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# Algorithm for Speckle Reduction and Image Enhancement in SAR Images Using Wavelet Transforms

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## I. INTRODUCTION

Image Denoising and enhancement plays key role in the SAR imagery analysis. Detection of features is important and this can be done by image enhancement. The aim is to improve visibility of the low contrast features and suppressing the speckle. Every image has locally varying statistics, and different edges in it. Wavelet transform gives a superior quality of speckle reduction due to multi resolution aspects. SAR is a high resolution imaging radar. It generates images independent of weather and time conditions. It can penetrate through earth to some depth and useful for agriculture, forestry and hydrology ,etc. SAR images are inevitably accompanied by Speckle due to the coherent nature of the imaging system. The speckle reduces detectability of image features. It is essential to remove speckle for proper identification of features and image analysis. Any feature in ribbon like shape like roads runways or edge features require speckle removal for analysis. The effect of speckle can be reduced in two methods. First, in the processing of image during image formation and second using image filtering techniques. The second method suppresses speckle noise using filters like a Lee filter, Kuan/ Nathan filter, etc. In speckled radar images, filtering must achieve a tradeoff between smoothing of homogeneous area and edge and texture preservation. In this work processing has been carried out in wavelet domain. Donoho and Johnstone pioneered the theoretical formalization of filtering additive *i.i.d.* Gaussian noise (of zero mean and standard deviations) via thresholding wavelet coefficients. A wavelet coefficient is compared to a given threshold and is set to zero if its magnitude is less than the threshold; otherwise, it is kept or modified (depending upon the thresholding rule). The threshold acts as an *oracle*, which distinguishes between the insignificant coefficients likely due to noise, and the significant coefficients consisting of important signal structures. For image denoising, the threshold choice proposed by Dohono yield overly smoothed images as the threshold choice of $s$ 2log$M$ (called the universal threshold), can be unwarranted large due to its dependence on the number of samples, M, which is more than 105 for a typical test image of size 512 x 512. This thresholding mechanism also requires the knowledge of the amount of noise present in the image. Wavelet transform performs a hierarchical decomposition of the signal space into a nested sequence of approximation spaces by translations and dilatations of one mother wavelet function. The statistics of SAR image was extensively studied in Godman 1976, and concluded that SAR intensity is a ultiplicative noise. Logarithmic transformation of image speckle is approximately Gaussian noise. The image compression and denoising can be done using wavelet based speckle noise removal approaches. Donoho described the speckle noise removal approach in following steps as given below

*A.* Preconditioning of image: take logarithmic transform of the image.
*B.* Apply Orthogonal discrete wavelet transforms for wavelet coefficients
*C.* Select threshold based on noise variance and apply soft thresholding
*D.* Apply inverse orthogonal discrete wavelet transform to reconstruct the denoised image.

## II. WAVELET TRANSFORM AND ALGORITHM

SAR system is modeled as two dimensional linear systems and speckle is a white noise Gaussian process. Input signal to SAR system is

$$F(t) = r(t).\, n(t)$$

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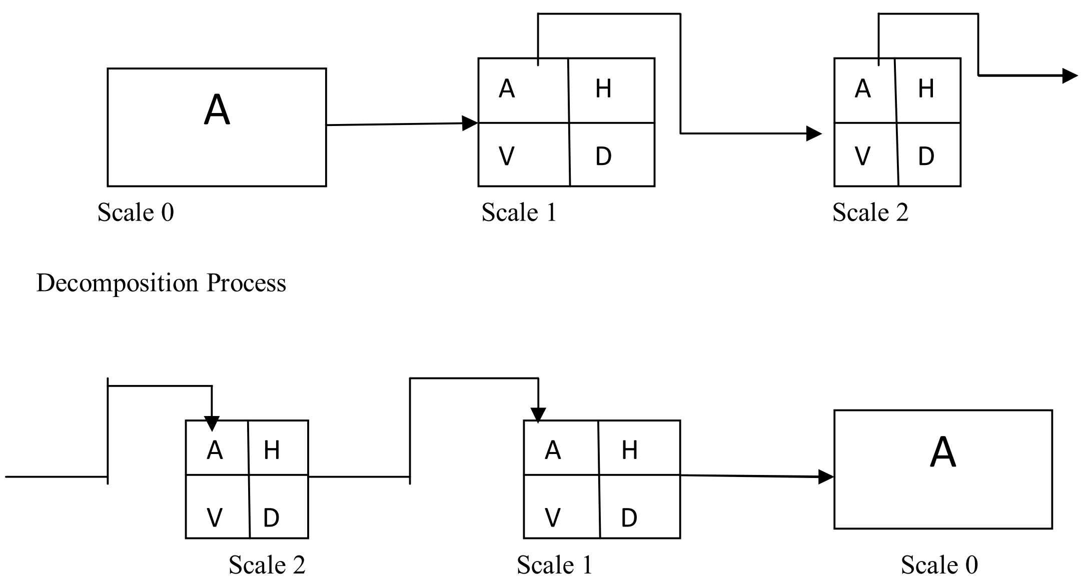
Where r(t) is reflectivity and n(t) is speckle noise.
The wavelet transform of the image is given by two dimensional scaling function which can be expressed as the product of two one dimensional scaling functions.
$\Phi(x,y) = \Phi(x)\,\Phi(y)$

And 2D wavelet basis function $\psi(x, y)$ is a product of 1-D functions of $\Phi$ and $\psi$

$\Psi_1(x,y) = \Phi(x)\,\psi(y) \quad \psi_2(x,y) = \psi(x)\,\Phi(y) \quad \psi_3(x,y) = \psi(x)\,\psi(y)$

Corresponding filter functions are
$h_{LL}(k,l) = h(k)\,h(l) \qquad h_{LH}(k,l) = h(k)\,g(l)$
$h_{HL}(k,l) = g(k)\,h(l) \qquad h_{HH}(k,l) = g(k)\,g(l)$

First and second subscripts denote low pass and high pass filter characteristics in horizontal and vertical directions. The wavelet transform is a pair of two 1-D wavelet transforms along vertical and horizontal directions. Image decomposition and restructure can be treated as separable filtering of each signal of the image along row and column.




Reconstruction Process

Fig.1. Two step PSWT

Using a pyramid structured wavelet transform (PSWT) (Mallat, 1989). Two step PSWT is as shown in fig 1. Using Multi resolution analysis technique despeckles is done with an acceptable compromise between edges and speckle reduction. This is followed by an enhancement in wavelet domain which gives consistent results.

Wavelet transform based techniques proved to be effective due to compressibility of the signal and the incompressibility of noise. Multi resolution analysis gives better speckle filtering. Speckle noise is suppressed by reducing the amplitude of pixels in image with horizontal, vertical and diagonal orientations.
The proposed algorithm is as shown in the flowchart (fig 2)

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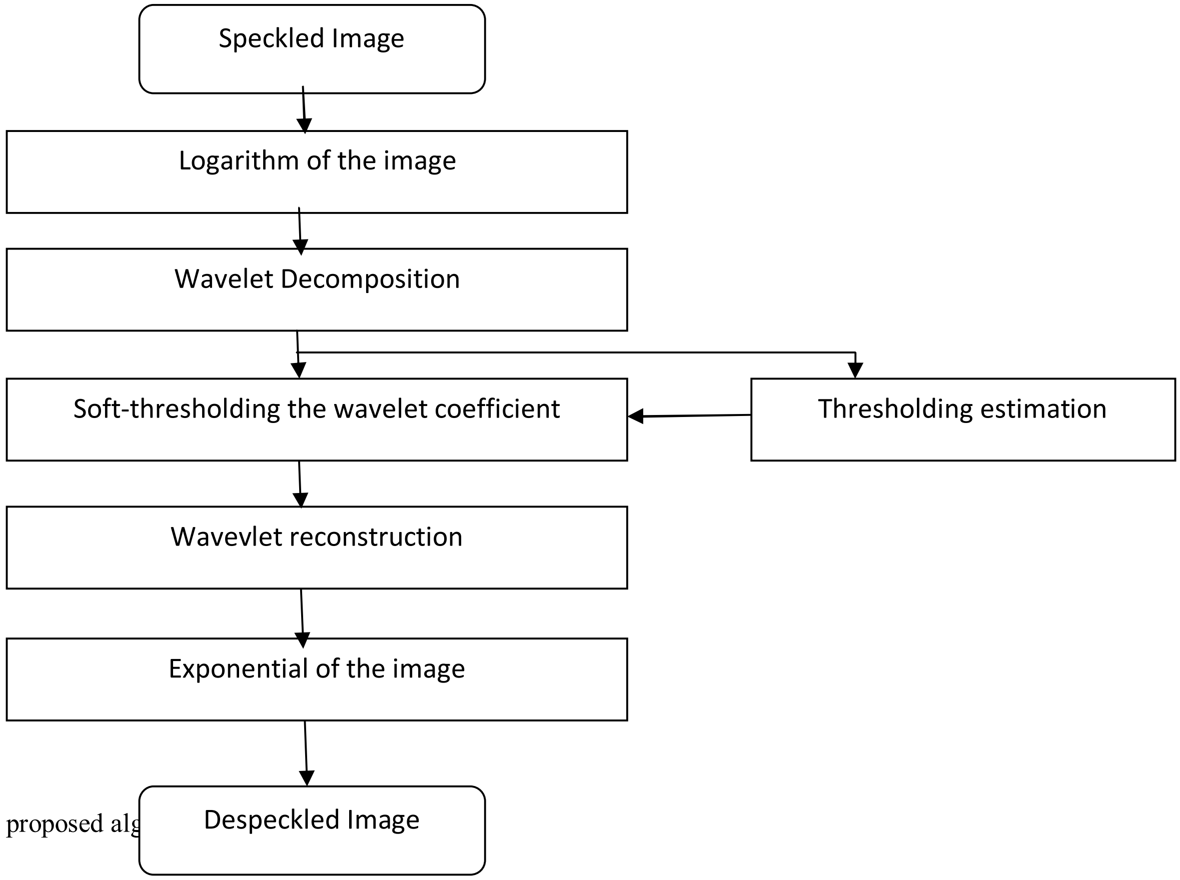


Fig.2 proposed alg

## III. EXPERIMENTAL RESULTS AND ANALYSIS

The proposed method was tested for speckle noise removal on a simulated image and on a single band image of 512 x 512 images of an urban area in AP. . The image is normalized to variance range between 0 and 1, All filters were implemented with MATLAB. Figures 8(a) and 8(b) original image and noisy image and figure 8(c) shows despeckled image. The image shows clear delineation of edges for other features. The result shows that the algorithm enhances edges properly and this technique is better than other standard filters like Lee, gamma, Kuan and median filters. Results show that the wavelet domain enhancement gives good results and there is a significant speckle reduction in noise and edges can be identified in a better way.

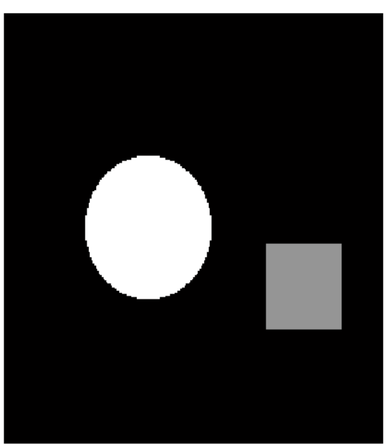

Fig 3 original image (Test)

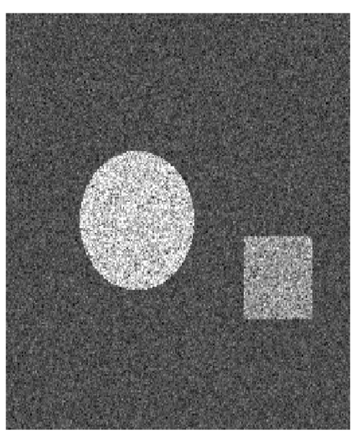

Fig 4. Speckled image

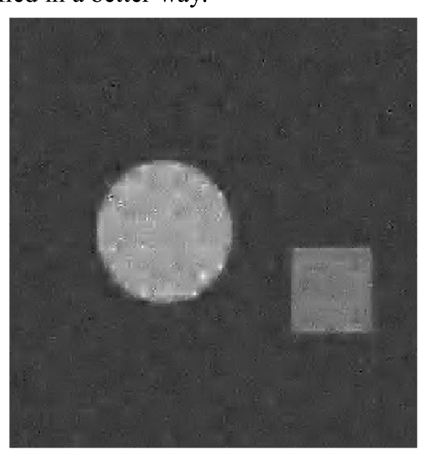

Fig.5 Denoised image using algorithm

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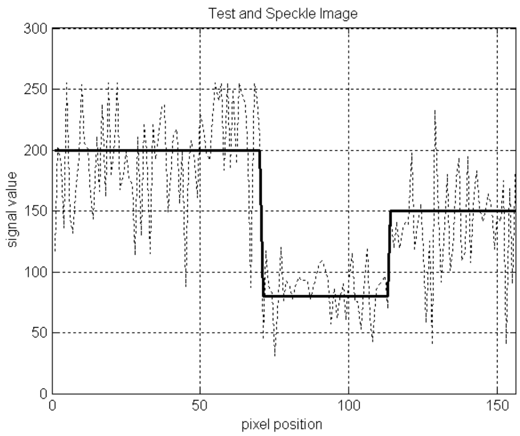


Fig 6 Test and speckled image

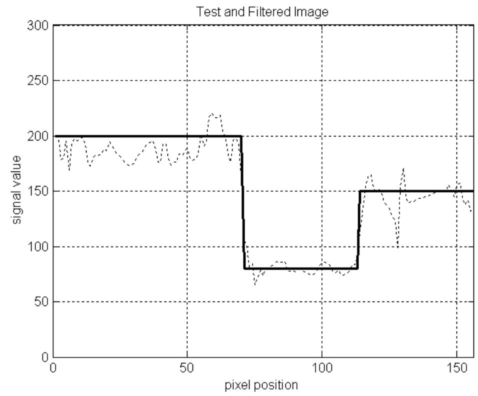


Fig 7 Test and denoised image

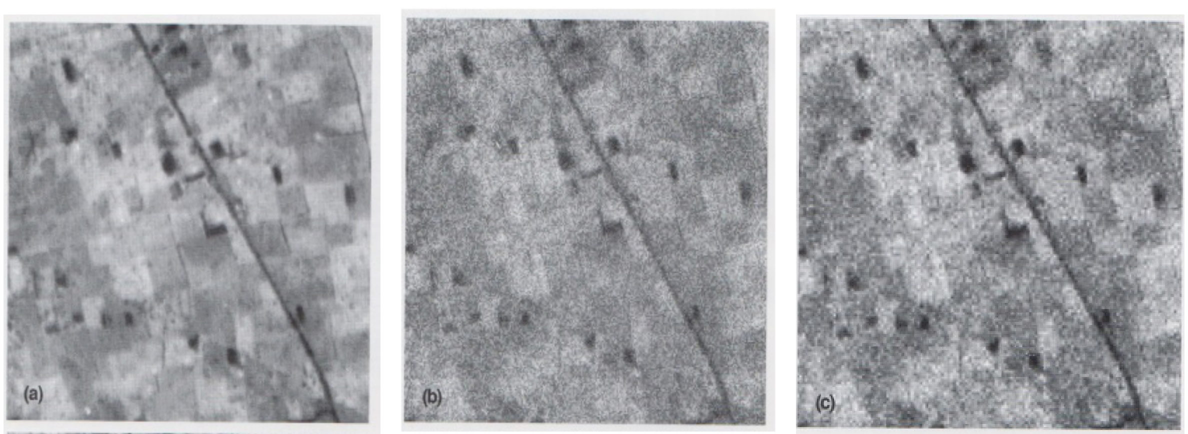


Fig.8(a) original Fig.8(b) speckle noised image Fig. 8(c) despeckled image

Performance of despeckle filter is compared with other filters in spatial domain and through Mean Square Difference or Error (MSE) which is average difference of pixels throughout image and Signal to Noise Ratio of image The higher the MSE value, the more is the difference between original image and denoised image. The image is normalized with pixel values between 0 and 1, and for a noise variance of 0.025, The MSE and SNR are given in table 1.

| Method | Speckle variance 0.025 | |
|---|---|---|
| | MSE | SNR |
| Original image | 0.033 | 16.0136 |
| Lee | 0.0058 | 21.8173 |
| gamma | 0.2443 | 4.5859 |
| Kuan | 0.0026 | 25.0089 |
| Frost | 0.0052 | 22.2212 |
| Wavelet Transform (proposed) | 0.000832 | 29.4652 |

Table 1. MSE and SNR values for speckle variance 0.025

The results show that image enhancement and denoising are more efficient with wavelet based transforms,

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## BIBILIOGRAPHY

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