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Image Denoising Using Complex Framelets

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ABSTRACT: In certain signal processing applications, like denoising, over complete transforms can offer a better tradeoff between performance and complexity, compared to critically sampled transforms. This paper introduces the double-density (DD) dual-tree discrete wavelet transform (DWT), which is a DWT that combines the double-density DWT and the dual-tree DWT, has its own characteristics and it has own advantages. The transform corresponds to a dyadic wavelet tight frames based on two scaling functions and four distinct wavelets. Experiments are conducted to not only demonstrate that the proposed method is more suitable than conventional methods, but also show shows that the proposed image denoising approach outperforms the conventional approaches.

KEYWORDS: Double density (DD) DWT, DD dual tree DWT, Image Denoising, thresholding, Complex Framelets.

I.INTRODUCTION

Noise reduction is an important part of image processing systems. An image is always affected by the noise. Image denoising is a technique which removes out noise which is added in the original image. While capturing, processing and storing the image ,image quality may get disturbed. Noise is nothing but the signals and which are not part of the original signal. In images, noise removal is a particularly delicate task.

Non-stationary signal processing applications use standard non-redundant DWT (Discrete Wavelet Transform) which is very powerful tool. But it suffers from shift sensitivity, absence of phase information, and poor directionality. To remove out these, many researchers developed extensions to the standard DWT such as WP (Wavelet Packet Transform), and SWT (Stationary Wavelet Transform). These transformations are highly redundant and computationally intensive. Complex Wavelet Transform (CWT) is also an impressive option, complex-valued extension to the standard DWT. There are various applications of Redundant CWT (RCWT) in an image processing such as Denoising, Motion estimation, Image fusion, Edge detection, and Texture analysis. By using a denoising method we can improve the quality of image corrupted by a lot of noise due to the undesired conditions for image acquisition. The image quality is measured by means of peak signal-to-noise ratio (PSNR) and mean square error (MSE).

In this paper, we propose algorithms based on wavelet based image denoising methods of an image. The techniques used are Dual-Tree Complex DWT and Double-Density Dual-Tree Complex DWT. These techniques give high performance as compared to the existing basic DWT methods. The performance of Complex Dual Tree DWT and Double Density Complex DWT image denoising methods can be compared by comparing PSNR (Peak-Signal-to-Noise ratio) value of each system.

II. IMAGE DENOISING

Image denoising can be formally defined as removal of noise present in the image while preserving the important and sharp features of the image. In acquiring, transmitting or processing a digital image for example, the noise induced degradation may be dependent or independent of data which is shown in fig. 1, where noisy image includes the original image and independent identically distributed noise process (n) with variance σ^2.

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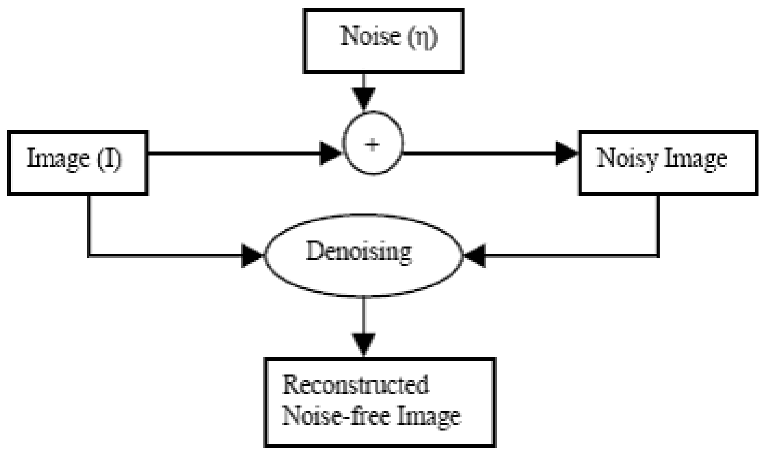

Fig. 1. Block diagram of Image Denoising Process

The goal of image denoising is to find an estimate of noise free image based on the knowledge of noise [7]. A more precise explanation of the Dual Tree DWT based denoising procedure can be given as follows. Transform is applied to a noisy image. The image I has an image function u(x,y) as a union of modified copies of itself. The net result is that target u is approximated by the attractive fixed point of transform T that performs the thresholding operation on the image function.

III. COMPLEX WAVELET TRANSFORM (CWT)

Complex wavelet transforms (CWT) uses complex-valued filtering (analytic filter) that decomposes the real/complex signals into real and imaginary parts in transform domain. The real and imaginary coefficients are used to calculate the amplitude and phase information, it is the type of information needed to describe the energy localization of oscillating functions (wavelet basis). The Fourier transform is based on complex-valued oscillating sinusoids.

$$e^{j\Omega t} = \cos(\Omega t) + j\sin(\Omega t)$$

The corresponding complex-valued scaling function and complex-valued wavelet is given as

$$\psi_c(t) = \psi_r(t) + \mathrm{j}\psi_i(t)$$

Where $\psi_r(t)$ is real and even,

$j\psi_i(t)$ is imaginary and odd.

Gabor introduced the Hilbert transform into signal theory in [9], by defining a complex extension of a real signal $f(t)$ as:

$$x(t) = f(t) + j\,g(t)$$

Where, $g(t)$ is the Hilbert transform of $f(t)$ and denoted as $H\{f(t)\}$ *and* $j = (-1)^{1/2}$.

The signal $g(t)$ is the 90^{o} shifted version of $f(t)$ as shown in figure (3.1 a).The real part $f(t)$ and imaginary part $g(t)$ of the analytic signal $x(t)$ are also termed as the 'Hardy Space' projections of original real signal $f(t)$ in Hilbert space. Signal $g(t)$ is orthogonal to $f(t)$. In the time domain, $g(t)$ can be represented as [7]

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$$g(t)=H\{f(t)\}=\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{f(t)}{t-\tau}d\tau=f(t)*\frac{1}{\pi t}$$

If $F(\omega)$ is the Fourier transform of signal $f(t)$ and $G(\omega)$ is the Fourier transform of signal $g(t)$, then the Hilbert transform relation between $f(t)$ and $g(t)$ in the frequency domain is given by

$$G(\omega)=F\{H\{f(t)\}\}=-j\,\mathrm{sgn}(\omega)F(\omega)$$

Where, $-j\ \mathrm{sgn}(\omega)$ is a modified 'signum' function.

This analytic extension provides the estimate of instantaneous frequency and amplitude of the given signal $x(t)$ as:

Magnitude of $x(t)=\sqrt{(f(t)^2+g(t)^2}$

Angle of $x(t)=\tan^{-1}[g(t)/f(t)]$

The other unique benefit of this quadrature representation is the non-negative spectral representation in Fourier domain [7] and [8], which utilises half of the bandwidth . The reduced bandwidth consumption is helpful to avoid aliasing of filter bands especially in multirate signal processing applications. The reduced aliasing of filter bands is the key for shift-invariant property of CWT. In one dimension, the so-called dual-tree complex wavelet transform provides a representation of a signal $x(n)$ in terms of complex wavelets, consists of real and imaginary parts which are in turn wavelets themselves.

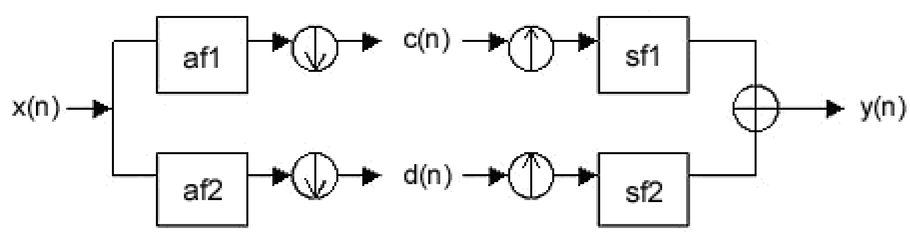

Figure 2 shows the Analysis and Synthesis of Dual tree complex wavelet transform for three levels.

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IV. DOUBLE-DENSITY COMPLEX WAVELET TRANSFORM

Both the double-density DWT and the dual-tree DWT have their own distinct characteristics and advantages, and as such, combining the two into one transform called the double density complex (or double-density dual-tree) DWT. By combining the properties of both the double density and dual-tree DWTs we ensure that: (1) one pair of the four wavelets is designed to be offset from the other pair of wavelets so that the integer translates of one wavelet pair fall midway between the integer translates of the other pair, and (2) one wavelet pair is designed to be approximate Hilbert transforms of the other pair of wavelets. By doing this, we are then able to use the double-density complex wavelet transform to implement complex and directional wavelet transforms.

To implement the double-density dual-tree DWT, we must first design an filter bank structure (one that combines the characteristics of the double-density and dual-tree DWTs). We know the type of filter bank structure is associated with the double-density DWT in the previous sections (mainly that it is composed of one low pass scaling filter and two high pass wavelet filters), so we will now see the properties of the dual-tree DWT. The dual-tree DWT is based on concatenating two critically sampled DWTs. We do this by constructing an filter bank that performs multiple iterations in parallel.

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Consequently, the filter bank structure corresponding to the double-density complex DWT consists of two oversampled iterated filter banks operating in parallel on the same input data. The iterated oversampled filter bank pair, corresponding to the implementation of the double-density and dual-tree DWTs, is illustrated in Figure below.

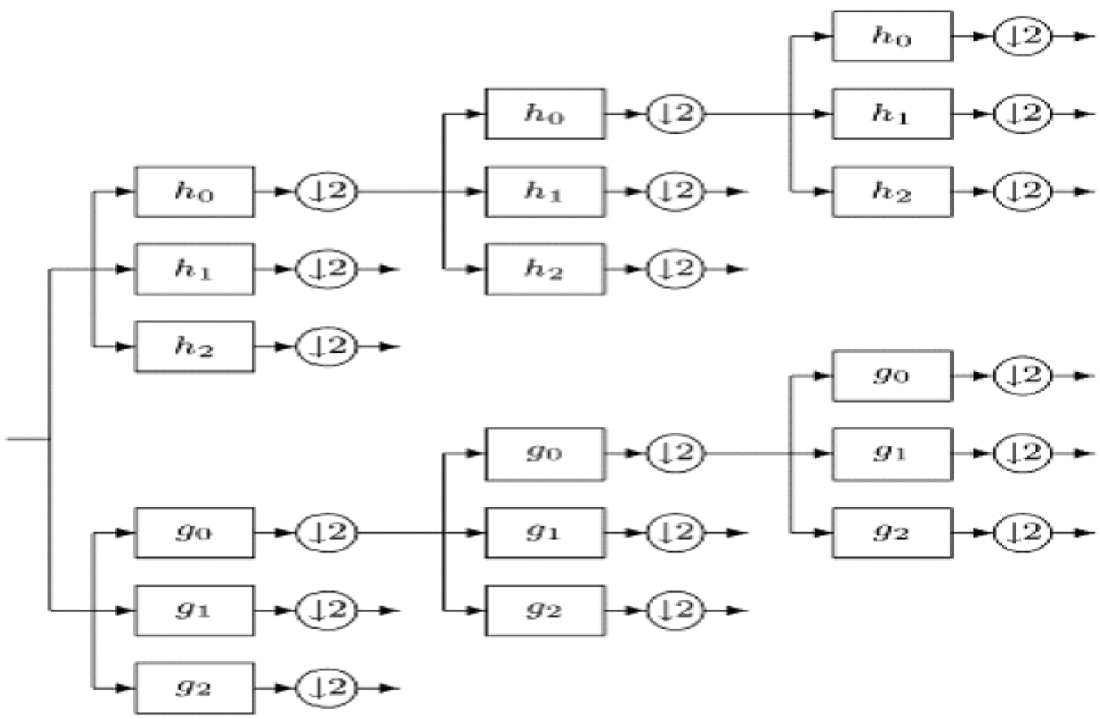

Fig 3. Iterated Filter bank for the Double-Density Complex DWT.

In the above figure, there are two separate filter banks denoted by hi(n) and gi(n) where i = 0, 1, 2. The filter banks hi(n) and gi(n) are unique and designed in a specific way so that the sub band signals of the upper DWT is taken as the real part of the complex wavelet transform, and the sub band signals of the lower DWT is taken as the imaginary part. For specially designed sets of filters, the wavelets with the upper DWT can be approximate Hilbert transforms of the wavelets. When we designed in this way, the double-density complex DWT can be used to implement 2-D oriented wavelet transforms, which are efficient in image processing. Due to this, the double-density complex DWT is expected to outperform the double-density DWT in various applications, such as image denoising and image enhancement.

V.SIMULATION RESULTS

Experiments are carried out on grey scale image to compare the performances of DT-CWT and DDDT-CWT methods. The performance of denoising is confirmed by the visual quality as shown in below Figures.

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Fig 4:original image

fig 4(a):noise added to an image

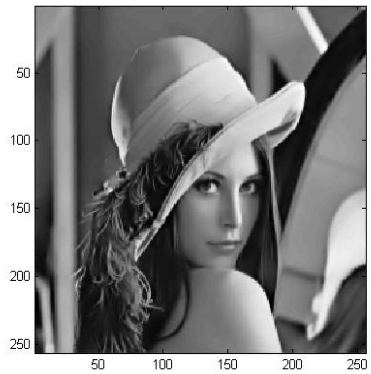


Fig 4(b) :output image when we apply standard Wavelet transform.

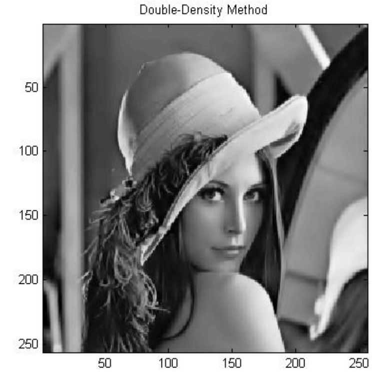


fig 4(c) :output image when we apply double density wavelet transform.

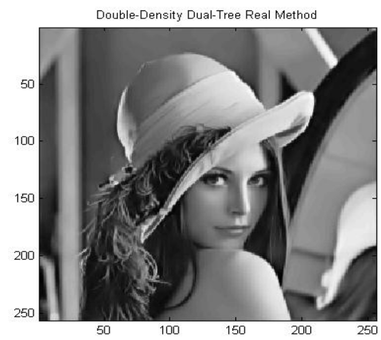
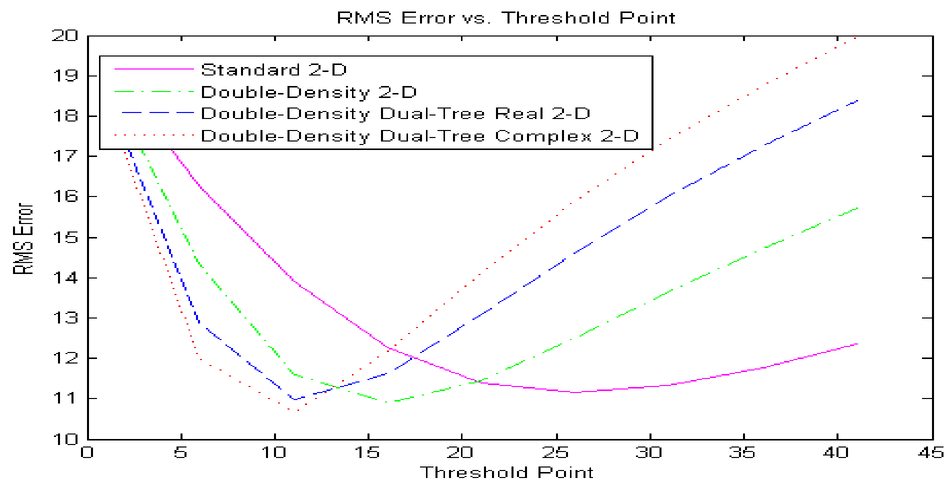


Fig 4(d):output image when we apply double density dual tree Wavelet transform.



GRAPH PLOTTED FOR DIFFERENT THRESHOLD AND RMS VALUES

VI.CONCLUSION

This paper highlighted the wavelet based enhancement of gray scale digital images corrupted by a noise. In this study we have evaluated and compared the performances of wavelet transforms. The double density dual tree discrete wavelet transform (DDDTDWT) outperforms in comparison with others wavelet transform in the highly corrupted images. The simulation results indicate that the complex double density dual tree discrete wavelet transform performances better than others wavelet transform.

The double-density dual-tree DWT, which is an over complete discrete wavelet transform (DWT) designed to simultaneously possess the properties of the double-density DWT and the dual-tree complex DWT. The double-density DWT and the dual-tree complex DWT are similar in several respects (they are both over complete by a factor of two, they are both nearly shift-invariant, and they are both based on FIR perfect reconstruction filter banks), but they are quite different from one another in other important respects. Both wavelet transforms can outperform the critically sampled DWT for several signal processing applications, but they do so for different reasons. It is therefore natural to investigate the possibility of a single wavelet transform that has the characteristics of both the double-density DWT and dual-tree complex DWT.

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