. Noise in images is produced due to intrinsic and extrinsic conditions that are unavoidable in practical situations. A noise cleaned image is required for a wide range of applications like restoration of an images,the image registration & classification of that image, etc. The making denoising of images a very important aspect.
Here, a review on the use of wavelet thresholding techniques for denoising of the images distorted due to noise is presented. These techniques although, prevent the loss of image details but still leaving a scope for development for improvement of the quality of the recovered image. Denoising of images henceforth needs fundamental researches to be carried on for further enhancement of the quality of the noise cleaned image.
Keywords- Image denoising, Image restoration, DWT.

1.Introduction

The removal of noise from a signal is known as denoising. All recording devices, either analog or digital have characteristics which make them susceptible to the noise. The requirement for the effective method for restoration of images has increased with massive production of the digital images and all kinds of movie, often taken in the poor condition. Despite of however good the camera may be, It is always desirable to improve an image in order to extend their range of the action. The 2 major obstructions in the accuracy of an image are categorized as noise & blur. Blur is intrinsic (sensors) to the acquisition systems for images [1], as infinite number of samples exist in digital images and they must satisfy the Shannon's Nyquist sampling condition. The other kind of the image disruption is due to the presence of noise. Digital medical images are more prone to noises as these images are captured using measurement and recording techniques, such as magnetic resonance imaging, which involve the use of beam of rays like X-Ray, RF pulse and others to the pass through body which is opaque and leads to disruption of image detail. The noises that degrade the quality of an image are:

1.Salt & Pepper Noise (also known as Impulsive Noise) has scattered bright & dark disruptions and the pixels of an image have different intensities of color in comparison with their neighboring pixels. The noisy pixel in case of salt & pepper noise has no relation with the color of the neighboring pixel. This affects a small no. of pixels. The contaminated image looks like it contains light and dark dots which led its name to be salt & pepper noise.

2. Gaussian Noise makes every pixel of the image to change from its real value by tiny amount. This noise type has a Gaussian distribution which has the probability distribution function of bell-shape.

*3. Speckle Noi*se is a granular noise that is multiplicative in nature. It degrades the images obtained using active image devices like active radar and SAR (Synthetic Aperture Radar) image. It elevate that means grey level of local area.

4. Shot Noise exists in brighter areas of an image. It is produced from an image sensor and is caused due to statistical quantum fluctuations. Its also known as photon shot noise. It has its root-mean-square value proportional to the square-root of intensity of image and different pixels have noises independent of one another. It follows Poisson distribution which led its name to be Poisson noise.

2.Discrete wavelet transform

In imaging systems removal of noise without blurring the edges of images is very critical. Mainly, noise is characterized by high spatial frequencies in the image. Fourier based method tend to suppress high frequency components and affect sharpness of the edges. As the Discrete Wavelet transform (DWT) provides good localization in both spatial and spectral domain, low pass filtering is inherent to this transform.

The Multiscale Analysis gives us a method of decomposing a signal into components of different resolution. We get the details by apply the wavelet function and the approximations with the scaling function .To the coarse level we can apply the filters on the approximation recursively. If (x)j is approximation at level j and (x)j the detail we can write this as:[25].

$$\lambda(x)_{j+1} = \sum_{k=-\infty}^{k=\infty} h(k)\,\lambda_j(2x+k) \qquad (1)$$

$$\gamma(x)_{j+1} = \sum_{k=-\infty}^{k=\infty} g(k)\lambda_j\,(2x+k+1) \qquad (2)$$

This algorithm is called the Discrete Wavelet Transform.Unlinke the CWT the DWT contains no redundancy. A block diagram showing 3- levels of the DWT is shown in Figure 1.

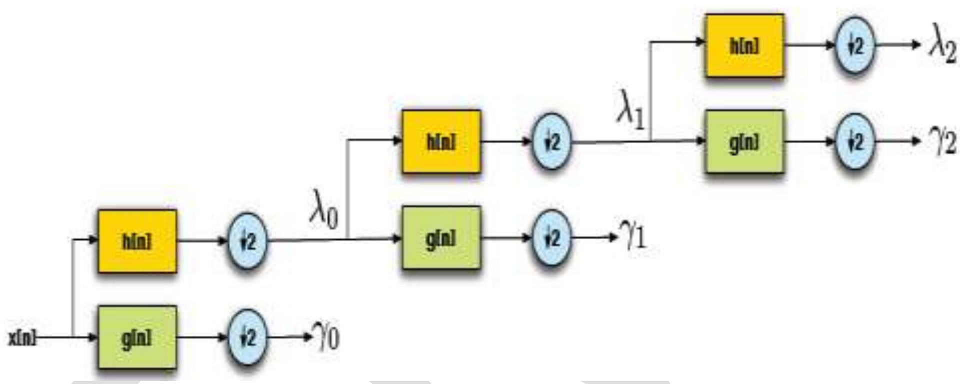


Fig 1. An example with 3 levels DWT

The Discrete Wavelet Transform is sometimes referred as the Fast Wavelet Transform due to analogy to the Fast Fourier Transform (FFT). Actually, the DWT is faster than the FFT, its complexity is O(n) compared to FFT's O(n log(n)).

It is important to understand that the DWT is not simply sampling the CWT. The wavelet have to be chosen carefully so that they are a basis of L2(R) choice for wavelets is quite restricted. If we further restrict our filters g and h to have finite response (FIR), we can create the inverse filters h0 and g0 in such a way that we get perfect reconstruction. We call this reconstruction synthesis and it can be written as[25]

$$\lambda_j(x) = \sum_{k=-\infty}^{k=\infty} h'(k)\lambda_{j-1}(x+k) + \sum_{k=-\infty}^{k=\infty} g'(k)\gamma_{j-1}\,(x+k) \qquad (3)$$

2.1 2D Discrete Wavelet Transform

The separable 2D DWT is achieved by first applying the 1D DWT on the rows, and
Then on the columns. It gives us four decomposed signals for each level of DWT.

• LL: The approximation. This is the signal that will be recursed further upon.
• LH: Horizontal approximation, vertical detail. This signal will contain specifically the vertical details and can be used if one wants to apply a special filter for the vertical details.
• HL: Horizontal detail, vertical approximation.
• HH: Detail in both vertical and horizontal direction.[25]

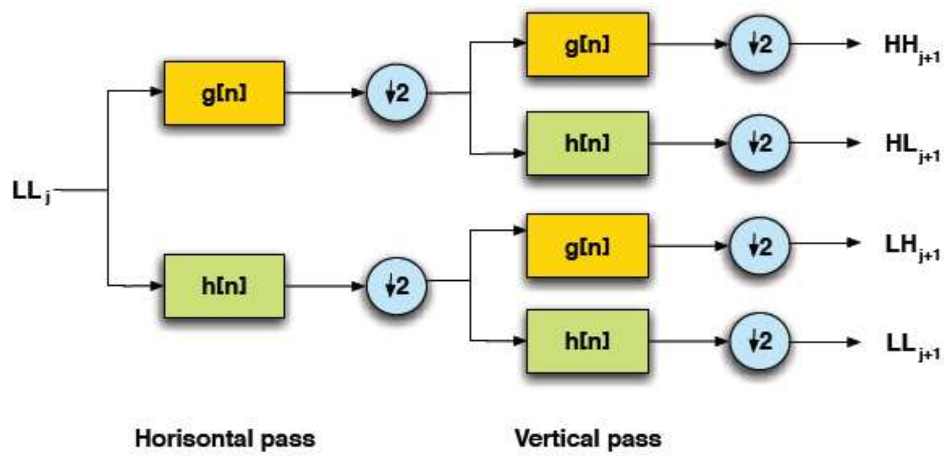
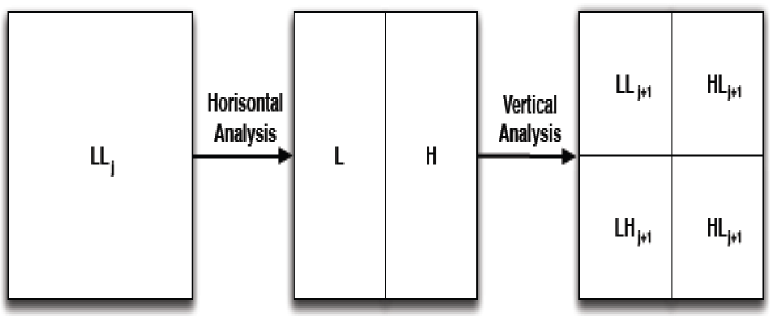


Fig 2a. One level of 2D forward DWT



(b) How (a) is usually visualized on screen.

Fig 3. 2-D Forward DWT

In Figure 2a the 2D Forward DWT is shown, Figure 3. (b) shows how the four signals are visualized. The LL is used for further decomposition.

Wavelet transform is further classified as follows:

- Wavelet thresholding
- Wavelet packet analysis
- Multiwavelet
- Undecimated wavelet
- In this, main focus is given on wavelet thresholding only.

3.Thresholding and threshold estimation techniques

The simple way to the remove noise or to reconstructed the original signal from a contaminated Signal, in case of 2D, using the wavelet coefficients which are the result of decomposition in wavelet transform, is to eliminate the small coefficient associated to the noise. After updating the coefficients by removing the small coefficients assume that noise, the real signal can be easily obtain by the reconstruction algorithm using the noise coefficient.The elimination of small coefficient are applied on the detail coefficients after the decomposition. the main idea of the wavelet denoising to that obtain the ideal components of the signal from the noisy signal requires estimation of the noise level. The estimated noise level is used in order to threshold the small coefficient assumed as noise. The procedure of the denoising based on DWT is consist of three steps; decomposition of that a signal. Many method are use this idea

proposed and implements it in different ways of the underlying signal leads to different statistical treatments of the available information.
In the linear penalization method every wavelet coefficient is affected by a linear shrinkage particular associated to the resolution level of the coefficient. So that linear thresholding is appropriate only for homogeny signals with important levels of regularity.
The wavelet thresholding or shrinkage methods are usually more suitable since the work of Donoho and Johnstone .There has been a lot of research on the way of defining the threshold levels and their type. Donoho and Johnstone proposed a non-linear strategy for thresholding. In this approach, Thresholding can be applied by implementing either hard or soft thresholding method, which also called as shrinkage [12].
In the hard thresholding, the wavelet coefficient below a give value are set to zero .On the other hand, the wavelet coefficient are reduced be a quantity to the thresh value in soft thresholding. The threshold value is nothing but the estimation of the noise level, which is generally calculated from standard deviation of the detail coefficient [12].
Threshold plays vital role in the denoising process. The main focus is on to the find an optimum threshold value.The small threshold value will retain noisy coefficients where as a large threshold value leads to the loss of coefficients that carry image details. There are 2 types of thresholding techniques that are used for denoising. There exist various method for wavelet thresholding, For all thresholding method, the image is first subjected to a discrete wavelet transform, which decompose image into the various sub-band. It can be represented as shown in Figure 4.

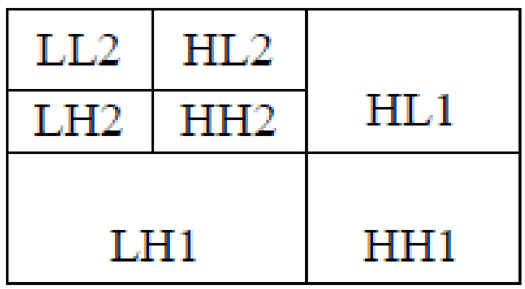


Fig 4. .Two level 2-D DWT of image

In fig, the sub-bands HHk, HLk, LHk, k = 1, 2… j are called the detail, where k is the scale and j denotes largest or coarsest scale in decomposition. LLk is the low resolutions components. Thresholding is applied to the detail components of these sub bands to remove the unwanted coefficients, which contribute to noise [18].
The simpler way to the remove noise or to the reconstruct the original signal from a contaminated signal, in case of 1D or 2D, using the wavelet coefficients which are the result of decomposition in wavelet transform, is to eliminate the small coefficient associated to the noise. After updating the coefficients by removing the small coefficients assume that noise, the real signal can be easily obtain by the reconstruction algorithm using the noise coefficient.The elimination of small coefficient are applied on the detail coefficients after the decomposition. the main idea of the wavelet denoising to that obtain the ideal components of the signal from the noisy signal requires estimation of the noise level. The estimated noise level is used in order to threshold the small coefficient assumed as noise. The procedure of the denoising based on DWT is consist of three steps; decomposition of that a signal. Many method are use this idea proposed and implements it in different ways of the underlying signal leads to different statistical treatments of the available information. In their approaches, the thresholding can be applied by implementing either hard or soft thresholding method, which are also called shrinkage. In the hard thresholding, the wavelet coefficient below a give value are stetted to zero, while in the soft thresholding the wavelet coefficient are reduced be a quantity to the thresh value.

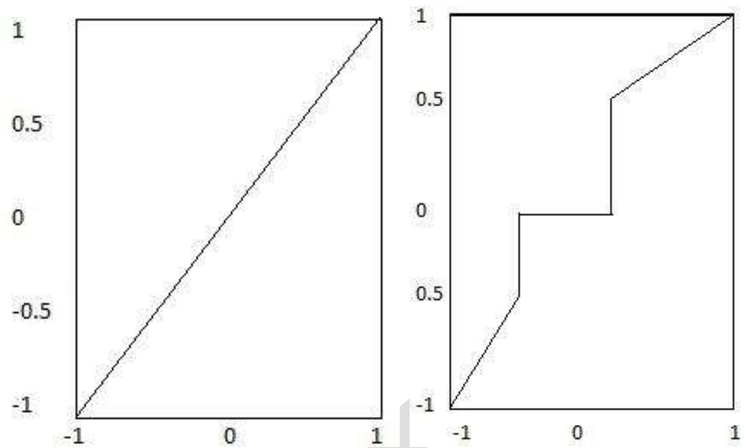
3.1 Hard Thresholding

Hard threshold is a "kill or keep" procedure and is more intuitively appealing. The Hard thresholding may seem to be natural. Sometimes pure noise coefficients may be pass the hard threshold and thus this thresholding method is mainly used in medical image processing [1].
Hard thresholding deletes all the coefficients that are smaller than the threshold λ and keeps the other unchanged. The hard thresholding is defined as follows:

$$\overline{Cs}(k) = sign\, C(K)\, |C(K)| \qquad if\ |c(K)| > \lambda \qquad (4)$$

$$0 \qquad if\ |C(K)| \leq \lambda$$

Where λ is the threshold value .The coefficients that are above the threshold are the only ones to be considered while the coefficients whose absolute values are lower than the thresholds are set to zero [9].



Original signal Hard threshold signal

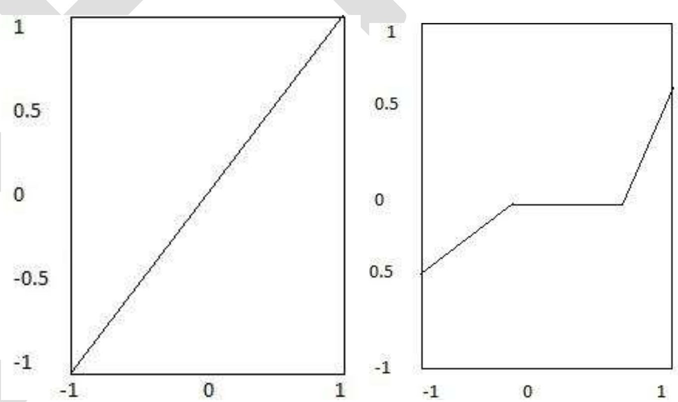
Fig 5. Original &Hard threshold signal

3.2 Soft Thresholding

Soft threshold shrinks the coefficients above the threshold in absolute value. The false structure in hard thresholding can be overcome by soft thresholding. Nowadays, wavelet based denoising methods have received a greater attentions. Important feature are characterized by large wavelet coefficient across scales in most of the timer scales. The Soft thresholding deletes the coefficients under the threshold, but scale the one of that are left. The soft shrinkage rule is defined by:

$$\overline{Cs}(k) = sign\ C(K)\ |C(K)| - \lambda \qquad if\ \ |c(K)| > \lambda \qquad (5)$$

$$0 \qquad\qquad if\ \ |c(K)| \leq \lambda$$



Original Signal Soft threshold signal

Fig 6. Original & Soft thresholding signal

Hard thresholding method does not affect on the detail coefficients that grater the threshold levels, whereas soft thresholding method to these coefficients. There are several considerations about the properties and limitation of the two strategies. However the hard thresholding may be unstable and sensitive even to small changes in the signals, Soft thresholding can create unnecessary bias when the true coefficients are large. Although more sophisticated methods have been proposed to overcome the drawbacks of the described nonlinear method, the most efficient and reliable method are still the hard and soft thresholding techniques [12].

One important point in thresholding methods is to find the appropriate value for threshold, many approaches have been proposed for calculating threshold values. But, all this approaches require estimation of noise level. However the standard deviation of the data values may be use as an estimator, Donoho proposed good estimator σ for the wavelet denoising given as;

$$\sigma = \frac{\mathrm{median}(d_{L-1,K})}{0.6745} \qquad k = 0,1 \dots, 2^{L-1} - 1 \qquad (6)$$

L is the number of decomposition levels. This median selection made on detail coefficient of the analyzed signal.
The most known threshold selection n algorithm are minimax, universal and rigorous sure
threshold estimation techniques.
The minimax threshold value λM consists an optimal threshold that is derived by minimizing the constant term in an upper bound of the risk involved in the estimation. The proposed threshold value depends on the available data and also takes into account the noise level contaminating the signal. The optimal threshold is defined as[12];

$$\lambda M = \sigma \lambda n^* \qquad (7)$$

Where λn* is defined as the value of λ and satisfying.

$$\lambda^* n = \inf_{\lambda} \sup_{d} \left\{ \frac{R_{\lambda(d)}}{n^{-1+R_{oracle(d)}}} \right\} \qquad (8)$$

Where Rλ (d) =E (δλ (d)-d)2 and Oracle(d) named as oracle which is used to account for the risk associated to the modification of the value of a given wavelet coefficient. In this, two oracles are considered, the diagonal liner projection (DLP) and the diagonal linear shrinker (DLS). The ideal risks for these oracles are given by

$$R_{oracle}^{DLP}(d) = \min(d^2, 1) \qquad (9)$$

$$R_{oracle}^{DLS}(d) = \frac{d^2}{d^2+1} \qquad (10)$$

This method is used in statistics to design estimator and the minimax estimator is realizes the minimum of the maximum mean square error, over given set of the functions.
Another proposed threshold estimator by Donoho is the universal threshold or global threshold, which is an alternative to the minimax threshold, however it uses a fixed threshold form given as[12];

$$\lambda = \sigma\sqrt{2\log(N)} \qquad (11)$$

Where n is the length of the analyzed signal and σ is given by Equation. The main advantage of this thresholding appears in software implementation as it is easy to remember and coding. Additionally, this threshold estimator ensures every sample in the wavelet transform in which the underlying function is exactly zero will be estimated as zero.
Another common estimator is Rigorous Sure which threshold proposed by Donoho. This threshold gives a scheme which uses a threshold λ at each resolution level l of the wavelet coeffient. The Rigorous Sure, is also as known SureShrink.The threshold is given as follows;

$$\lambda_s = \mathrm{argmin}_{0<\lambda<\lambda u} \mathrm{Sure}\left(\lambda, \frac{s(a,b)}{\sigma}\right) \qquad (12)$$

4.RESULT

We used MATLAB to implement the de-noising algorithm. MATLAB has wavelet toolbox and functions which are very convenient to do the DWT. A usual way to de-noise is to find a processed image such that it minimizes mean square error MSE and increases the value of the PSNR.
Keeping MRI images same we have varied noise add to image, wavelet family & threshold type (hard & soft Thresholding). The PSNR for rician noise is better.So that, We used MATLAB to implement the de-noised algorithm. MATLAB has a wavelet toolbox and function which are very convenient to do DWT.
In below Fig 3. is shows 2D discreat wavelet transformer

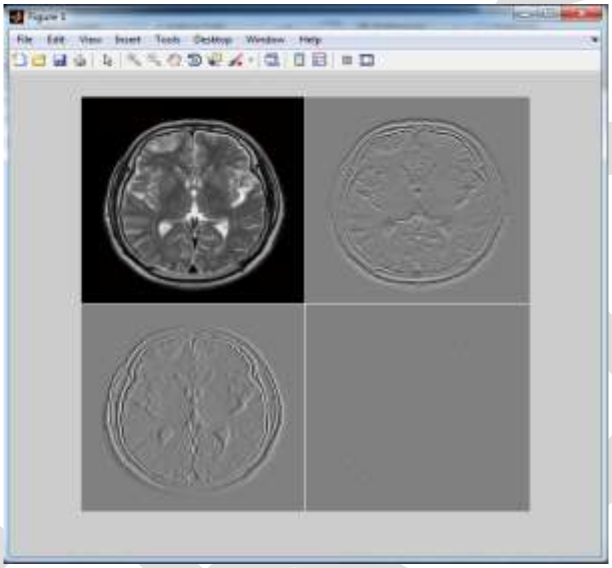


Fig 7. 2D discrete wavelet transforms

5.CONCLUSION

In this paper, we have presented the denoising method based on wavelet thresholding which offers high quality and flexibility for noise problem of signal and images. By comparing soft and hard thresholding ,it is seen that PSNR values for soft is better as compared to hard thresholding when it is used for rician noise and also MSE is less in case of soft thresholding. Wavelet denoising technique works well for rician type of noise as compared to Gaussian and salt & pepper noise.

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