DESPECKLING OF SAR IMAGES USING WAVELET BASED SPATIALLY ADAPTIVE METHOD

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ABSTRACT: In the past two decades, many speckle reduction techniques have been developed for removing speckle and retaining edge details in Synthetic Aperture Radar(SAR) images. Most of the standard algorithms use a defined filter window to estimate the local noise variance of a speckle image and perform the individual unique filtering process.The primary goal of speckle reduction is to remove the speckle without losing much detail contained in an image. To achieve this goal, we make use of a mathematical function known as the wavelet transform and apply multi-resolution analysis to localize an image into different frequency components or useful sub-bands and effectively reduce the speckle in the sub-bands according to the local statistics within the bands. The main advantage of the wavelet transform is that the image fidelity after reconstruction is visually lossless.In this project, we will study and investigate the application of using the Daubechies wavelet with denoising techniques to remove speckle in SAR images. We combine the wavelet shrinkage denoising techniques with different wavelet basis and decomposition levels on the individual sub-bands to achieve the best acceptable speckle reduction while maintaining the fidelity of the image. The analysis of the statistical results will be calculated using matlab to demonstrate the advantages and disadvantages of using complex wavelet shrinking techniques over standard speckle filters.

KEYWORDS: Synthetic Aperture Radar, speckle image, denoising techniques, filters, wavelet transformation.

I. INTRODUCTION

Synthetic aperture radar (SAR) images are widely used in various applications such as monitoring of crops, detecting oil spill in sea, search and rescue operation and military target detection.However, a SAR image, being the output of a coherent imaging system, is inherently corrupted by the speckle noise. The presence of speckle in SAR images makes tasks such as segmentation and target detection quite difficult. In recent years, there has been a growing interest in using the wavelet-based approaches for reducing the speckle in the SAR images. Gagon and Jouan have shown that the thresholding of the wavelet coefficients of the log-transformed SAR images provides a better speckle reduction than the conventional spatial domain filters. However, the accuracy of the corresponding method for estimating the alpha-stable parameters is highly dependent on the location and number of samples in characteristic function domain; for each subband, the number of samples are set manually which is a disadvantage. In this paper, a new spatially adaptive wavelet-based method to reduce the speckle noise in SAR images is proposed. In signal processing, it is often desirable to be able to perform some kind of noise reduction on an image or signal.

The median filter is a non-linear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise. Lee filter with the non-local mean filter, and a new similarity measure is derived based on the statistics of speckle noise, which extended the non-local means from the additive noise to the multiplicative noise.Also directional projection is adopted to accelerate the process of similarity computation. The results show its effectiveness.

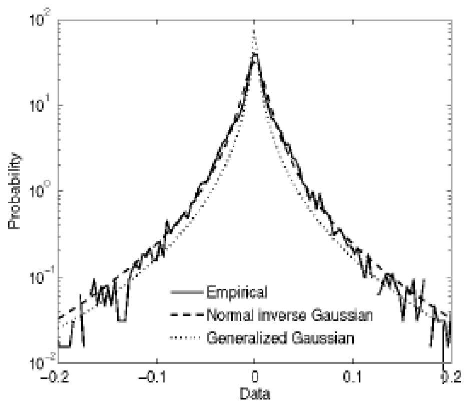
Experimental results illustrate that the proposed method can effectively smooth the speckle while preserving the details with reduced complexity. But, the wavelets are much more advantageous and effective than the filters which are mentioned above. In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which thewavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution:it captures both frequency *and* location information (location in time). The dual-tree wavelet transform is more effective than the discrete wavelet transform hence, the dual-tree is implemented here.

The Dual-tree complex wavelet transform (DTCWT) calculates the complex transform of a signal using two separate DWT decompositions (tree *a* and tree *b*). If the filters used in one are specifically designed different from those in the other it is possible for one DWT to produce the real coefficients and the other the imaginary.Simulations are carried out to study the performance of the proposed method and to compare it with those of the standard wavelet-based techniques and the spatial domain filters using synthetically speckled and real SAR images.

II. RELATED WORK

Let y(k, 1) denote the (k, I)-th pixel in a SAR image, s(k, 1) the reflectance image pixel and n(k, 1) the multiplicative speckle component. Assuming a fully developed speckle noise, independent of the reflectance image, we can write y(k, 1) =s(k, l)n(k, 1)

For an L look SAR image in intensity format, the PDF of the speckle noise is often described by a gamma distribution with a unit mean and a variance of 1/L, and is expressed as



PDFs of the wavelet coefficients in the sub-band HHI for the log- transformed House image, the NIG prior and the GG distribution.

$$P_n(n) = \frac{L^L n^{L-1} e^{-Ln}}{\Gamma(L)}$$. After logarithmic transformation becomes

$$f(k,l) = g(k,l) + \xi(k,l)$$

Where, $f(k,l) = \ln y(k,l),\ g(k,l) = \ln s(k,l)$

Is the mean and variance of ε are

$\psi(0, L) - \ln(L)$ and $\psi(1, L)$. respectively.

Where, $\psi(i, .)$ denotes the i-th polygamma function.

III. PROPOSED DESPECKLING METHODS

A. *Filters*

1) *Median Filter:*

This filter first sorts the surrounding pixels' values in the window to an orderly set and replaces the centre pixel within the defined window with the middle value in the set. Median filter is a non-linear filtering technique that works best with impulse noise (salt and pepper noise) whilst retaining sharp edges in the image. The main disadvantage in the median filter is, the extra computation time needed to sort the intensity value of each set.

2) *Statistic LEE Filter:*

The Lee filter is based on the approach that if the variance over an area is low or constant, then the smoothing will be performed. Otherwise, if the variance is high (E.g. near edges), smoothing will not be performed. The Lee filter assumes that the speckle noise is multiplicative, than the SAR images can be approximated by a linear model given in the below equation.

Img(i,j)=Im+W*(Cp-Im)

Where, Img(i,j) is the gray scale value of the pixel at indices i and j after filtering.

If there is no smoothing, the filter will output only the main intensity value of the filter window Im. Otherwise, the difference between Cp (centre pixel) and Im is calculated and multiplied with a weighting function W given in equation below and summed with Im:

$$W=\sigma^2/(\sigma^2 + \rho^2)$$

Where σ^2 is the variance of the pixel values within the filter window given in the equation below, N is the size of the filter window and Xj is the pixel value within the filter window at indices J.

The parameter ρ^2 is the additive noise variance of the image given in equation below. M is the size of the image and Y_i is the value of each pixel in the image.

$$\rho^2 = \frac{1}{-}\sum_{=0}^{N-1}(Y_i)^2$$

The main disadvantage of lee filter is that it tends to ignore speckle noise in the areas closest to edges and lines.

B. *Wavelet Transformation*

1) *Discreet Wavelet Transform*

It's the initial wavelet transform that is being implemented, the process is as follows:

Comparison with Fourier transforms:

To illustrate the differences and similarities between the discrete wavelet transform with the discrete Fourier transform, consider the DWT and DFT of the following sequence: (1,0,0,0), a unit impulse.

The DFT has orthogonal basis (DFT matrix):

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -i & -1 & i \\ 1 & -1 & 1 & -1 \\ 1 & i & -1 & -i \end{bmatrix}$$

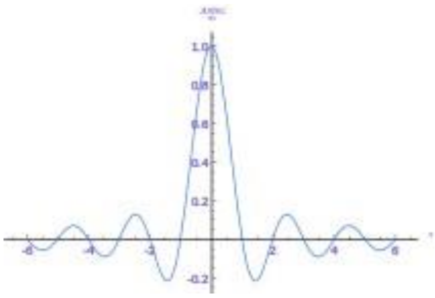
While the DWT with Haar wavelets for length 4 data has orthogonal basis in the rows of:

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \end{bmatrix}$$

$$\left(\frac{1}{4},\frac{1}{4},\frac{1}{4},\frac{1}{4}\right)$$

$$\left(\frac{3}{4},\frac{1}{4},-\frac{1}{4},\frac{1}{4}\right) \qquad \text{2-term truncation}$$

$$(1,0,0,0)$$



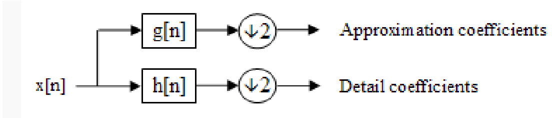
The sinc function, showing the time domain artifacts (undershoot andringing) of truncating a Fourier series.

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k]$$

$$y_{\mathrm{low}}[n] = \sum_{k=-\infty}^{\infty} x[k]h[2n-k]$$

$$y_{\mathrm{high}}[n] = \sum_{k=-\infty}^{\infty} x[k]g[2n-k]$$

Block diagram of filter analysis

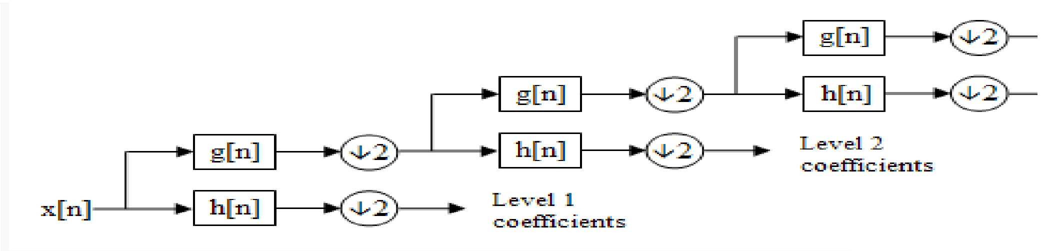


With the subsampling operator $\downarrow$

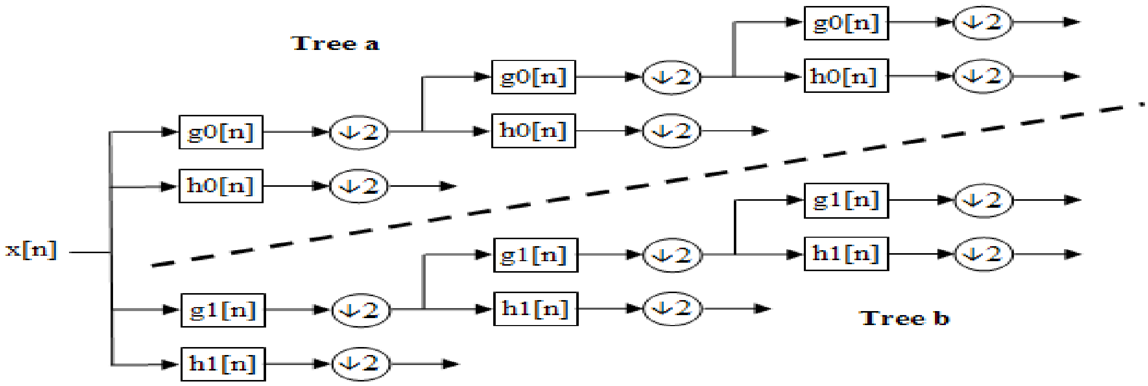
$$(y \downarrow k)[n] = y[kn]$$

$$y_{\text{low}} = (x * g) \downarrow 2$$
$$y_{\text{high}} = (x * h) \downarrow 2$$

Cascading and Filter Banks:



2. *Dual-Tree Wavelet Transform:*



This redundancy of two provides extra information for analysis but at the expense of extra computational power. It also provides approximate shift-invariance (unlike the DWT) yet still allows perfect reconstruction of the signal.

The design of the filters is particularly important for the transform to occur correctly and the necessary characteristics are:

-The low-pass filters in the two trees must differ by half a sample period

-Reconstruction filters are the reverse of analysis

-All filters from the same orthonormal set

-Tree *a* filters are the reverse of tree *b* filters

-Both trees have the same frequency response

III. SIMULATION RESULTS

In this section, the performance of the proposed technique is compared with those, Zeng and Cummings, and the FTMAP filter. Experiments are carried out on three images: two synthetically speckled images obtained by corrupting typical noise-free House and Boat images with simulated speckle noise, and a real SAR image. Symlet wavelet of order 8 is used for a 4-level decomposition of the images. In order to calculate the dispersion parameter a and d using, Q is set to 50.

Using filters and wavelet transformations the splecked input image is processed and despeckling methods are implemented on the image and its ddenoising is done effectively. This is shown below:

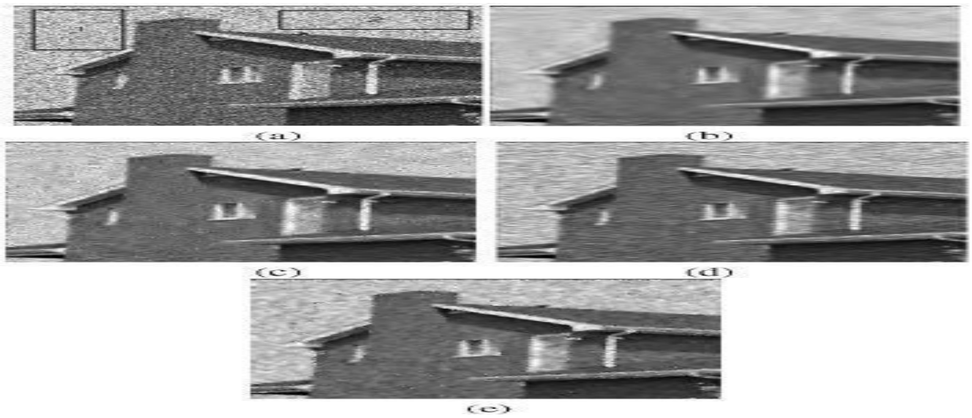


Fig.1 Output results of Despeckling using Filters

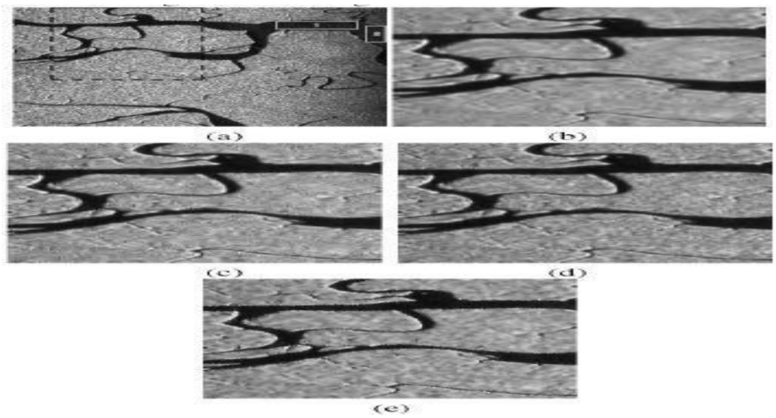


Fig.2 Output results of Despeckling using Wavelet Transforms

IV. CONCLUSION

In this paper, a new spatially adaptive wavelet-based method for reduction of the speckle noise in SAR images has been proposed. The wavelet coefficients of the log-transformed reflectance have been modeled using a symmetric NIG distribution,whereas those of the speckle noise image using filters and wavelet transforms.

The wavelet transforms which are implemented in this section are more effective than the filtering methods respectively. Hence in the initial stage the filters are implemented and the image is processed then the discreet wavelet transform is implemented and hence to despeckle or denoise the image more effectively the Dual-Tree wavelet transform is implemented for effective results. The more effective methods of despeckling images are being explored and will be implemented in the further processes.

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