Contourlet Transform for Speckle Denoising

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***Abstract*—**In image processing, considering fields like remote sensing and medical applications, Speckle (Multiplicative) noise dominates which affects the valuable features and important information of the image. To denoise an image, various transforms are used. But they are not efficient in case of preserving the edges which is the important factor in image processing for Image denoising. In this paper we have used the new algorithm based on the transformation named 'Contourlet Transform'. This algorithm is more efficient than the wavelet algorithm in Image Denoising particularly for the removal of speckle noise. The parameters considered for comparing the wavelet and Contourlet Transforms are SNR and IEF. The results show that this proposed algorithm outperforms the wavelet in terms of SNR, IEF values and visual perspective as well.

***Keywords*—** Denoising, Contourlet Transform, SNR etc.

I. Introduction

In Remote sensing applications, the major problem arises with the Speckle noise. Speckle noise degrades the quality of the image and affects the performance of important image processing techniques such as detection, segmentation, and classification. Till now it's believed that Wavelet Transform is suited for denoising the Speckle noise. But using this proposed algorithm based on Contourlet Transform, we can achieve better results comparatively.

A. Contourlet Transform

The Contourlet transform [2] is a directional transform which is capable of capturing contour and fine details in a image. The approach in this transformation starts with the discrete domain construction and then sparse expansion in the continuous domain. The main difference between Contourlet and other transformations is that, in this new transformation Laplacian pyramid [4] along with the Directional Filter Banks [1, 3] are used. As a result, this not only detects the edge discontinuities, but also converts all these discontinuities into continuous domain. The figure below illustrates the Contourlet Transformation, in which the input image consists of frequency components like LL (Low Low), LH (Low High), HL (High Low), and HH (High Low). The Laplacian Pyramid at each level generates a Low pass output (LL) and a Band pass output (LH, HL, and HH). The Band pass output is then passed into Directional Filter Bank [1, 3] which results in Contourlet coefficients. The Low pass output is again passed through the Laplacian Pyramid [4] to obtain more coefficients and this is done till the fine details of the image are obtained.

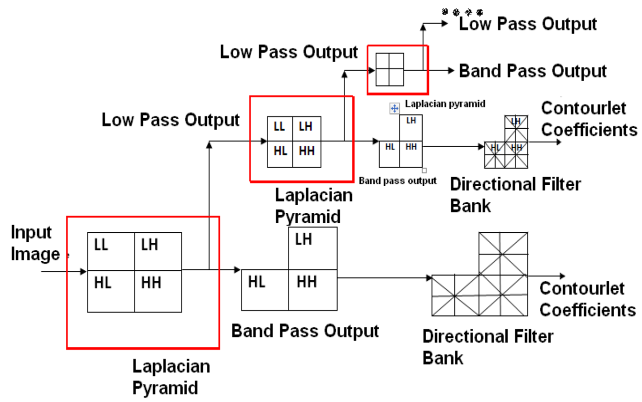

Fig 1.1 Illustration of Contourlet Transform

The Contourlet Transform [2] of a signal 'x' is calculated by passing it through a series of low pass and band pass filters. The output of these two filters are required to calculate the Contourlet coefficients.

$$Y_{low}[n] = \sum_{k=-\infty}^{\infty} x[k]g[2n-k] \qquad 1.1$$

$$Y_{band}[n] = \sum_{k=-\infty}^{\infty} x[k]h[2n-k] \qquad 1.2$$

Equation 1.1 and 1.2 are the outputs of the filter and are the contourlet coefficients. The Low pass and Band pass filters are used for Contourlet decomposition.

II. DENOISING ALGORITHM

A common approach for image denoising is to convert the noisy image into a transform domain such as the wavelet and Contourlet domain, and then compare the transform coefficients with a fixed threshold. We propose an algorithm which defines a new threshold value to eliminate the corrupted pixels.

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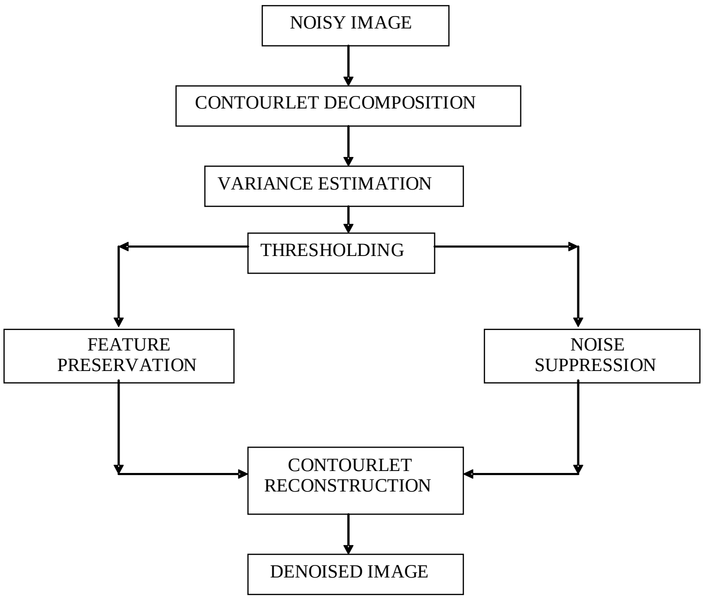

FIG 2.1 Threshold Algorithm

III. ALGORITHM DESCRIPTION

A. The process starts with the noisy image.

B. This image is converted into Contourlet Transform domain, using the decomposition process. In Wavelet, we determine the coefficients using scaling and a wavelet filter. But, in Contourlet, we construct discrete-domain multiresolution and multi direction using non-separable filter banks, in the same way wavelets are obtained from the filter banks. This construction results in flexible multiresolution, local and directional image expansion using contour sectors and so named Contourlet transform.

C. Thus from the decomposition process the coefficients are determined.

D. Then for each noisy image pixels, the variance is estimated.

E. The resultant values are then compared with a threshold value to determine whether the pixel is corrupted or not.

F. If the pixels are corrupted, they are suppressed or modified. Otherwise the pixels are preserved for further process.

G. Then all the resultant coefficients are reconstructed which results in denoised image.

H. After reconstruction the SNR and the IEF values are calculated for this algorithm.

IV. THRESHOLDING

Generally for denoising, the coefficients of the noisy image are compared with the threshold value. These threshold values are either obtained by trial and error method. Since human eyes are very sensitive to intensity of neighboring pixel values, in image denoising techniques, the variance in homogeneous regions must be less. Considering the threshold values depending on the variance, the noise level in the corrupted image still decreases.

In this algorithm, a threshold value is set based upon the variance of the corrupted image. Based upon the results from various variance levels (nvar), the threshold is fixed. The intensity of the noise being added to the image (th) and the standard deviation of the noise less image (sigma) are also the deciding factors in fixing the threshold values.

Based upon the various results obtained, we deduce that the threshold values must be fixed depending upon the high noise level and low noise level. In Speckle noise, the default variance level is 0.04, so considering Speckle noise variance (nvar) above 0.05 as high noise level and below 0.05 as low noise level, we introduced two threshold values separately. The results also prove that this two separate threshold values improve the denoising ability of the algorithm.

Now to reconstruct the image, the coefficients above the threshold values are retained for Contourlet reconstruction and the coefficients below the threshold values are suppressed. The retained coefficients are reconstructed to obtain the Denoised image. This process is shown in the figure 2.1.

There are many other algorithms available for denoising the image particularly for the speckle corrupted images in remote sensing applications. But this algorithm is very simpler and effective compared to other algorithms. If the algorithm is simpler, then the time consumed for complete denoising of the image will be less and the hardware implementation will also be feasible with high memory VLSI technologies.

V.RESULTS AND DISCUSSION

A. Quantitative Results For Multiplicative (Speckle) Noise

The Standard test images considered for denoising are Lena, Pepper, Barbara and Satellite, Medical images. The evaluation parameters used for comparing Wavelet and the proposed algorithm using Contourlet Transform are SNR, IEF and Visual quality assessment. The table 5.1 below shows the comparative results between wavelet and proposed algorithm using Contourlet Transform.

The significance and definition of these parameters are that,

Signal to Noise Ratio (SNR) is the ratio between amplitude of the signal value (M) to the amplitude of noise (N).

SNR = 10 log (M/N) dB

Higher the SNR value more is the amount of information that can be obtained from the test sample.

IEF (Image Enhancement Factor) is used to determine the edge preserving capabilities of the considered transformation.

IEF can be defined as the ratio between the square of difference between the noisy image and the original image to the square of difference between the enhanced image and the reference image.

If the IEF (Image Enhancement Factor**)** value is high, it means that more edges are preserved and the information in those edge regions also can be extracted.

For different Speckle noise level densities we have obtained various SNR and IEF values of Wavelet and the

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proposed algorithm using Contourlet Transform, that are tabulated. From these quantitative results we infer that the new proposed algorithm using Contourlet Transform outperforms Wavelet.

Images	SNR(dB)		IEF	
	Wavelet	Proposed algorithm using Contourlet	Wavelet	Proposed algorithm using Contourlet
	NOISE LEVEL=0.03dB			
LENA	9.44	11.77	2.01	3.45
PEPPER	10.73	11.36	2.10	2.43
SATELLITE	8.22	10.32	1.85	3.00
MEDICAL	13.36	15.73	3.02	5.25
BARBARA	10.04	9.81	1.65	1.57
	NOISE LEVEL=0.04dB			
LENA	7.94	10.95	1.87	3.75
PEPPER	9.21	10.68	1.97	2.75
SATELLITE	6.65	9.34	1.69	3.16
MEDICAL	11.55	14.81	2.66	5.62
BARBARA	8.84	9.39	1.66	1.88
	NOISE LEVEL=0.06dB			
LENA	5.75	10.01	1.66	4.44
PEPPER	7.02	9.65	1.75	3.19
SATELLITE	4.47	8.40	1.52	3.76
MEDICAL	8.84	14.56	2.13	8.03
BARBARA	6.99	8.67	1.58	2.33
	NOISE LEVEL=0.1dB			
LENA	3.15	8.20	1.47	4.75
PEPPER	4.44	8.56	1.55	3.97
SATELLITE	1.95	6.48	1.37	3.88
MEDICAL	5.65	12.00	1.71	7.36
BARBARA	4.56	7.66	1.45	2.96

Table5.1 Comparative results between wavelet and proposed algorithm using Contourle

B. Qualitative Results

a) Original image

b) noisy image

c) Wavelet denoising
SNR = 3.15 dB
IEF = 1.47

d) Proposed algorithm
SNR = 8.20 dB
IEF = 4.75

FIG 5.1 Results of filter(for Lena image with speckle variance= 0.1)

The test image considered for testing is the 'Lena' image, shown in fig 5.1a. The image is corrupted with the Speckle noise variance of 0.1 and the corrupted image is shown in fig 5.1b. The fig 5.1c show the Wavelet denoised image and the fig 5.1d shows the proposed algorithm based on Contourlet transformation. There is a significant improvement in SNR and IEF values in the proposed algorithm compared to the Wavelet transform. Visually too, it's evident that the Proposed algorithm has more information comparatively.

Another test image considered for experimenting is the 'Satellite image', shown in 5.2a. The image is corrupted with the Speckle noise variance of 0.04 and the corrupted image is shown in fig 5.2b. The fig 5.2c show the Wavelet denoised image and the fig 5.2d shows the proposed algorithm based on Contourlet transformation. In remote sensing applications, extracting information from the contours is crucial. With high IEF value it's apparent in the proposed algorithm that it contains more information to be extracted.

a) Original image

b) noisy image

c) Wavelet denoising
SNR = 6.65 dB
IEF = 1.69

d) Proposed algorithm
SNR = 9.34 dB
IEF = 3.16

FIG 5.2 Results of filter (for Satellite image with speckle variance= 0.04)

So it is evident with the results that this proposed algorithm based on Contourlet transform is best suit for Satellite image applications.

VI. CONCLUSION

In this paper, the removal of speckle noise from images has been discussed. Hence the new proposed algorithm based on the Contourlet transformation is found to be more efficient than the wavelet algorithm in Image Denoising particularly for the removal of speckle noise. This is concluded based on considering test images like Lena, Barbara, Peppers along with Satellite images and Medical images after corrupting with Speckle noise which is a multiplicative noise of various noise levels like 0.03dB, 0.04dB, 0.06dB and 0.1dB. Thus the obtained results in qualitative and quantitative analysis shows that this proposed algorithm outperforms the wavelet in terms of SNR, IEF values and visual perspective as well. The algorithms are implemented using MATLAB 7.5 R2007b. This can be implemented using hardware also and the feasible hardware is using VLSI with high memory.

VII. REFERENCES

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