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Efficient Speckle Noise Reduction in SAR Images By Using simplified Bivariate Shrinkage Function

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***Abstract*— Usually in Synthetic Aperture Imagery (SAR) large amount of de-phased echoes due to pulse scattering causes the Speckel noise. Bivariate shrinkage function used to reduce noise speckle at reduced resolution levels using the wavelet based de-noising method. Results obtained have shown significant speckle reduction then standard filter methods such as Lee filter, Kuan filter and median filter are among the better de-noising algorithms in radar community. Finally by parametric study it is concluded that wavelet based de-noising algorithm is more efficient than standard speckle filters.**

Key words: Image de-noising, Speckle reduction, Synthetic aperture radar (SAR), wavelet transform,

I. Introduction

In the past two decades, many noise reduction techniques have been developed for removing noise and retaining edge details in Synthetic Aperture Radar (SAR) images. Since' 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. In this paper SAR images were captured from the satellite, Air born environments and are taken from the previous literature. With the increasing use of SAR images creates the demand of processing these images. since mostly the SAR images suffers from the presence of Speckle noise. Therefore, it is requiring to filter these SAR images for speckle reduction before extracting any information.

Over the last two decades, the wavelet transform has become a tool for many research applications. This paper 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 paper proposes and compares the methods of speckle noise reduction in Synthetic Aperture Radar (SAR) images. Paper 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..

To achieve this goal, we make use of a mathematical Bivariate Shrinkage Function and the 2D discrete wavelet transform. DWT is used to localize an image into different frequency components or useful sub bands and effectively reduce the noise in the sub bands using the different filters within the bands. The main advantage of the wavelet transform is that the image fidelity after reconstruction is visually lossless

II. SYNTHETIC APERTURE RADAR (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].

III SPECKLE REDUCTION

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. were designed by the researchers viz. Mean filter, Median filter, Lee filter, Kuan filter, Frost filter, and Wiener filter. The best way of designing the noise reduction filters are;

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

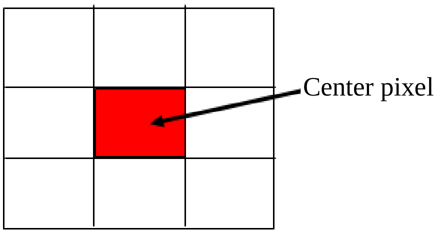


Figure-1 A: 3 x 3 filtering kernel

Each of these speckle filters has a unique speckle reduction method which performs spatial domain filtering within the M x M window known as kernel or mask. The central pixel is replaced by statistical value of the pixels in the mask as shown in Figure 1.

IV VARIOUS SPECKLE FILTERS

Speckle filters are widely used for improving the quality of the given SAR images. Various speckle filters were designed such as Lee, Kuan, Frost or wiener filters. these are described sequentially.

A. Kuan Filter

The Kuan filter [14] are modeled as similar to the Lee filters and are widely used for SAR images. these filters are also based on the minimum mean square error (MMSE) filtering technique, to remove speckle noise from the image by using the modified weighting function [19] given as;

$$W(i,j) = \frac{1-\frac{C_B^2}{C_I^2}}{1+C_B^2} \qquad (1)$$

B. Frost Filter

The Frost filter is an adaptive and exponentially weighted averaging filter based on the coefficient of variation, which is the ratio of the local standard deviation to the local mean of the degraded image [18]..

$$W(x,y) = e^{-kC_I^2(x',y')|(x,y)|} \qquad (2)$$

C. Wiener Filter

The Wiener filter estimate is generated using the mean and variance estimates as;

$$g(x,y) = \mu + \frac{\sigma^2 - v^2}{\sigma^2}(f(x,y) - \mu) \qquad (3)$$

Where, v2 is the noise variance. This adaptive wiener filter approach often produces better results than linear mean and median filtering

V. PROPOSED IMAGE DE-NOISING

A simple and efficient modified bivariant shrinkage function is proposed for the Speckle reduction with global threshold. Then in order to preserve the information content the entropy analysis is done and based on it wavelet based fusion is used to preserve the information content.

A. Algorithm

The sequential algorithm for the proposed Speckle noise reduction method is as follows;

1. Read the noisy SAR image and convert the RGB image to the Gray image.
2. Resize the image to the square image of size 256 x 256.
3. Using the 2-D discrete wavelet transform decompose the image till second level of decomposition.
4. Filter the wavelet coefficients using Frost filter. Set the global threshold then use the filtered Frost image as the expanded image input for the bivariant shrinkage function for filtering.
5. Use 2-D inverse discrete wavelet transform to reconstruct the full size filtered images.
6. Now
   - if the entropy or information preservation is required then use wavelet based image fusion to fuse the Frost filtered image with Bivariant shrinkage filtered image.
   - if SNR is required to be higher without preservation of information then take Bivariant Shrinkage image as output.

A similar approach can be applied to a speckle SAR image. The wavelet decomposition process is iterated with successive approximations being decomposed in turn, so that the image is broken down and represented by a small number coarser component in the lower spectral band (LL block) and a large number of detailed components in the higher spectral band (LH, HL and HH blocks). Using Bivariate shrinkage function ;

$$\hat{w}_1 = \frac{\left(\sqrt{y_1^2 + y_2^2} - \sqrt{3}\,\frac{\sigma_n^2}{\sigma}\right)_+ . y_1}{\sqrt{y_1^2 + y_2^2}} \qquad (4)$$

B. Thresholding Techniques

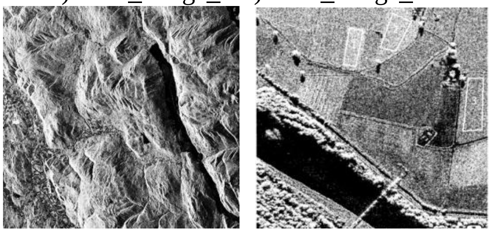
There are three schemes to shrink the wavelet coefficients, namely the “keep-or-kill” hard thresholding, “shrink-or-kill” soft thresholding introduced by Donoho et al. (1995) and third is semi-soft or firm thresholding from Bruce and Gao (1997).

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.

VI EXPERIMENTAL RESULTS

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 thresholding. The results are presented in three stages as results of Wavelet decompositions, results of various Speckle filters, results of Wavelet based fusion and qualitative analysis

a) SAR_image_3 b) SAR_image_2

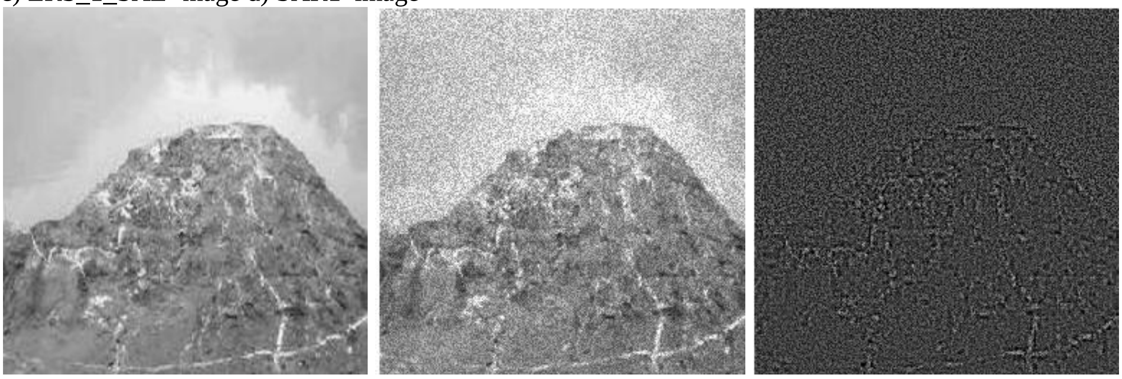


c) ERS_1_SAE -mage d) SAR1 image

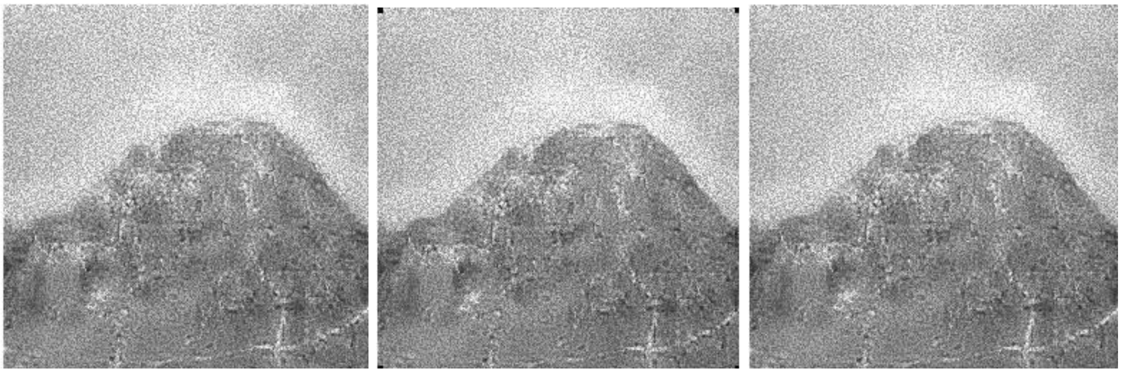
Figure 2 Input image database for performance evaluation

The data base of the various kind of input SAR images is shown in Figure..2 four different types of SAR images are used for comparison.

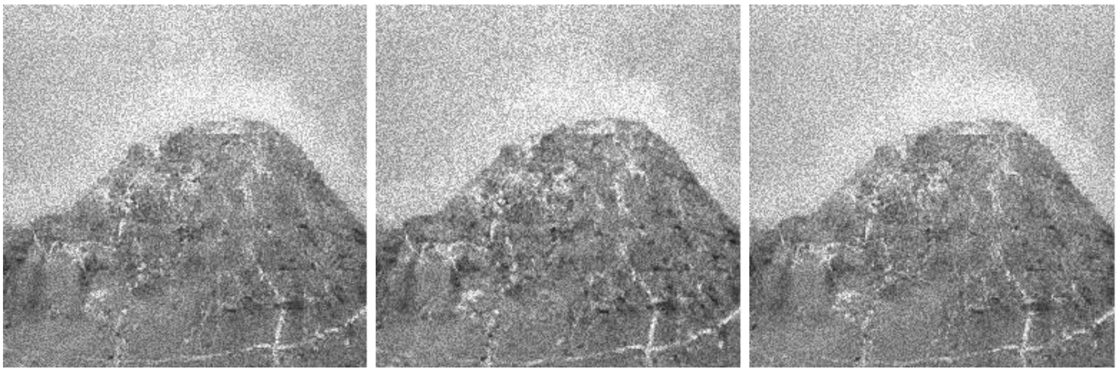
In this paper the result of the four different speckle noise filtering methods based on the mean square minimization are compared. In the Figure 3 comparison of the various Filtered Images with proposed result for SAR_image_3 for noise variance of 0.02 are presented.



a) Original SAR_image_ b) Noisy SAR Image c) Kuan Filtered image



d) Frost Filtered image e) Median Filtered image f) Wiener Filtered image



g) Bivariant Shrinkage filtered h) BVS fused with Wiener Filtered i) BVS fused with Frost Filtered

Figure 3 Comparison of the various Filtered Images

A Performance Analysis

The analysis of the images is done on the basis of their mean brightness, Mean square error (MSE) and Signal to Noise ratio (SNR). Analysis is done to find the quality of the image. Segmentation is also considered as part of analysis.

1. Mean Square Error (MSE):

The mean square error of all image results are computed and listed in Table 1. As to each source image, it can be found that proposed filter gives minimum mean square error. The mean square error for an image is given as,

$$MSE = \sum_{i=1}^{row}\sum_{j=1}^{col}\frac{(a(i,j)-b(i,j))^2}{C} \qquad (5)$$

2. Signal to Noise Ratio (SNR):

The Signal to Noise power ration of all filtered image results are computed and listed in Table 2. As to each source image, it can be found that proposed filter significantly improves the SNR value. The SNR for an image is given as,

$$SNR = \frac{\sum_{i=1}^{row}\sum_{j=1}^{col} a(i,j)^2}{\sum_{i=1}^{row}\sum_{j=1}^{col}(a(i,j)-b(i,j))^2} \qquad (6)$$

3 Entropy :

The entropy defines the measure of information and is compared in Table 3. The differential entropy h(X) of a continuous random variable X with a probability density f(x) is defined as

$$E = \sum_{i=0}^{M-1}\sum_{j=0}^{N-1} p(i,j) * \log(p(i,j)) \qquad (7)$$

The parametric performance comparison of various speckle reduction filters with the proposed method with and without fusion is given in the Table 1, 2 and 3 respectively for MSE, PSNR and Entropy..It can be observed that proposed method not only improves the PSNR for noise reduction but also preserves the entropy for the most of the cases..

VII. CONCLUSION

The performance comparison of various Speckle Reduction filters are presented in the paper. It is observed that proposed filter using modified bivariant Shrinlage function performs better than other methods in terms of SNR and Entropy both. It is observed that using Fusion not only provides higher SNR value but also increases the entropy of the image.

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Table 1 Comparison of MSE

Images	Kuan Filter	Frost filter	Medan filter	Wiener filter	Bivt_Shk	Fused_BVT_SHk
SAR image 3	131.2415	7.61958	14.1012	6.144175	3.538673	4.207573
SAR image 2	92.86472	13.27199	16.18868	11.868978	3.535689	6.920629
SAR 1	98.76698	18.57219	23.750482	14.060553	3.52656	9.52789

Table 1 Comparison of PSNR

Images	Kuan Filter	Frost filter	Medan filter	Wiener filter	Bivt_Shk	Fused_BVT_SHk
SAR image 3	4.04594	32.5091	26.35373	34.661286	40.17881	38.44747
SAR image 2	5.36706	24.82194	22.835376	25.939219	38.04941 6	31.333434
SAR 1	5.17955	21.89053	19.43116	24.673453	38.50394	28.56495

Table 1 Comparison of Entropy

Images	Original	Kuan Filter	Frost filter	Medan filter	Wiener filter	Bivt_Shk	Fused_BVT _SHk
SAR image 3	7.42828	6.70327	7.423942	7.43911	7.42827	7.43869	7.454547
S AR image 2	7.25817	6.646162	7.21314	7.199933	7.214033	7.25609	7.231944

SAR 1	7.596697	7.01884	7.76474	7.67716	7.83051	7.49906	7.771956

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