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Implementation of Entropy Efficient Model for Various Noise Reduction Method using Bivariate Shrinkage Function for SAR Image

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Abstract— In last two decades, demand of the wavelet transform has exponentially increased for many research applications. This dissertation focuses on to design a image de-noising method in wavelet domain for SAR images. This research work compares the methods of speckle noise reduction in Synthetic Aperture Radar (SAR) images. Dissertation deals with the various speckle filters which are based on wavelet based de-noising in SAR images. In the proposed method first existing speckle noise reduction methods are compared and then a simple Speckle noise reduction filter is designed using simplified Bivariate Shrinkage function in wavelet domain and in order to improve the entropy the wavelet fusion is used. The original image is used as reference and the wiener filtered image is used as expanded image in Bivariate shrinkage function therefore the filter is simple and fast. In order to improve the entropy the Frost filtered image is fused with Bivariate filtered image. The proposed method using fusion improves the entropy of the image significantly. Although modified Bivariate Shrinkage filter gives better SNR but reduces the entropy of image. Thus fusion is used to improve the scenario. Method minimizes the MSE and significantly increases the SNR value for all the cases. Although the SNR of proposed Bivariate shrinkage function is better than the fused results but since fusion also minimizes the mean brightness thus is better.

Keywords — Speckle reduction, Synthetic aperture radar (SAR), Complex wavelet.

I. Introduction

Images are captured from sophisticated camera systems. Every captured image suffers from some amount of noise. Presence of noise in an image reduces the contrast level and thus degrades the objects features [1]. Noise can be modeled as additive noise or multiplicative noise. Since any captured image has some amount of noise therefore it is an important factor that affects the image quality. The main causes of noise are produced during the processes of image environment and transmission medium. It can be additive

Gaussian noise and is easy to model and remove. Whereas, multiplicative noise is complex to model and it varies with image environment. Therefore noise reduction algorithms are the primary stage of the high level image processing and interpretation. There are different types of noises; each of them can be interpreted in different ways.

Over the last two decades, the wavelet transform has become a tool for many research applications. This dissertation aims to design a wavelet based image de-noising method. The major sad drawback of different existing noise reduction methods [1, 3, and 5] is the loss of information. This dissertation proposes and compares the methods of speckle noise reduction in Synthetic Aperture Radar (SAR) images. Dissertation deals with the various speckle filters which are based on wavelet based de-noising in SAR images. Present research work is developed in two pass, first existing speckle noise reduction methods are compared and then proposed a simple and efficient hybrid noise reduction methods.

A. Synthetic Aperture Imagery (SAR)

There are various applications which require high resolutions broad area imaging. These applications includes; mapping of earth-resources, monitoring of environment, military and air force applications. Usually, apart from day time these images are acquired at night or during stormy weather. Synthetic Aperture Radar (SAR) imaging systems are capable to serve these applications. SAR is a method of fundamentally synthesizing a large efficient antenna and is practical to use on a satellite or aircrafts. Synthetic aperture radar (SAR) system is an active microwave sensor which transmits the microwave or a radio wave and detects the wave reflected back from the objects [19]. The SAR sensor is totally different from the passive optical sensors. It provides higher resolution, higher contrast levels and accurate determination of topographical areas when captured from the aircrafts/planes or from satellite. This is because SAR imageries make use of radar waves for gathering the earth image data [19].

B. Different Types of Noises

Image denoising involves the manipulation of the image data to produce a visually high quality image. Different noise models including additive and multiplicative types are used. They include Gaussian noise, salt and pepper noise, speckle noise and Brownian noise. Selection of the denoising algorithm is application dependent.

II. LITERATURE REVIEW

SAR images are contains many small dots, or scene elements or pixels. This scene element in the radar images represents the radar back-scatter from captured ground area as shown in Figure 1 Darker area represents the low back-scatter and bright areas represent relatively higher back-scatter [1, 2]. Back-scatter for a target area at particular wavelength varies with different conditions Viz. scatters size and moisture content in the target areas, polarization of the radio pulses, and there observation angles. Back-scatter will be also different when radio waves of different wavelengths are used.

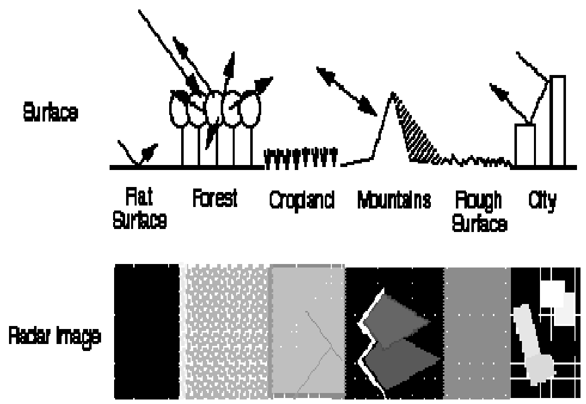


Fig.1: Imaging different types of surface with radar

Backscatter is also sensitive to the target's electrical properties, including water content. Wetter objects will appear bright, and drier targets will appear dark. The exception to this is a smooth body of water, which will act as a flat surface and reflect incoming pulses away from a target; these bodies will appear dark.

A. Speckle Filters

There are various speckle reduction filters available to process SAR images. Some give better visual interpretations while others have good noise reduction or smoothing capabilities. The use of each filter depends on the specification for a particular application. In practice, the standard speckle filters such as Median, Statistical Lee, Kuan and Frost are considered to be the best speckle removing algorithms in the radar community. Each of these filters has a unique speckle reduction approach that performs spatial filtering in a square-moving window known as kernel. The filtering is based on the statistical relationship between the central pixel and its surrounding pixels as shown in Figure 2.

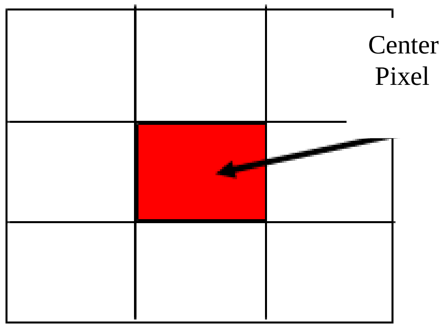


Figure-2: 3.1: 3 x 3 kernel

$$\psi(\tau, s) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right)$$

B. Review of Speckle Noise Reduction Methods

The best way of designing the noise reduction filters are;

I. Based on directly filter on the received signals before forming the beam.
II. Or based on a mixing the various existing de-noising process.

In this dissertation we have followed the second way to design a speckle noise reduction method. First various existing noise reduction methods are reviewed sequentially. There are many speckle noise reduction algorithms [1, 2, 28, 30] which were designed by the researchers viz. Mean filter, Median filter, Lee filter, Kuan filter, Frost filter, and Wiener filter. These noise reduction filters are classified as shown in Figure 3 as follows.

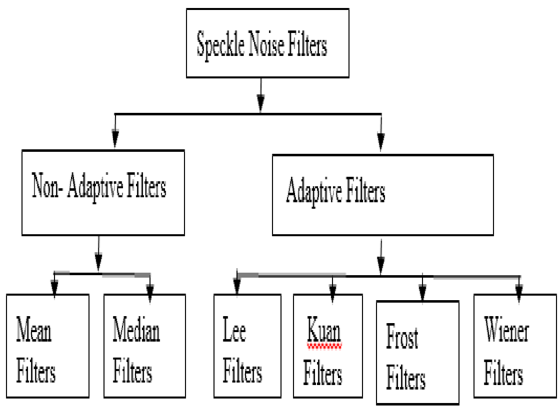


Figure 3 Classification of Speckle Reduction methods

III. THEORY OF SPECKLE NOISE REDUCTION METHODS

A, Spatial Domain Methods The term spatial domain means working on the brightness in the given color space [11]. In this case, the image, it implies working directly with the pixels values or in other words, working directly with the raw data. Let $f(x,y)$ be the original image where f is the gray level value and (x,y) are the image coordinates. An 8 bit image f can take values from $0-255$ where 0 represents black, 255 represents white and all the intermediate values represent shades of color. In a color image of size $256\,x\,256\,x\,3$, x and y can take values from $(0\ ,0)$ to $(255,255)$ for RGB each color space as shown in Fig. 4.

The 2-D continuous image $f(x,y)$ is divided into *N*rows and *M*columns. The intersection of a row and a column is termed a *pixel*. The value assigned to the integer coordinates $[m,\ \ n]$ with $\{m = 0,1,2,\dots,M-1\}$ and $\{n=0,1,2,\dots,N-1\}$ is $a[m\,,n]$ .The modified image can be expressed in the form of function as;

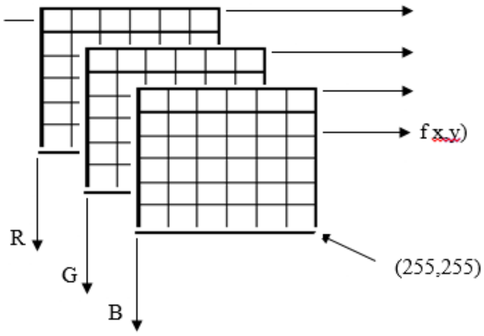


Fig. 4: Spatial domain representation of color image

B. Fourier versus Wavelet Transform

Short Time Fourier Transform (STFT) is developed by Gabor (1946), to overcome the problem of Fourier transform. It uses a fixed-size window to analyze the non-stationary signal as shown in Fig. 5. A small window gives better time resolution and poor frequency resolution, while a large window gives poor time resolution and good frequency resolution. In both cases, the resolution is fixed for high and low frequencies of the signals.

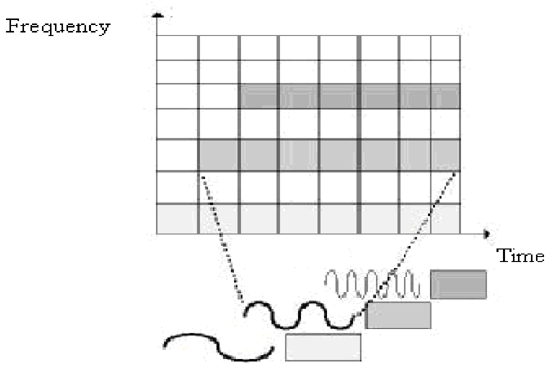


Fig.5: Fourier basis functions, time-frequency coverage of the time-frequency plane.

There is no way to achieve an ideal window size for both time and frequency analysis. Therefore, using STFT will require a compromise between the time and the frequency view of the signal.

C. Wavelet Transform

Wavelet analysis adopts a wavelet prototype function known as the mother wavelet given in eqn. (4.2). This mother wavelet in turns generates a set of basis functions known as child wavelets through recursive scaling and translation. The variable *s* reflects the scale or width of a basis function and the variable *t is* the translation that specifies its translated position on the time axis. [10][14]

D. Wavelet Decomposition

In wavelet analysis, approximations and details are often used for describing the upper and lower portions of the frequency. The approximations are the high magnitude and low frequency components of the signal while the details are represented by the low magnitude and high frequency components.

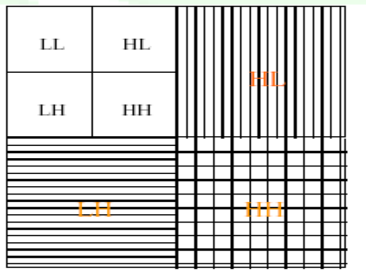


Fig. 6: Image representation 2 levels of decomposition

IV. PROPOSED METHOD

A. Proposed Speckle Reduction Filter

In this dissertation a simple Speckle noise reduction filter is designed using simplified Bivariant Shrinkage (BVS) function in wavelet domain and in order to improve the entropy the wavelet fusion is used. The original image is used as reference and the wiener filtered image is used as expanded image in bivariant shrinkage function therefore the filter is simple and fast. in order to improve the entropy the Frost filtered image is fused with bivariant filtered image. The block diagram of the proposed method is shown in the Figure 7.

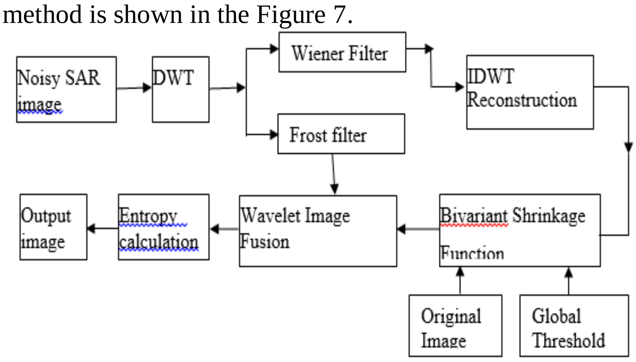


Fig. 7 Proposed Speckle reduction filter

B. Flow Chart

Based on the algorithm mentioned above the detailed flow chart of the proposed speckle filtering method is given in the Fig.8. As can be seen that proposed method is implemented in three stage as wavelet speckle filtering, entropy comparison, and wavelet Fusion.

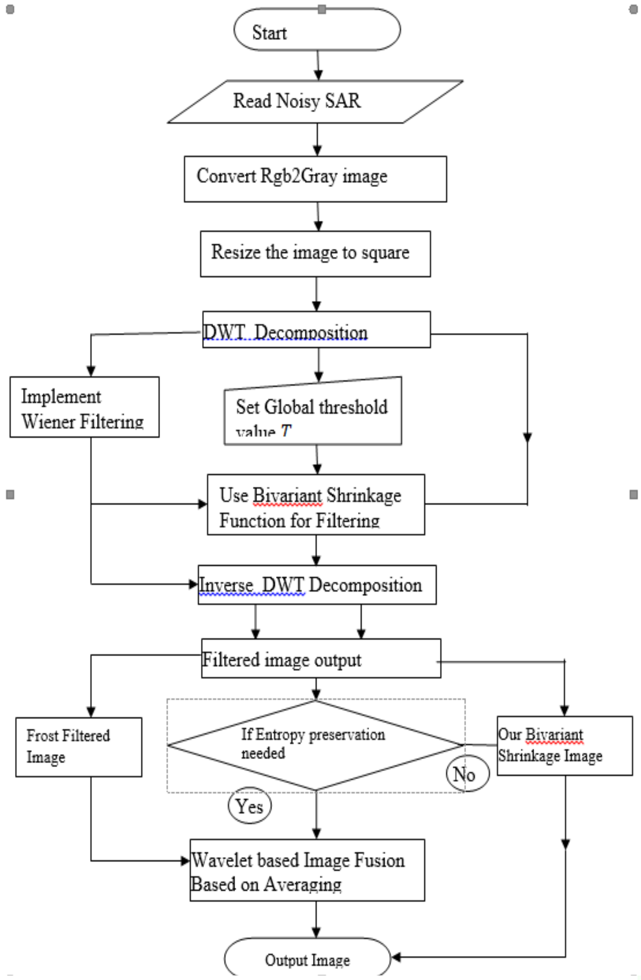


Fig.8: Flow Chart of the Proposed Filter method

C. Threshold

There are three schemes to shrink the wavelet coefficients, namely the "keep-or-kill" hard threshold, "shrink-or-kill" soft threshold introduced by Donoho et al. (1995) and third is semi-soft or firm thresholding from Bruce and Gao (1997).

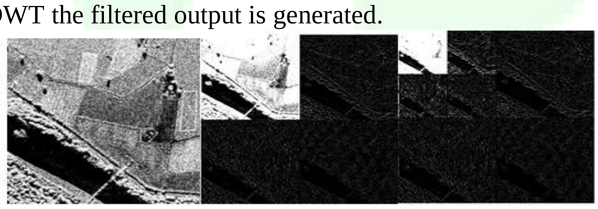
In order to reduce the complexity a global gray level threshold T is used here instead of existing adaptive soft threshold. Then this global threshold is passed to the Bivariant Shrinkage function to find the filtered coefficients. in the current work the global threshold is proposed to select as 20 if higher SNR is required and is required to increased to 50 for better entropy.

V. RESULT AND DISCUSSION

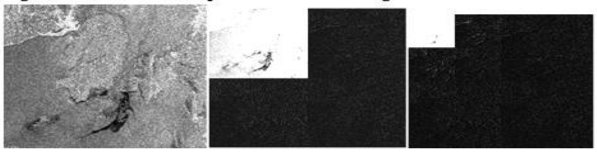
This section presents some of experimental results for the current research work on proposed Hybrid Speckle De-noising method for SAR images. The proposed filtering method takes advantage of Frost filtered image and bivariant Shrinkage function based on global threshold. The results are presented in three stages as results of Wavelet decompositions, Then in the second stage the results of various wavelet based Speckle filters are presented. Finally the results of Wavelet based fusion and qualitative analysis are presented.

Fig. 9: Input image database used for performance evaluation

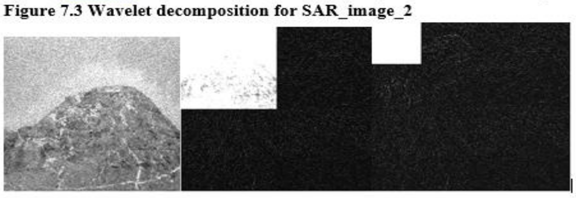
In wavelet based de-noising initially second level DWT is implemented and then on the LL component the filtering algorithm is performed as shown in Figure 10 Figure 11 for different input images. Finally using the two level inverse DWT the filtered output is generated.



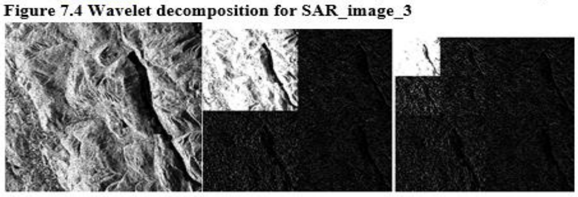
a) Noisy image b) first level Decomposed image c) Second level Decomposed image
Figure 7.2 Wavelet decomposition for SAR1 image



a) Noisy image b) first level Decomposed image c) Second level Decomposed image
Figure 7.3 Wavelet decomposition for SAR_image_2



a) Noisy image b) first level Decomposed image c) Second level Decomposed image
Figure 7.4 Wavelet decomposition for SAR_image_3



a) Noisy image b) first level Decomposed image c) Second level Decomposed image

Fig.10: Wavelet decomposition for ERS_1 image

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The Haar wavelet is used as wavelet filter for the decompositions. This section presents the our DWT decomposition results level vise for different input images. it can be seen that the ERS_1 and SAR image 1 are since having more features and therefore are much better represented by the wavelet decomposition levels.

Histogram

Histogram of images provides a global description of the appearance of the image. The information obtained from histogram is enormous and hence comparison of histogram modeling through the Speckle filtering techniques is introduced as a separate section. A gray level histogram of an image is the frequency of each gray level occurring in the image. Where the gray levels in an image range from 0 – m, the value of the histogram at a particular gray level r, is the number of pixels in that image with that gray level as shown in Figure 11.

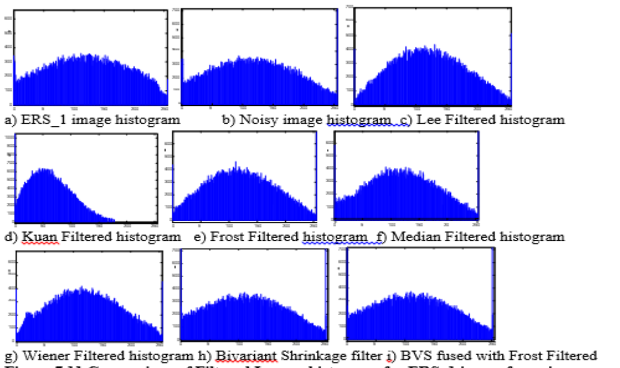

Figure 7.11 Comparison of Filtered Images histogram for ERS_1 image for noise variance 0.02

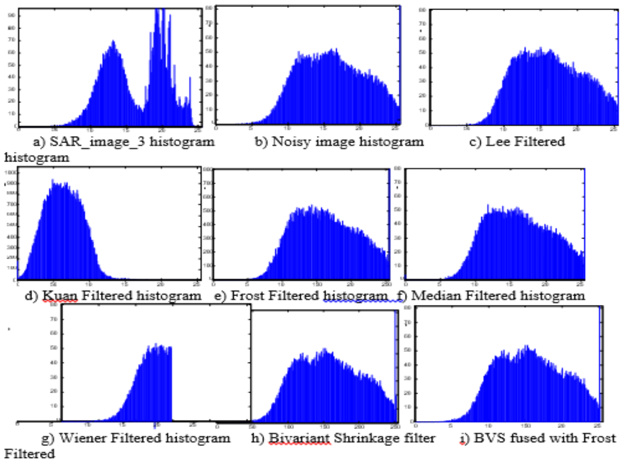

Fig. 11: Comparison of Filtered Images histogram for SAR image 3 for noise variance 0.02

VI. CONCLUSION

There are following conclusions of our research work.

- This research work wanted to determine whether suitable Speckle de-noising techniques can be designed to process SAR images, allowing the noise reduction as well as preserving the information within the images for further scientific applications.
- The increasing use of SAR images creates the demand of processing these images. since mostly the AR images suffers from the presence of Speckle noise. For this reason, it is required to process these images for speckle reduction.
- While image acquisition is subject to motion between cameras and objects, some controlling algorithm must be required for correcting the geometrical distortions. Due to transmission, de-phasing during reflection, and scattering of radio waves the quality of SAR images are degraded by noise. Therefore, it is requiring to filter the SAR image before extracting any information.
- In the study of many research papers it is found that Image Denoising by Wavelet Transformation in SAR produce good result as compare to other proposed methods. It is an efficient method which will be very useful in critical applications like satellite imaging, remote explorations, medical imaging etc.
- In this dissertation SAR images were captured from the satellite, and Air born environments are taken from the previous literature. A simple and efficient image de-noising method with preservation of information for SAR images has been designed by using the Wiener filtered image in bivariant shrinkage filter along with global threshold of T and the fusing the result with Frost filtered image.

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