Noise Reduction in Video using Double Density Dual Tree Complex DWT

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***Abstract*- The wavelet transform provides a multiresolution representation using a set of analyzing functions that are dilations and translations of a few functions (wavelets). Images are getting corrupted by impulse noise during image acquisition and transmission. Here random noise is removed using this algorithm. So the image denoising is implemented using double density dual tree complex discrete wavelet transform which has significant advantages over real wavelet transform for certain signal processing problems. In this technique, two wavelet trees are used; one is generating the real part of the complex wavelet coefficient real tree and other generating the imaginary part of the complex wavelet coefficients imaginary tree. Simulation and experimental results demonstrate that the proposed technique can obtain better performance in the terms of both quantitative evaluation and visual Quality than the existing methods.**

***Index Terms*- Denoising, CWT, DWT, DTCWT and DDDTCWT.**

I. INTRODUCTION

Denoising is an important task in image processing and analysis and it plays a significant role in modern applications in different fields including medical imaging and preprocessing for computer vision. 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. A denoising method is used to 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 the peak signal to noise ratio. Traditionally, this is achieved by linear processing such as wiener filtering. Recently introduced dual tree complex wavelet transforms and double density dual tree complex dwt can give best results in image denoising applications.

Image denoising means usually compute the soft threshold in such a way that information present in image is preserved. Here the basic steps of wavelet based image denoising are given below.

1. Decompose corrupted image by noise using wavelet transform.
2. Compute threshold in wavelet domain and apply to noisy coefficients.
3. Apply inverse wavelet transform to reconstruct image.

A Fourier Transform (FT) is only able to retrieve the global frequency content of a signal, the time information is lost. A multi-resolution analysis becomes possible by using wavelet analysis. The Wavelet Transform (WT) retrieves frequency and time content of a signal. The basic types of wavelet transform are namely, (i) Continuous Wavelet Transform, (ii) Discrete Wavelet Transform and (iii) Complex Wavelet Transform.

A) Fourier Transform

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. The multi-resolution analysis becomes possible by using wavelet analysis. A Continuous Wavelet Transform (CoWT) is calculated analogous to the Fourier transform (FT), by the convolution between the signal and analysis function.

B) Discrete Wavelet Transform

The Discrete Wavelet Transform uses filter banks to perform the wavelet analysis. The simplest wavelet transform for multi-dimensional digital data is the critically sampled separable wavelet transform. This transform uses a 1-D wavelet transform in each dimension and is the one that is conventionally used. However, one way to improve the performance of wavelet based signal and image processing algorithms is to use specialized wavelet transforms in place of the conventional wavelet transform. There are several advances in the design of specific wavelet transforms that lead to substantially improved performance. For example, the undecimated wavelet transform, the steerable pyramid and curvelet transform all give improved results in applications involving multidimensional data. Recently developed dual- tree transform, an oriented complex-valued wavelet transform shown to be highly beneficial for multi dimensional signal and image processing. This transform has several advantages over the conventional multi dimensional wavelet transform: (1) near shift invariance (2) directional selectivity and (3) improved energy compaction. The discrete wavelet transform are based on perfect reconstruction two-channel filter banks. It consists of recursively applying a 2-channel filter bank - the successive decomposition is performed only on the low pass output.

C) Complex wavelet transform

This is a newly introduced technique of DWT. Orthogonal wavelet decompositions, based on separable, multirate filtering systems have been widely used in image and signal processing, largely for data compression. Kingsbury introduced a very elegant computational structure, the Dual-Tree complex wavelet transform which displays near-shift invariant properties. Kingsbury pointed out the problems of Mallat-type algorithms. These algorithms have the lack of shift invariance. Complex wavelets have not been used widely in image processing due to the difficulty in designing complex filters which satisfy a perfect reconstruction property. To overcome this, Kingsbury proposed a Dual-Tree implementation of the CWT (DT CWT), which uses two trees of real filters to generate the real and imaginary parts of the wavelet coefficients separately.

II. DUAL-TREE WAVELET TRANSFORM

Kingsbury's complex Dual Tree DWT is based on (approximate) Hilbert pairs of wavelets. Kingsbury found that the Dual Tree DWT is nearly shift-invariant when the lowpass filters of one DWT interpolate midway between the lowpass filters of the second DWT. The Dual-Tree Complex Discrete Wavelet Transform has been developed to incorporate the good properties of the Fourier transform in the wavelet transform. As the name implies, two wavelet trees are used, one generating the real part of the complex wavelet coefficients tree and the other generating the imaginary part tree.

The Dual Tree Complex DWT can be implemented using two critically-sampled DWTs in parallel as shown in the Fig. 3. This transform gives 2N DWT coefficients for an N-point signal. Hence this transform is known as 2-times expansive. Here the filters are designed in such a way that the subband signals of the upper DWT can be interpreted as the real part of a CWT and subbands signals of the lower DWT can be interpreted as the imaginary part. For specially designed sets of filters, the wavelet associated with the upper DWT can be an approximate Hilbert transform of the wavelet associated with the lower DWT. In this manner, the designed DTCWT is nearly shift-invariant than the critically sampled DWT.

The DTCWT gives wavelets in six distinct directions. In each direction, there are two wavelets. In each direction, one of the two wavelets can be interpreted as the real part and the other wavelet can be interpreted as the imaginary part of a complex-valued two dimensional (2D) wavelet. The DTCWT is implemented as four critically sampled separable 2D DWTs operating in parallel. However, different filter sets are used along the rows and columns. Fig. 1 indicates Dual Tree Complex DWT.

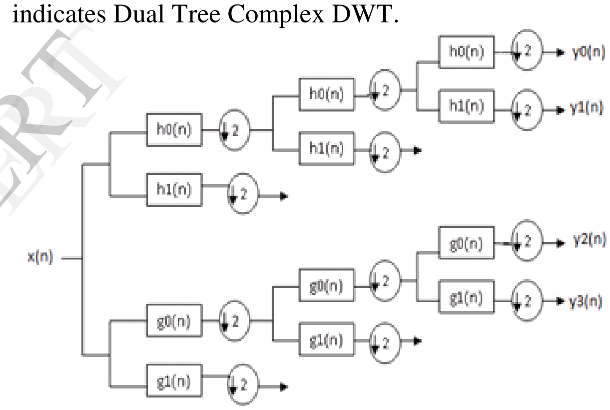


Fig. 1 Dual Tree Complex DWT

In the DTCWT, real valued wavelet filters produce the real and imaginary parts of the transform in parallel decomposition trees, permitting exploitation of well established real valued wavelet implementations and methodologies. A primary advantage of the DTCWT lies in that it results in decomposition with a much higher degree of directionality than that possessed by the traditional DWT. The real valued filter coefficients are replaced by Complex valued coefficients by proper design methodology that satisfies the required conditions for convergence. Then the complex filter can again be decomposed into two real valued filters. Thus two real valued filters that give their respective impulse responses in quadrature will form the Hilbert transform pair. The combined pair of two such filters is termed as an analytic filter.

III. PROPOSED SYSTEMS

By introducing Complex wavelet transforms concept, we can achieve Dual Tree Complex DWT system. Also combining the Double Density DWT and Dual Tree Complex DWT, we can achieve the Double Density Dual Tree Complex DWT system. Complex wavelet transform use 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 compute amplitude and phase information.

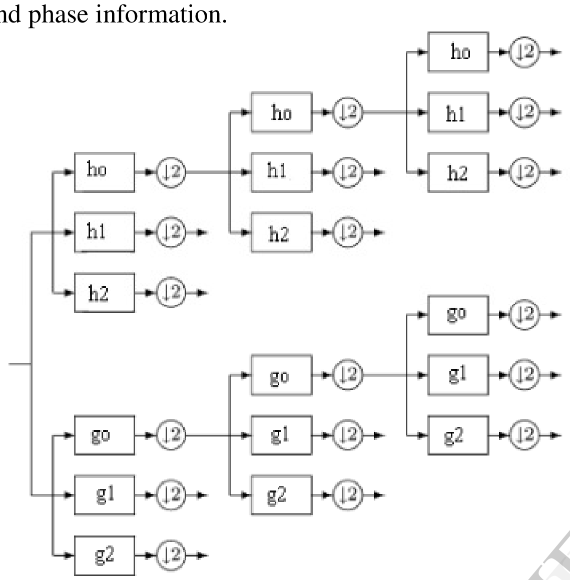


Fig. 2 Double Density Dual Tree Complex DWT

Double Density DWT performs superior than the standard DWT in terms of enhancement in two dimensions. But here all of the wavelets are not directional. Though the Double Density DWT utilizes more wavelets, some lack a dominant spatial orientation, which prevents them from being able to isolate those directions. A solution to this problem is provided by the Double Density Dual Tree Complex DWT, which combines the characteristics of the Double Density DWT and the Dual Tree DWT. The DDDTCWT is based on two scaling functions and four distinct wavelets, each of which is specifically designed such that the two wavelets of the first pair are offset from one other by one half, and the other pair of wavelets form an approximate Hilbert transform pair. The DDDTCWT is 4-times expansive. It yields two wavelets in the same dominating orientations.

By ensuring these properties, the double-density complex DWT possesses improved directional selectivity and can be used to implement complex and directional wavelet transforms in multiple dimensions. We construct the filter bank structures for both the double-density DWT and the double- density complex DWT using finite impulse response (FIR) perfect reconstruction filter banks. These filter banks are then applied recursively to the low pass subband, using the analysis filters for the forward transform and the synthesis filters for the inverse transform. By doing this, it is then possible to evaluate each transforms performance in several applications including signal and image enhancement.

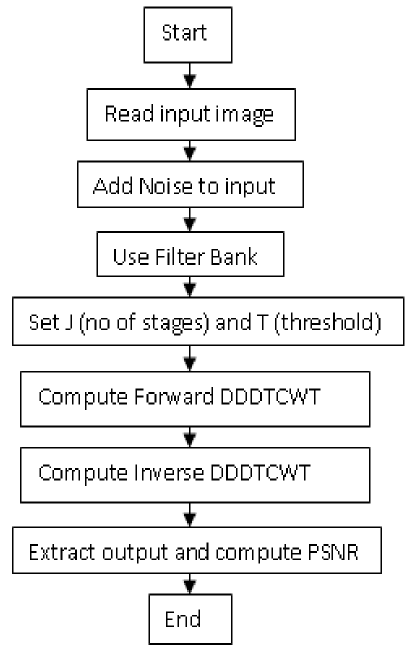


Fig. 3 Flowchart of Double Density Dual Tree Complex DWT

The differences between the double-density DWT and the dual-tree DWT can be clarified with the following comparisons.

1) In the dual-tree DWT, the two wavelets form an approximate Hilbert transform pair, whereas in the double-density DWT, the two wavelets are offset by one half.

2) For the dual-tree DWT, there are fewer degrees of freedom for design (achieving the Hilbert pair property adds constraints), whereas for the double-density DWT, there are more degrees of freedom for design.

3) Different filter bank structures are used to implement the dual-tree and double-density DWTs.

4) The dual-tree DWT can be interpreted as a complex valued wavelet transform, which is useful for signal modeling and denoising (the double-density DWT cannot be interpreted as such).

5) The dual-tree DWT can be used to implement 2-D transforms with directional Gabor-like wavelets, which is highly desirable for image processing (the double-density DWT cannot be, although it can be used in conjunction with specialized post- filters to implement a complex wavelet transform with low-redundancy, as developed.

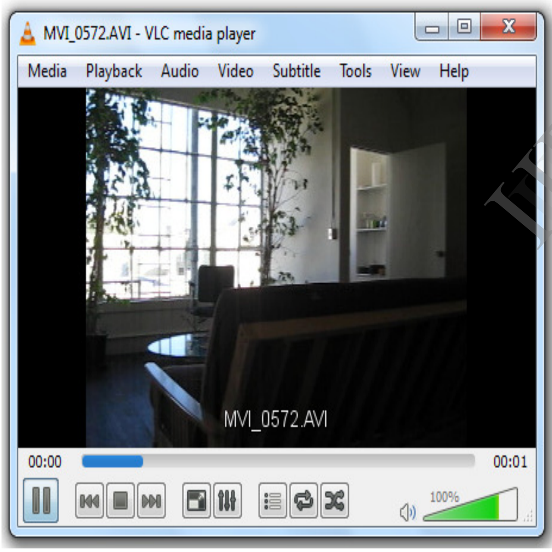
IV. RESULTS AND DISCUSSIONS

The performance of the proposed algorithm is tested for various levels of noise corruption and compared with Dual Tree Complex Wavelet Transform. The algorithm is implemented in MATLAB 7.2 on a PC equipped with 2.4 GHz CPU and 2 GB RAM memory for the evaluation of computation time of algorithms. The Quantitative performance of the proposed algorithm is evaluated based on Peak signal to noise ratio and Mean Square Error which is given as

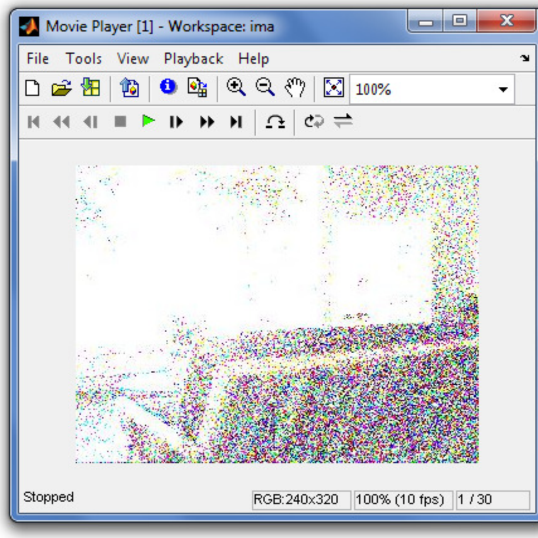
$$\text{PSNR} = 10\log_{10}\frac{255^2}{MSE} \quad (1)$$

$$\text{MSE} = \frac{1}{MN}\sum_{i-1}^{M}\sum_{j-1}^{N}(Rij - Xij)^2 \quad (2)$$

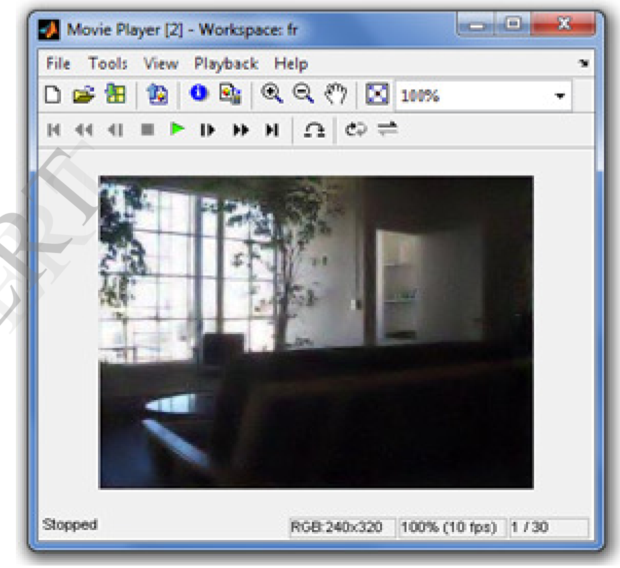
In addition to the visual quality, the performance of the developed algorithm and other standard algorithms are quantitatively measured by the following parameters such as peak signal-to-noise ratio (PSNR) and Mean square error (MSE).



(a) Input Video



(b) Noisy Video



(c)

(d) Restored Video

Fig. 4 (a) Input Video (b) Video corrupted by random noise with 20 Percent noise density and (c) Restored Video

TABLE I

PSNR of DTCWT and DDDTCWT for different noise densities

Noise Density	DTCWT PSNR (db)	DDDTCWT PSNR (db)
10	34.3432	32.3623
30	29.6963	30.4888
50	28.5542	28.8194

70	28.1860	28.2885

The proposed algorithm shows excellent noise suppression and edge preservation capabilities. The proposed algorithm effectively removes the random noise and preserves edges for low, medium and high detail images.

The PSNR value of the proposed algorithm is compared against the DTCWT by varying the noise density from 10% to 70% and is shown in Table I. From the table, it is clear that the DDDTCWT gives better PSNR values irrespective of the nature of the input image.

V. CONCLUSION

The newly invented extensions of the DWT perform best in image processing applications. In this paper, the concept focused is wavelet based image denoising methods of an image which is corrupted by additive Gaussian noise. The proposed one is a hybrid model of Complex Dual Tree DWT and Complex Double Density DWT. The complex double density dual tree discrete wavelet transform outperforms in comparison with others wavelet transform in the highly corrupted images. The techniques used are Dual-Tree Complex DWT and Double-Density Dual-Tree Complex DWT. By using this technique, the noise is getting reduced and also we can get the originality of the image. These techniques give high performance as compared to the existing basic DWT methods. As noise increases Double-Density Dual-Tree Complex DWT works superior than Dual-Tree Complex DWT.

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