

2D-DTDWT Based Image Denoising using Hard and Soft Thresholding

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ABSTRACT

Wavelet Techniques can be applied successfully in various signal and image processing techniques such as image denoising, segmentation and motion estimation. Complex Discrete Wavelet Transform (CDWT) has significant advantages over real wavelet transform for certain signal processing problems. CDWT is a form of discrete wavelet transform, which generates complex coefficients by using a dual tree of wavelet filters to obtain their real and imaginary parts. This Paper describes the application of complex wavelets for denoising the corrupted images and the results are compared with normal Discrete Wavelet Transform (DWT) and Stationary Wavelet Transform (SWT). The algorithm exhibits consistency in denoising for different Signal to Noise Ratios (SNRs).

Keywords - Complex Wavelet Transform (CWT), Denoising, Discrete Wavelet Transform (DWT), Stationary Wavelet Transform (SWT).

1. INTRODUCTION

It is important to reduce noise before trying to extract features from a noisy image. Many filters have been developed to improve image quality. Recently there has been considerable interest in using wavelet transform as a powerful tool for recovering data from noisy data. It also suffers from the following problems (Kingsbury 2001).

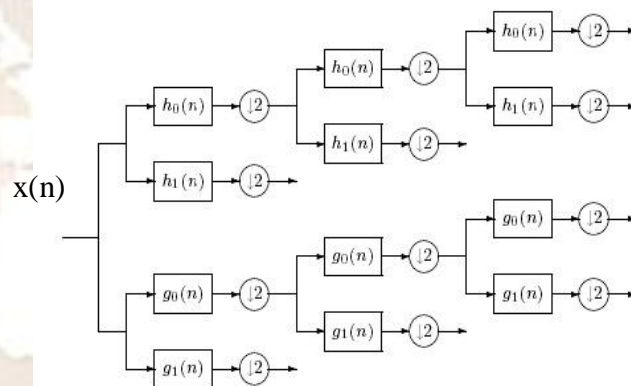
- Lack of shift invariance - when the input signal is shifted slightly, the amplitude of the wavelet coefficients varies so much.
- Lack of directional selectivity - as the DWT filters are real and separable the DWT cannot distinguish between the opposing diagonal directions.

These problems delay the progress of using the wavelets. The first problem can be avoided if the filter outputs from each level are not down sampled but this increase the computational cost. The resulting undecimated Wavelet transform still cannot distinguish between opposing diagonals. To achieve this complex wavelet filters can be used. But the complex wavelets have difficulty in designing complex filters which satisfy perfect reconstruction.

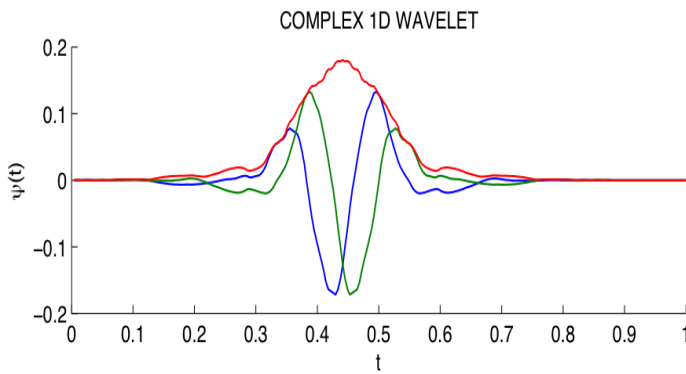
To overcome this, Kingsbury proposed a dual tree implementation of the complex wavelet transform (DT CWT) which uses 2 trees of real filters to generate the real and imaginary parts of the wavelet coefficients separately.

II. DUAL TREE COMPLEX WAVELET TRANSFORM

The dual-tree complex DWT of a signal X is implemented using two critically-sampled DWTs in parallel on the same data, as shown in the figure.



The transform is 2-times expansive because for an N -point signal it gives $2N$ DWT coefficients. If the filters in the upper and lower DWTs are the same, then no advantage is gained. However, if the filters are designed in a specific way, then the subband signals of the upper DWT can be interpreted as the real part of a complex wavelet transform, and subband signals of the lower DWT can be interpreted as the imaginary part. Equivalently, 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. When designed in this way, the dual-tree complex DWT is nearly shift-invariant, in contrast with the critically-sampled DWT. Moreover, the dual-tree complex DWT can be used to implement 2D wavelet transforms where each wavelet is oriented, which is especially useful for image processing. (For the separable 2D DWT, recall that one of the three wavelets does not have a dominant orientation.) The dual-tree complex DWT outperforms the critically-sampled DWT for applications like image denoising and enhancement.



III. 2D DUAL TREE WAVELET TRANSFORM

One of the advantages of the dual-tree complex wavelet transform is that it can be used to implement 2D wavelet transforms that are more selective with respect to orientation than is the separable 2D DWT. 2-D dual-tree DWT of an image x is implemented using two critically-sampled separable 2-D DWTs in parallel. Then for each pair of subbands we take the sum and difference. The wavelet coefficients w are stored as a cell array. For $j = 1..J$, $k = 1..2$, $d = 1..3$, $w\{j\}\{k\}\{d\}$ are the wavelet coefficients produced at scale j and orientation (k,d) . The six wavelets associated with the real 2D dual-tree DWT are illustrated in the following figures as gray scale images.

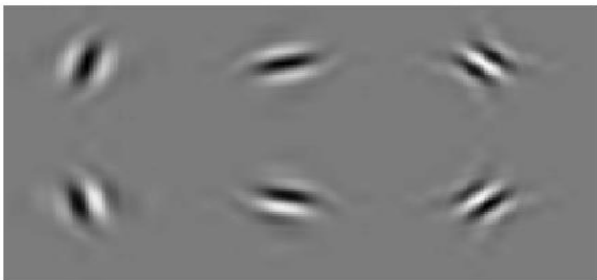


Fig: Directional wavelets for reduced 2-D DWT

Note that each of the six wavelet are oriented in a distinct direction. Unlike the critically-sampled separable DWT, all of the wavelets are free of checker board artifact. Each subband of the 2-D dual-tree transform corresponds to a specific orientation.

IV. DENOISING

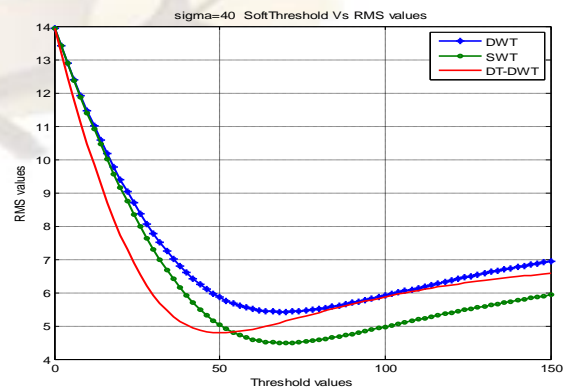
In an image like bacteria the information (micro cells) are very important, if it is corrupted with noise it will be difficult to segment the number of cells. Hence denoising may be useful for improving the SNR. By improving the SNR the segmentation is related to SNR. Thus the probability of detecting the number of cells may be improved.

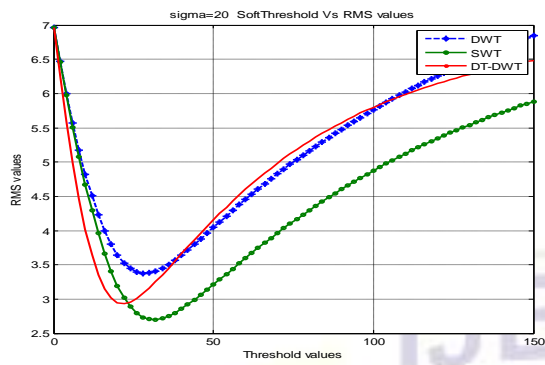
One technique for denoising is wavelet thresholding (or "shrinkage"). When we decompose the data using the wavelet transform, some of the resulting wavelet coefficients correspond to details in the data set (high frequency sub-bands). If the details are small, they might be omitted without substantially affecting the main features of the data set. The idea of thresholding is to set all high frequency sub-band coefficients that are less than a particular threshold to zero. These coefficients are used in an inverse wavelet transformation to reconstruct the data set

V. ALGORITHM

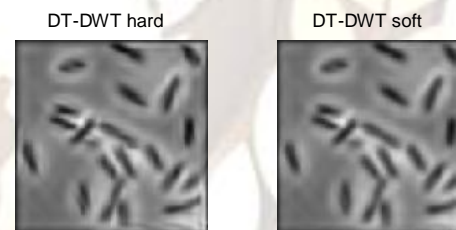
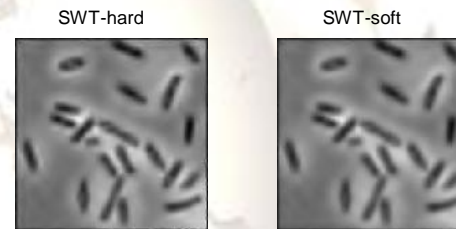
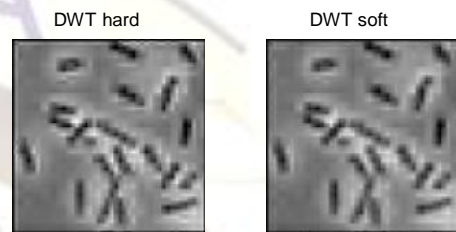
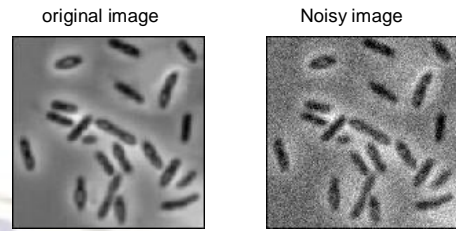
1. The standard test images like bacteria, lena are considered and are corrupted by additive White Gaussian Noise. It is given as $x = s + \sigma.g$ where s is original image, x is noisy image corrupted by additive white gaussian noise g of standard deviation σ . Both s and x are of same sizes
2. The dual tree complex wavelet transform uses 10 tap filters for analysis at different stages. The reconstruction filters are obtained by simply reversing the alternate coefficients of analysis filters.
3. Perform the 2D Dual tree DWT to level $J = 4$. During each level the filter bank is applied to the rows and columns of an image.
4. Different threshold values with soft Thresholding is applied for each subband coefficients.
5. The inverse DT DWT is performed to get the Denoised image.
6. The quantitative measures, Mean Square Error and Peak Signal to Noise Ratio are determined for different thresholds.

Graphs have been plotted for different values of Thresholds and the RMSE values for $\sigma = 40$ and $\sigma = 20$.

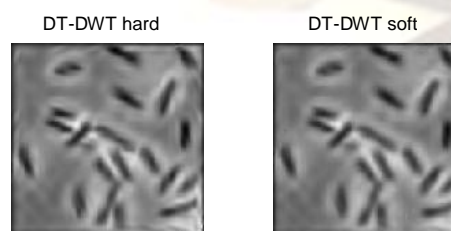
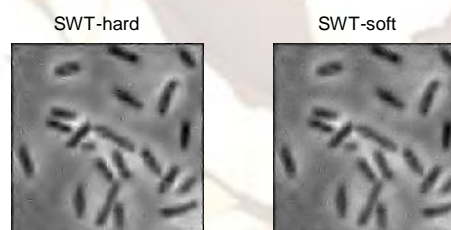
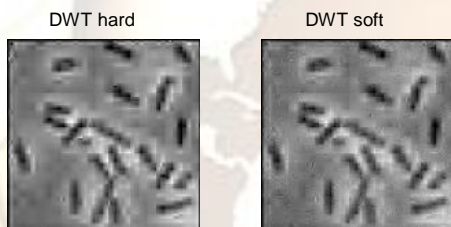
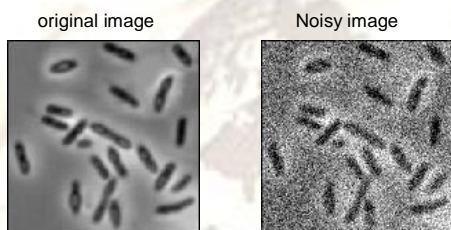




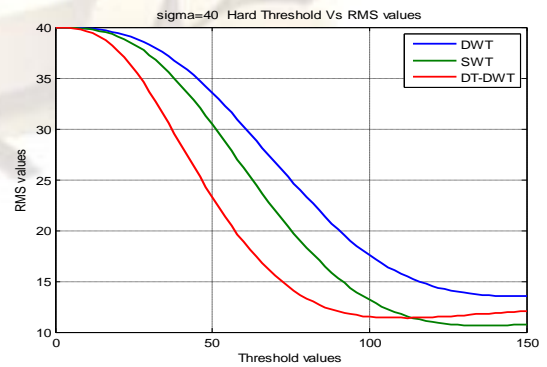
sigma=20

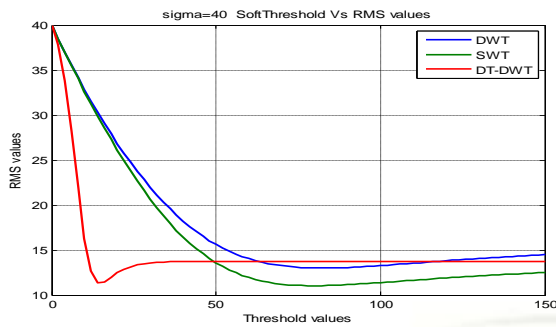


Sigma=40



Results for Lena image.





VI. RESULTS

1. Under low noise conditions SWT method performs better than DWT and DT-DWT
2. Under high noise conditions DT-DWT method performs better than DWT and SWT

3. For Low threshold values and under low noise conditions SWT method performs better than DWT and DT-DWT
4. For Low threshold values and under high noise conditions DT-DWT method performs better than DWT and SWT
5. Hence Low threshold values give superior denoising capabilities where as high threshold values results the probability of losing the information more.

CONCLUSION

Significant improvement of PSNR is reported by denoising using 2D Dual tree wavelet transform compared to other transform techniques. This method is useful whenever segmentation of objects is needed

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