Comparative Analysis of DWT, Reduced Wavelet Transform, Complex Wavelet Transform and Curvelet Transform

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Abstract— Image denoising is the process to remove the noise from the image naturally corrupted by the noise. The wavelet method is one among various methods for recovering infinite dimensional objects like curves, densities, images, etc. The wavelet techniques are very effective to remove the noise because of their ability to capture the energy of a signal in few energy transform values. Though the wavelet transform have the best bases when it represents target functions which has dot singularity, it can hardly get the best bases when it present the singularity of line and hyper-plane. This makes the traditional two-dimensional wavelet transform in dealing with the image have some limitations. To overcome the above-mentioned shortcomings of Wavelet transform the theory of Curvelet transform was promoted.

Key words: Image denoising, wavelet method, wavelet transform, Reduced Wavelet Transform, Comparative Analysis of DWT, Reduced Wavelet Transform, Complex Wavelet Transform, Curvelet Transform

I. INTRODUCTION

Image denoising is a technique which removes out noise which is added in the original image. Noise reduction is an important part of image processing systems. An image is always affected by noise. Image quality may get disturbed while capturing, processing and storing the image. Noise is nothing but the real world signals and which are not part of the original signal. In images, noise suppression is a particularly delicate task. In this task, noise reduction and the preservation of actual image features are the main focusing parts. The wavelet transform provides a multiresolution representation using a set of analyzing functions that are dilations and translations of a few functions (wavelets). It overcomes some of the limitations of the Fourier transform with its ability to represent a function simultaneously in the frequency and time domains using a single prototype function (or wavelet) and its scales and shifts.

II. WAVELET TRANSFORM

The Wavelet Transform (WT) retrieves frequency and time content of a signal. The basic types of wavelet transform are namely, i) Continuous Wavelet Transform (CoWT) ii) Discrete Wavelet Transform (DWT) iii) Complex Wavelet Transform (CWT). A multi-resolution analysis is not possible with Fourier Transform (FT) and Short Time Fourier Transform (STFT) and hence there is a restriction to apply these tools in image processing systems; particularly in image denoising applications. A filter bank plays an important role in wavelet transform applications. It consists of two banks namely, analysis filter bank and synthesis filter bank. The one dimensional filter bank is constructed with analysis and synthesis filter bank which is shown in[1]

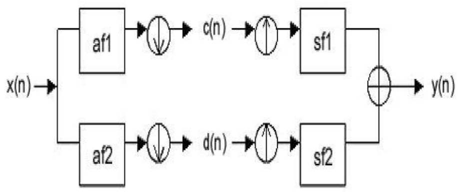

Fig. 1: one dimensional filter bank

III. CURVELET TRANSFORM

To overcome the disadvantages of wavelet, the theory of multiscale geometric analysis has been developed. In 1999, Donoho et al. proposed the concept of curvelet transform. Unlike wavelets, curvelets are localized not only in position (the spatial domain) and scale (the frequency domain), but also in orientation. This localization provides the curvelet frame with surprising properties: it is an optimally sparse representation for singularities supported on curves in two dimensions; it forms an optimally sparse basis for pseudo differential operators and Fourier integral operators and has become a promising tool for various image processing applications. Ridgelet transform overcomes the weakness of wavelet transform representing in two or higher dimensional .The edges of natural image are almost in curve, so the Ridgelet analysis of the images of the entire single-scale is not very effective. To singular curve with the multi-variable function, its performance is only close to the equivalent of wavelet transform. In order to solve the singular curve with the multi-variable function of the sparse approximation problem, we can turn to curvelet transform. The basic steps are as shown in Figure 2:[2]

Sub –band decomposition . through the wavelet transform it divided into a number of sub band

Components. For $N\times N$ image f, the first break will be:

$$f = P_0 f + \sum_{i=1}^{I} \Delta_i f_0 \qquad (1)$$

$P_0 f$ is for the low frequency components ,and $\sum_{i=1}^{I} \Delta_i f_0$ are for the high frequency components

Smooth partitioning . Each sub-band high frequency sub –divided into a number of pieces , with different sub-component division of the sub –block size can be different.

$$\Delta_s f \rightarrow \left(W_Q \Delta_s f\right) Q \epsilon Q_s \qquad (2)$$

W_Q represented in binary box as

$$Q = [\tfrac{K_1}{2^s}, (k_1+1)2^s] \times [\tfrac{K_1}{2^s}, (k_2+1)2^s] \qquad (3)$$

And it is the set of smooth function. This step allows each sub-band was smoothed by window function block.

Ridgelet decomposition. Each sub-band smooth partition of the sub block is for Ridgelet transform.

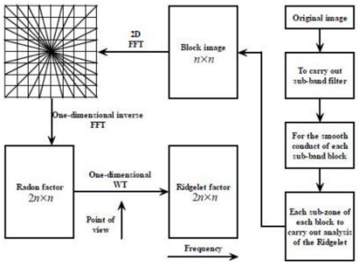

Fig. 2: Curvelet transform flow chart

IV. RESULT

Comparative analysis of Discrete wavelet transform(DWT), Reduced 2-D dual tree wavelet transform , Complex Dual tree wavelet transform and curvelet transform in terms of PSNR,SSIM and MSE we get following result.

A. PSNR Comparison

Standard gray scale test images of 512x512	PSNR (dB)				
	Before	After			
		DWT	Reduced 2-D dual-tree Wavelet Transform	complex 2-D dual-tree Wavelet Transform	Curvelet Transform
Lena	25.6564	27.9665	29.0392	29.7117	**32.6408**
Barbara	25.8873	27.8504	28.7825	29.3148	**30.1894**
Cameraman	25.6164	28.1392	29.2082	29.8796	**33.2439**
Mandril	25.5538	27.3255	28.0941	28.5299	**27.8725**
Peppers	26.6218	29.1801	30.2794	30.9655	**32.6090**
Pirate	26.4480	28.6461	29.5786	30.1635	**30.3077**

Table 1: Comparison of PSNR

B. SSIM Comparison

Standard gray scale test images of 512x512	SSIM				
	Before	After			
		DWT	Reduced 2-D dual-tree Wavelet Transform	complex 2-D dual-tree Wavelet Transform	Curvelet Transform
Lena	0.8058	0.8639	0.8892	0.9016	**0.9461**
Barbara	0.8694	0.9061	0.9231	0.9304	**0.9423**
Cameraman	0.7647	0.8335	0.8643	0.8796	**0.9435**
Mandril	0.9092	0.9248	0.9329	0.9361	**0.8965**
Peppers	0.8378	0.8920	0.9144	0.9248	**0.9504**
Pirate	0.8730	0.9079	0.9228	0.9295	**0.9213**

Table 2: Comparison of SSIM

C. MSE Comparison

Standard gray scale test images of 512x512	MSE			
	DWT	Reduced 2-D dual-tree Wavelet Transform	complex 2-D dual-tree Wavelet Transform	Curvelet Transform
Lena	103.8554	81.1270	69.4879	**35.3997**
Barbara	106.6707	86.0663	76.1375	**62.2499**
Cameraman	99.8058	78.0294	66.8533	**30.8099**
Mandril	120.3729	100.8483	91.2192	**106.1275**
Peppers	78.5363	60.9730	52.0633	**35.6598**
Pirate	88.8117	71.6499	62.6231	**60.5776**

Table 3: Comparison of MSE


Lena_org


Lena_noise


Lena_rec_standard


Lena_rec_reduced_2D_dual_tree

	
Lena_rec_complex_2D_dual_tree	Lena_rec_curvelet

Fig. 3: comparision of all images

V. CONCLUSION

The newly invented Curvelet transform perform best in image processing applications. In this paper, the concept focused is denoising using wavelet based image denoising methods of an image which is corrupted by noise. The techniques used are Dual-Tree Complex DWT andy Dual-Tree reduced DWT. These techniques give low performance as compared to the curvelet transform.

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