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Satellite Image Enhancement and denoising

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Abstract: Now a day image processing has a great application in satellite science. This paper proposed a denoising technique based on wavelet transform for satellite images. Acquisition and Transformation of satellite images caused noise. The noises in the satellite images can be additive and multiplicative noises. The proposed method is efficient in removing both the noises. A threshold value is determined using soft thresholding and the wavelet coefficients are thresholded and recovered. Performance parameters such as Peak Signal-to-Noise Ratio (PSNR), Structural Similarity (SSIM) and Edge Preservation Index (EPI) are used in this paper to evaluate the efficacy of the proposed method. From the simulation results it is found that the proposed denoising method has achieved improved results than the state-of-the-art methods.

Keywords: Wavelet Transform, De-noising, Satellite Images

1. INTRODUCTION

Satellite images quality degradation occurs due to the contamination of noise during acquisition and transformation which results the degradation of image quality. So in satellite image processing, an image de-noising process is highly required. In literature several filtering approaches have been implemented by authors for reducing noise from satellite images. These filtering approaches can be broadly categorized in to three categories. They are algorithmic, transform, and statistical modeling approaches. Algorithmic approaches include Adaptive median [1], Bilateral filtering [2], Rotating kernel transformation [3], Non-local mean filter [4] and Anisotropic diffusion filter [5]. Transform approach involves filtering using wavelet transform [6], Contourlet transform [7], and Curvelet transform [8]. Statistical modeling

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approached filters are designed by utilizing the statistical behavior of the noise and signal. Filters based on algorithmic approach suffer from limitations like loss of structural details and high computational complexity. Filters based on transform approach suffer from determination of accurate threshold value. Statistical modeled filters are generally depending on the choice of prior and estimator [9, 17].

Wavelet thresholding filter is a common type of wavelet-based filter. The basic steps of this type of filters involve generation of wavelet coefficients, modification of wavelet coefficients and recovering of image from the modified wavelet coefficients. For modifying the wavelet coefficients a threshold value is required and the denoising efficiency depends on the threshold value. Soft and Hard thresholding methods are widely used by the researchers and have been proved more promising in removing the multiplicative noise.

This paper applies soft thresholding to the logarithmic transformed wavelet coefficients and the thresholding value is found out by modeling the wavelet coefficients statistically. The organization of the paper is as follows. Section 2 discusses about Cauchy PDF, statistical modeling of wavelet coefficients and Soft thresholding. Section 3 gives the denoising methodology. Simulation results are elaborated in section 4 and conclusion is given in section 5.

2. BACKGROUND

This section discusses the preliminaries of the proposed denoising method. Cauchy PDF which is used for modeling the wavelet coefficients is discussed. Soft threshold methodology is also discussed in this section.

2.1 Cauchy PDF

A well appropriate probability density function (PDF) is required for estimating the noise-free wavelet coefficients. This paper utilizes Cauchy PDF for modeling the wavelet coefficients due to its heavy-tail structure. Assuming X as a Cauchy random variable, Cauchy PDF and Cumulative Distribution Function (CDF) are defined by the following expressions [11]:

$$f(x) = \frac{1}{\pi} \frac{c}{(x-m)^2 + c^2} \tag{2}$$

$$F(x) = \frac{1}{2} + \frac{1}{\pi} \tan^{-1}\left(\frac{x-m}{c}\right) \tag{3}$$

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Where m is the location and c is the scaling parameters. The PDF and CDF graphs are shown in figures 2 and 3 respectively.

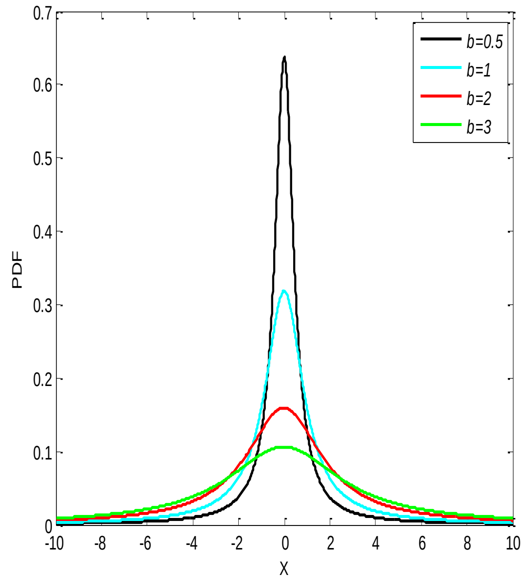

Fig. 2: Cauchy PDF for different values of scaling parameters

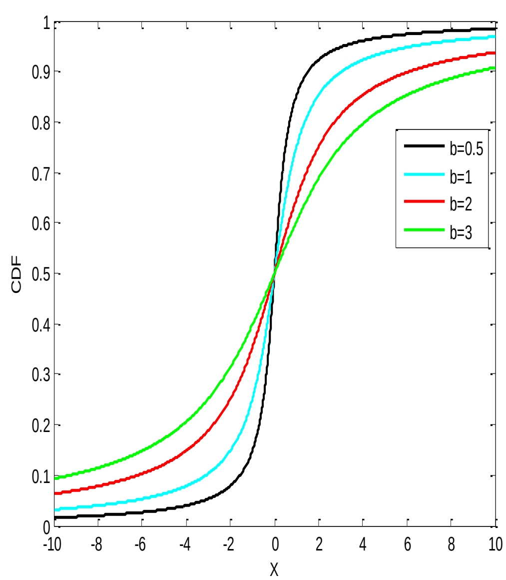

Fig. 3: Cauchy CDF for different values of scaling parameters

2.2 Statistical Modeling of Wavelet Coefficients of Satellite Image

Wavelet coefficients are generated from the satellite image are modeled using Cauchy PDF to find out the signal and noise information. The distribution of wavelet coefficients in the approximation sub-band at level-1 is shown in figure 4. The noise-free signal density is calculated from the detailed sub-bands. The noise density is calculated from the diagonal detail sub-band of at level-1 [12].

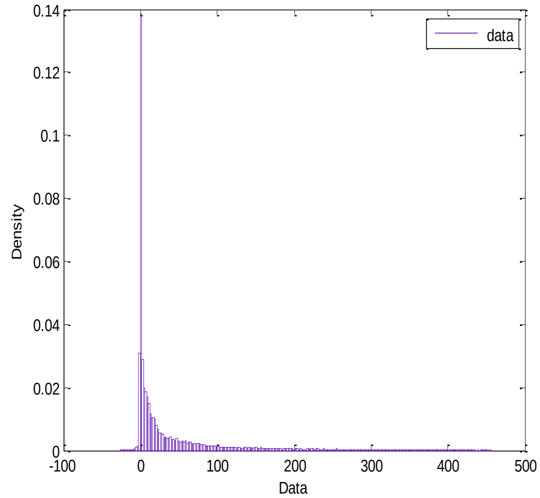

Fig. 4: Wavelet coefficient distribution in approximation sub-band at level-1

2.3 Soft Thresholding

Soft thresholding procedure narrows the wavelet coefficients C whose values lies above the threshold level. The soft thresholding function given by Zaki et al. [13] is:

$$Soft_{th} = \begin{cases} 0; & |C| \leq t_h \\ sgn(C) \quad [|C| - t_h]; & |C| > t_h \end{cases} \tag{4}$$

t_h is the threshold value which is defines as:

$$t_h = \frac{\sigma_N^2}{\sigma_S} \tag{5}$$

σ_N^2 is the variance of the noise and calculated from the diagonal sub-band coefficients at level-1 ($D1$). It is given by [14]:

$$\sigma_N^2 = \left(\frac{median(D1)}{0.6745}\right)^2 \tag{5}$$

σ_S is the standard deviation of the noise-free signal defined by the fundamental theorem of probability as:

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$$\sigma_S = \sqrt{\overline{C^2}} \tag{17}$$

$\overline{( )}$ is the expectation operation.

3. METHODOLOGY

The complete denoising procedure is explained through the following procedural steps and also the explained through the block diagram given in the figure 5.

Step 1. Input satellite image.

Step 2. Application of discrete wavelet transform (DWT) to the image obtained from step2.

Step 3. Calculation of threshold value.

Step 4. Application of soft thresholding to recover the wavelet coefficients.

Step 5. Application of Inverse discrete wavelet waveform (IDWT) to recover the image.

Step 6. Application of exponential operation (EXP) to the image obtained from step 6 to get the noise free satellite image.

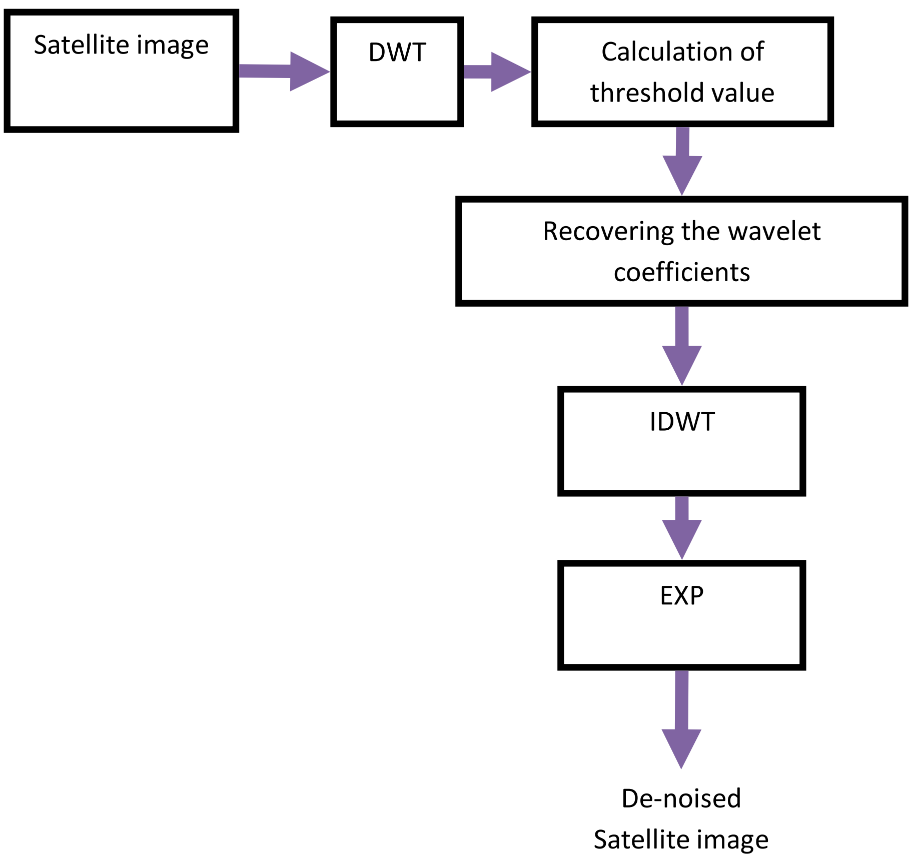

Fig. 5: Block diagram of the proposed method

4. SIMULATION RESULTS

The proposed methodology is simulated in ultrasound image of size 344×289 [15] using MATLAB environment. A third level db8 in Daubechies group is used for simulation. The proposed method is compared with different state-of-the-art methods [16, 13] using different parameters such as PSNR, SSIM and EPI. The qualitative comparison is shown in figure 6. From this figure it is seen that the visual quality of the satellite image obtained by applying the proposed method is better than the other state-of-the-art methods. The performance parameters comparisons are given in tables 1, 2, and 3.

From tables 1, 2 and 3 it can be viewed that the PSNR(dB), SSIM and EPI values are better for the proposed method than the state-of-the-art methods irrespective of the noise variance value. The PSNR improvement of the proposed method is 10.42% and 8.22% than the Donoho's Soft threshold [16] and Zaki et al. [13] methods respectively for noise variance of 0.1. The SSIM improvement of the proposed method is 2.27% and 0.72% than the Donoho's Soft threshold [16] and Zaki et al. [13] methods respectively for noise variance of 0.1. The EPI improvement of the proposed method is 3.21% and 1.99% than the Donoho's Soft threshold [16] and Zaki et al. [13] methods respectively for noise variance of 0.1.

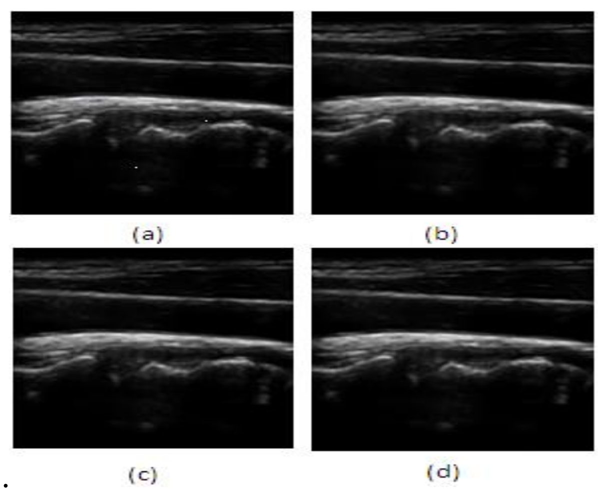

Fig. 6: De-noising performance (a) Original image (b) Donoho's Soft threshold method [19] (c) denoising result with Zaki et al. [10] (d) proposed method.

Table 1.PSNR (dB) Parameter comparison for different methods

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Noise Standard deviation	Donoho's Soft threshold [16]	Zaki et al. [13]	Proposed Method
0.1	28.66	29.34	31.88
0.2	27.39	28.05	30.32
0.3	26.82	27.98	29.66
0.4	25.55	26.77	28.52

Table 2. SSIM Parameter comparison for different methods

Noise Standard deviation	Donoho's Soft threshold [16]	Zaki et al. [13]	Proposed Method
0.1	0.947	0.968	0.966
0.2	0.864	0.913	0.955
0.3	0.835	0.875	0.943
0.4	0.747	0.867	0.911

Table 3. EPI Parameter comparison for different methods

Noise Standard deviation	Donoho's Soft threshold [16]	Zaki et al. [13]	Proposed Method
0.1	0.833	0.884	0.903
0.2	0.857	0.876	0.896
0.3	0.825	0.835	0.887
0.4	0.809	0.825	0.878

5. CONCLUSION

A de-noising technique using the improved Wavelet thresholding was presented in this paper. Multiresolution was applied to the image and resulted wavelet coefficients were modeled using Cauchy PDF and Gaussian PDF to get the signal and noise parameters. The threshold value was calculated from these information and further, the wavelet coefficients were soft thresholded to obtain the updated wavelet coefficients. From the comparison results it is seen that the proposed improved soft thresholding technique obtained better result than the state-of-the-art methods.

In future the proposed method may be applied for digital image to recover the true image.

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