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# Multiwavelet Image Denoising Based on VisuShrink Threshold Function

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**ABSTRACT**

***This paper presents a new algorithm of noise removal from an image corrupted with Gaussian noise based on discrete multiwavelet transform (DMWT) and multisoft threshold values using threshold function proposed by Donoho which is propose the concept of wavelet threshold denoising method (VisuShrink method). DMWTis better than Discrete wavelet transform (DWT) because it has all properties of scaler wavelet transform as well as some features such as short support, orthogonality, symmetry, and higher order of vanishing moments which are a good feature in image and signal processing. Scaler wavelet can't implement all these features at the same time but multiwavelet can. All results in this paper compared with results got from VisuShrink method. The experimental results show that the denoising results by a new proposed algorithm is better and PSNR larger than the results got from VisuShrink method for the same image.***

**Keywords:**Gaussian noise, Denoising, Soft Threshold, DMWT, DWT.

## 1. INTRODUCTION

Estimating a signal that is corrupted by additive noise has been of interest to many researchers for practical as well as theoretical reasons. To recover original signal from the noisy signal is the main challenge. We want the recovered signal to be as close as possible to the original signal [1].Usually there will be various noise in the images taken by different kind of electronic devices. Gaussian noise is one of the most important types of image noise. So, several denoisingtechniques and methods are developed by researchers to maintain and improve images by removing noise from it. Each denoising method and technique has advantages and limitation. The goal of researchers is to find an denoising method such that it gives us the highest possible peak signal-to-noise ratio (PSNR)[2].

Traditional methods of image denoising are apply its denoising technique directly to the information of image without transform it to another domain so it simple and weak to remove noise from image and sometime remove part from original image information. But in the last twenty years, multi transformation techniques are developed and used with different kinds of image denoising technique to get better results [2].

In 1995, Donoho and Johnstone proposed the concept of wavelet threshold denoising based on binary wavelet Transform, i.e. the VisuShrink image denoising method [3]. Wavelet transform is one of the most important method used in image and signal denoising via wavelet thresholding because it has good local time-frequency, multi-scale and multi-resolution characteristics. Wavelet threshold denoising has been widely used in many fields because it has the advantages of fast calculation speed, wide adaptability as well as being able to get the best estimation that any other linear estimates is not able to reach [2].

Multiwavelets transform[4] are a new addition to the body of wavelet theory. Realizable as matrix-valued filter banks leading to wavelet bases, multiwavelets offer simultaneous orthogonality, symmetry, and short support which can be implemented at the same time but wavelet could not [5]. In this paper, we propose a new algorithm using multi soft-thresholding values and Multiwavelets transform. We demonstrate that our proposed algorithm outperforms the traditional ones in terms of PSNR; thus improving thedenoisedresults significantly. Results got by our new algorithm are given toshow the efficiency of this proposed algorithm.Section2 explains some basic concepts ofdenoising image by soft threshold with wavelet transform (VisuShrink threshold) which is proposed by Donoho and Johnstone. Section 3 describes our proposed image denoising algorithm. Experimental results and analysis are given in section 4. Finally, our concluding remarks are given in section 5.

## 2. Denoising Image by VisuShrink threshold technique

Wavelet Thresholding is simple non-linear technique; it operates with one wavelet coefficient at a time. Consider an noisy image signal g(i,j) affected by Gaussian noise signal n(i,j), so the noisy image signal g(i,j) is consist of two parts, first is the original image signal f(i,j) and Gaussian noise signal n(i,j) as in equation (1)[1].

$$g(i,j)= f(i,j) + n(i,j) \qquad .(1)$$

Wavelet transform and threshold technique are used to remove noise from noisy image to get original image signal f(i,j). The wavelet coefficients of the noisy image signal is composed of two parts, the original image wavelet coefficients $W_f$ and noise wavelet coefficients $W_n$, so noisy image wavelet coefficients $W_g$ is consist of $W_f$ and $W_n$ as in equation (2)[1].

$$W_g = W_f + W_n \qquad . (2)$$

The image wavelet coefficients$W_g$ are always greater than the noise wavelet coefficients$W_n$ after wavelet decomposition, so it can calculate a suitable threshold value T to use it in algorithm of image denoising which will be used to remove noise signal and get original image signal. The important thing is how to calculate the best threshold value T in which it has smallest effect as much as possible on the values of original image. Suitable threshold value T is calculated based on wavelet coefficients which is proposed by Donoho and Johnstone also is called VisuShrink method [3].

Threshold value T is used to processing the wavelet coefficients to get the estimated wavelet coefficients by using the following threshold function:

**2.1.Hard threshold function**

The hard threshold function sets all wavelet coefficients that are less than the threshold value T to zero because these coefficients caused by noise and keep the others that are larger than T with no change because these coefficients mainly caused by image signal. The following equation (3) show how the hard threshold work:

$$\begin{aligned} F_{i,j} &= W_{i,j} && \text{if } |W_{i,j}| >= T \\ &= 0 && \text{if } |W_{i,j}| < T \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3) \end{aligned}$$

Where $W_{i,j}$ is the wavelet coefficients with high frequency of wavelet decomposition and $F_{i,j}$ is the estimated wavelet coefficients from threshold process [5].

**2.2. Soft threshold function**

Soft threshold will set all wavelet coefficients that are less than the given threshold valueT to zero and find the difference between T and the wavelet coefficients that are larger than threshold T value. The following equation (4) show how the soft threshold work [5]:

$$\begin{aligned} F_{i,j} &= (W_{i,j} - T) && \text{if } |W_{i,j}| >= T \\ &= 0 && \text{if } |W_{i,j}| < T \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4) \end{aligned}$$

Take inverse wavelet transform to the estimated wavelet coefficients $F_{i,j}$ to get denoised image. VisuShrink method tends to smooth the image signal and losing some details of original signal. VisuShrink method uses the Universal threshold, T, which is proportional to the standard deviation of the noise. Equation (5)show how to calculate the value of threshold T [2].

$$T = \sigma\sqrt{2\log M} \ldots (5)$$

Where $\sigma$ is noise standard deviation estimated from $HH_1$ subband of wavelet transform and M is the total number of imagepixels. Equation (6) show to calculate standard deviation $\sigma$ [1,2,5].

$$\sigma = median(|HH_1(i,j)|)/C \qquad ..(6)$$

Where c is constant (C=0.6745).

Because of using universal threshold, so it is very smooth visual appearance that is mean some details (sharpen edge) of image will be lost [1].

## 3. Denoising with Multiwavelet Transform and New ThresholdingAlgorithm

The major problem in image denoising is how to find the optimized threshold function to get better results from other threshold function. Some time, find the optimized threshold function alone is not enough to get a good result without interest with over all algorithm of image denoising. In this paper will use soft threshold function becausehard threshold function is not continuous on thethreshold value T, so the Pseudo-Gibbs phenomena[6] wasprone to appear in the signal reconstruction. Image denoising algorithm proposed in this paper is consists of calculating Multiwavelet coefficients followed by finding multi thresholding value depending upon Donoho technique and then denoising process. Figure 1 shows the block diagram of our proposed algorithm.The following subsections shows the procedure of our proposed algorithm.

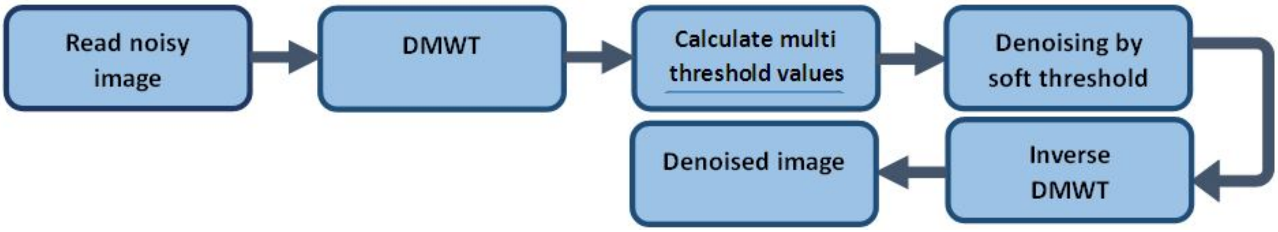


**Figure 1.**Block diagram ofimage denoising steps based on DMWT

**3.1 DMWT Operation**

DMWT will analyze the input image to two types of coefficients, the first one is approximation coefficients ($LL_k$where k= 1,2 …. the number of decomposition level) which is represent the main information about original image and the second one is detail coefficients ($LH_k$ ,$HL_k$ , $HH_k$) which are represent noise components of input image [7].

**3.2 Find Multi-threshold values**

Calculating Multi-threshold values for each decomposition level ($T_{mk}$) wherem=1,2,3(m=1 refer to $LH_k$ coefficients, m=2 refer to $HL_k$ coefficients and m=3 refer to $HH_k$ coefficients). Equation (5) and(6) will be used to calculate multi threshold values as follows (equation 7):

For the first level (k=1) of Multiwavelet decomposition

$$T_{m1} = \sigma_{m1}\sqrt{2\log M} \quad \text{............ (7)}$$

Where $\sigma_{m1}$ is standard deviation of detail coefficientsof level one.Three values of threshold and standard deviation can be calculated for each level of decomposition depending on value of m as mentioned above. Standard deviation can be calculated by using equation(8) as follows

$$\sigma_{m1} = median(|LH_1(i,j)|)/C \quad \text{.......... (8)}$$

Where C is constant (C=0.6745).

Second levelmultiwavelet coefficientscan be calculated by applying multiwavelet transform for $LL_1$approximation coefficients.Threshold values of the second multiwavelet decomposition level can be calculated by using the same equations (7) and (8) with new level coefficients ($LH_2$ , $HL_2$ , $HH_2$). The same procedure of second level can be applied for next decomposition level if we need.

**3.3 Denoising by Soft Threshold**

This step is very important because it is used to remove noise from analyzed image to get original image. To get denoised image, soft thresholding algorithm which is explained in section 2.2 should be applied on the detail coefficients $LH_k$, $HL_k$ and $HH_k$ with its threshold values $T_{1k}$, $T_{2k}$ and $T_{3k}$ respectively. Estimated detail coefficients can be calculated by usingequations (9) and (10).

$$\widehat{LH}_k(i,j) = 0 \quad if \quad LH_k(i,j) < T_{1k} \quad \text{................(9)}$$
$$\widehat{LH}_k(i,j) = LH_k(i,j) - T_{1k} \quad if \quad LH_k(i,j) > T_{1k} \quad (10)$$

Where i and j are the dimensions of detail coefficients and $\widehat{LH}_k$ is the first part of detail coefficients of level k. By the same way, equations (9) and (10) are applied to other detail coefficients $HL_k$ and $HH_k$to get estimated coefficients $\widehat{HL}_k$ and $\widehat{HH}_k$ by using its threshold values $T_{2k}$ and $T_{3k}$ respectively.

### 3.4 Inverse DMWT Operation (IDMWT)

This stage will use approximation coefficients and denoised detail coefficients to create denoised image [7].

## 4- Experiment Results and Analysis

Our proposed algorithm and VisuShrink method are applied to the various noisy image with different format like Lena (pixel value is 512*512, gray level is 256, png format) and Cameraman (pixel value is 256*256, gray level is 256, gif format) with different level of Gaussian noise. All results show that the new algorithm (DMWT with various soft threshold values) is better than the VisuShrink method (DWT with universal soft threshold value) as shown in figure (2)because our proposed algorithm decrease image blur caused by VisuShrink method,so objects in denoised image by new algorithm have good edges (sharpen). Furthermore, new algorithm is faster from VisuShrink method because it need to one level of DMWT decomposition while VisuShrink need to two level of DWT decompositions so it need about half calculations of VisuShrink method.

PSNR is the quality measurement which is used to compare between the results of new denoising algorithm and VisuShrink method which is proposed by Donoho. PSNR can be calculated by the following equations [6]:

$$PSNR = 10\,log\left[\frac{255^2}{MSE}\right] \qquad (11)$$

$$MSE = \frac{1}{m*n}\sum_{m,n}[I_2(m,n) - I_1(m,n)]^2 \qquad (12)$$

Where m and n is the dimension of input image, MSE is mean square error, $I_2$ is pixel value of noisy image and $I_1$ is pixel value of denoised image. Figure (4) shows that the curve of PSNR got from denoised Lena image by new algorithm for various Gaussian White noise level is better than the curve got from denoised image by VisuShrink method. So, new denoising algorithm is better than the old Donoho method.


**Figure 2.** Lena image: (a) Original, (b) Noisy image with noise level 20, (c) Denoising image of level 20 with new algorithm, (d) Denoising image of level 20 with VisuShrink method, (e) Noisy image with noise level 40, (f) Denoising image of level 40 with new algorithm, (g) Denoising image of level 40 with VisuShrink method.

## 5- Conclusion

A new image denoising algorithm based on DMWT and multi-threshold values are applied to the different noise images (Lena, Cameraman) with different level of noise (10, 20, 30, 40, 50). All results are compared with results got from apply VisuShrink method proposed by Donoho for the same images and levels of noise. The results of comparison show that a new algorithm is better than VisuShrink method because it decreases blur effect and time needed for denoising operation (one level of decomposition needed) as well as PSNR got from new algorithm is better than PSNR got from VisuShrink method.

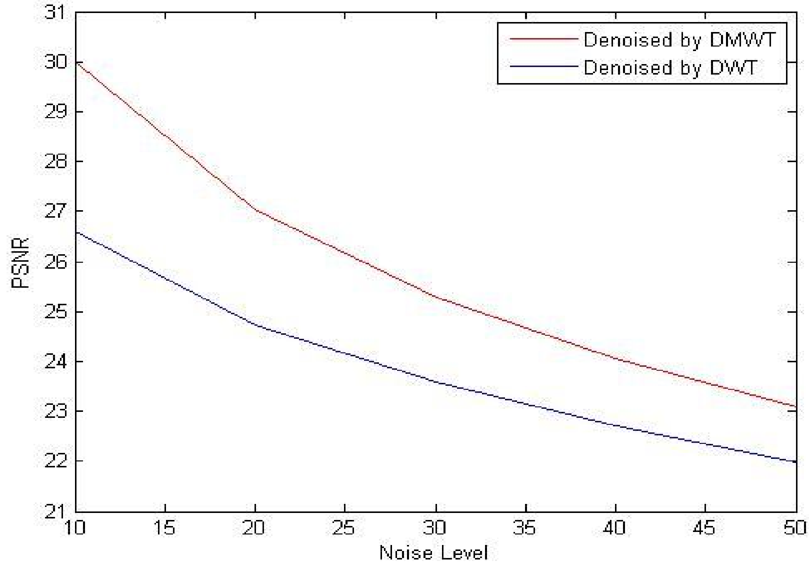


**Figure 4.** PSNR for Lena image denoised by DMWT soft threshold (Red curve) and denoised by DWT soft threshold (Blue curve).

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