Double Density Dual Tree Discrete Wavelet Transform implementation for Degraded Image Enhancement

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Abstract: Wavelet transform is a main tool for image processing applications in modern existence. A Double Density Dual Tree Discrete Wavelet Transform is used and investigated for image denoising. Images are considered for the analysis and the performance is compared with discrete wavelet transform and the Double Density DWT. Peak Signal to Noise Ratio values and Root Means Square error are calculated in all the three wavelet techniques for denoised images and the performance has evaluated. The proposed techniques give the better performance when comparing other two wavelet techniques.

1. Introduction
In image processing research field image denoising is an important issue. Due to the various reasons the images are corrupted. The reason may be outside interference, instruments noise and environment problems [1-2]. The researchers are using different methods for reduction of noise in images. Wavelet technique is one of the preferable techniques among them. Earlier method is Fourier transform which used only in time domain or frequency domain. The wavelet technique overcomes this limitation and its knack to represent a function at the same time as in the time and frequency domains. The wavelet transform has an oscillating wavelike characteristic but also can allow simultaneous time and frequency analysis. This technique is suitable for transient and time-varying functions. In recent years the Wavelet transform has been studied broadly as a talented tool for denoising [3-4]. Since the presence of noise in images restricts one's ability to obtain the information it has to be removed. Discrete Wavelet Transform has one scaling function and wavelet function [5]. To pick suitable wavelet is important. Various mother wavelets are Harr, Daubechies, Coiflet and Symmlet. One of the most popular and widely used known ortho-normal wavelets is Daubechies wavelet. In this paper, Daubechies family wavelet is selected as mother wavelet. Daubechies wavelets are orthogonal, compactly supported, and no marginal overlaps will happen during the signal reconstruction [6]. Daubechies6 is chosen since it gives a more accurate solution and minimum reconstruction error [7-8]. The core intention of the paper is to improve the image visualization. The flow of the paper as follows; II section gives the noise reduction using DWT and DDDWT. The proposed algorithm and experimental results reporting the performance are given in section III and IV respectively. Finally, conclusion is given in section V.

2. Noise Reduction Using DWT and DDDWT
The discrete wavelet decomposition can be performed by passing the corrupted image through the series of filter bank stages. The Wavelet breaks the image into four different sub-sampled images denoted by combination of high pass and low pass filters. Then one sub band contains only low pass filter coefficients. The low pass filter coefficients proceed to the next level of computation. The way of chosen proper filter is used to retrieve the original image it can be reconstructed from the inverse transform without loss of any information. The DDDWT will give excellence images because of more detailed sub-bands. The DDDWT has some additional properties when compared with DWT. (i) It has one scaling function and two distinct wavelets. (ii) The DDDWT is over complete by a factor of two. After one level of DDDWT decomposition we obtain nine sub bands, one low pass and eight high pass filters. Then the only low pass component value applied to the next level of decomposition. At the achievement the second level has sixteen sub-bands, one low pass and fifteen high pass components. The sub-bands are increased by N×8.where N represent the number of decomposition level. Then the inverse decomposition takes place to get the denoised image.

3. Noise Reduction Using DDDTDWT.
The proposed technique is a combination of DWT, dual tree and double density DWT. The iterated oversampled filter bank corresponding filter bank is shown in figure 1.

(i) Compute the forward DDDTDWT for the noisy image
(ii) Determine the threshold value for each sub-band using
(iii) Apply soft thresholding on each sub-band.
(iv) Perform the IDDDTDWT to obtain the denoised image
(v) Calculate the performance measure of RMSE and PSNR.

![Figure 1. Iterated filter bank for DDDTDWT.](image)

The noisy image \( x(m, n) \) is transfer through the filter bank. There are two similar set of wavelet filter bank in both upper and lower. The number of coefficients and sub bands are equal in two trees. After one level of decomposition the noisy images are representing by two low pass and twelve high pass coefficients. All the approximation values are stored in low pass filter and the detailed coefficient of the image in combination of the filters. The more detailed coefficients provide information about the image. Once the decomposition process is over, next necessary to apply threshold for each sub-band. Wavelet thresholding is a popular approach for denoising due to its efficiency and simplicity and therefore is an extensively investigated noise reduction method. Small wavelet coefficients are dominated by noise while coefficients with large absolute values carry more information than noise. There are two standard thresholding functions are available namely hard thresholding, soft thresholding [9-10]. In hard-thresholding, coefficients below the threshold are set to zero, and the remaining coefficients are left unchanged. For an estimated threshold value \( T \), hard-threshold of a coefficient \( x \) can be represented as
In practice, especially when the noise level is high, hard-thresholding yields abrupt artifacts in the reconstructed image. Due to this, in image processing applications soft-thresholding is usually preferred compared to hard thresholding. The soft-thresholding of a coefficient $x$ can be written as

$$T_{soft}(x) = \begin{cases} 0, & |x| \leq T \\ x, & |x| > T \end{cases}$$

(2)

The resultant detail sub bands are subjected to soft thresholding. For fixing the threshold value mini-max rule is applied.

$$\sqrt{\frac{1}{N} \sum (x_i - y_i)^2}$$

(3)

Where

$N$=Number of a pixel in the image.

$x_i$=The noisy image value

$y_i$= Denoised image value

4. Results and Discussion

The noisy test images like peppers, mandrill and ovary are chosen as test images. The noisy images denoised by DWT, DDDWT and DDDTDWT method with variance 15dB. For the denoising process the same level of decomposition and noise variances are maintained the systems are same. The size of the images for all methods is 512×512. The PSNR has been computed for three different denoising methods and the values are tabulated in Table 2. The RMSE values are calculated using equation 3 and the values are tabulated in Table 1. The denoised images are shown in figure 2. The graphical representation of denoised PSNR value for different Denoising methods is shown in figure 3. The simulation test results show that with the more detailed coefficients the Double Density Discrete Wavelet Transform provides high Peak signal to noise ratio (PSNR). The PSNR values are high compared with the other two methods like DWT and DDDWT.

Table 1: Comparison of RMSE value

| Noise Reduction Method | Noisy RMSE | Denoised RMSE |
|------------------------|------------|---------------|
| DDDTDWT                | 401.3      | **64.53**     |
| DDDWT                  | 401.3      | 82.04         |
| DWT                    | 401.3      | 198           |

Table 2: Comparison of Denoised PSNR value

| IMAGES | NOISY | DWT | DDDWT | DDDTDWT |
|--------|-------|-----|-------|---------|
| LENA   | 22.09 | 25.88 | 26.84 | **30.37** |
| PEPPERS| 22.09 | 25.56 | 27.05 | **30.03** |
| MANDRILL| 22.09 | 24.15 | 28.99 | **31.21** |
| OVARY  | 22.09 | 25.92 | 28.60 | **34.40** |
Figure 2. Noisy and denoised images by DDDTDWT method
5. Conclusion

This paper deals with the performance of three different wavelet techniques for image denoising of degraded images. The noisy test images are denoised using discrete wavelet transform, double density discrete wavelet transform and double density dual tree discrete wavelet transform. The RMSE values and PSNR value in percentage has been calculated for three different methods of wavelet transform and the results are compared. The denoised PSNR value of DDDTDWT increased by 37.29% than DWT and DDDWT. The performance measurement shows the DDDTDWT gives the best result for image denoising and can also be applied for various applications such as medical image denoising and satellite image denoising.

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