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EVALUATION OF SPECKLE REDUCTION FILTERING TECHNIQUES ON SAR IMAGES

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ABSTRACT

Synthetic Aperture Radar is Remote Sensing imaging used to generate high-resolution imagery of the ground from an aerial platform using radio waves. It transmits microwave pulses to the earth surface and stores the energy bounces back from the object. SAR images are obtained with speckle noise, due the interference of waves reflected from many elementary scatterers. It is more difficult to interpret with the speckle noise images obtained from SAR and also reduces the effectiveness of image segmentation and classification. To reduce deleterious effects of speckle, various filtering techniques are applied to the SAR images before segmentation process. This paper depicts the effects of various filter techniques on segmentation task, some quality measures are calculated from the processed images and used to indicate the filtering ability for features preservation.

Keywords:* Box Filter, *Frost Filter,Gamma MAP Filter, Kaun Filter, Lee Filter, Median Filter, SAR Images.

I. INTRODUCTION

Speckle noise is a common phenomenon in all articulate imaging systems like laser, acoustic and Synthetic Aperture Radar (SAR). The source of this noise is due the interference of waves reflected from many elementary scatterers. It is more difficult to interpret with the speckle noise images obtained from SAR and also reduces the effectiveness of image segmentation and classification. Therefore, filtering is a common pre-processing technique in SAR images applications that improves the class discrimination and image interpretation.

The aim of this paper is to evaluate the filtering effects over SAR image segmentation, some quality measures are applied to the processed image. Lot of speckle reduction techniques have been developed for removing speckle and retaining edge details in Synthetic Aperture Radar (SAR) images for clear image interpretation. However, it is still an unresolved problem. Basically, speckle reduction methods contain two categories such as multi-look integration and post-image techniques. Multi-look process is explained in this paper. Adaptive filtering techniques including Lee filter [1] [2] and Gamma filter [3] are among the better denoising post-image algorithms in radar community. The result is generally a greatly reduced speckle level in areas that are homogeneous, but the image is either over smoothed due to losses in details

and edges in heterogeneous areas. In recent years, wavelet-based denoising algorithm has been studied and applied successfully for speckle removal in SAR images [4] [5]. Here post processing category is discussed using various standard filters. When compare to other filters the Gamma MAP filter with a 7x7 window size gives the best performance based on experimental results.

II.SPECKLE STATISTICS

SAR images are obtained with speckle noise, due the interference of waves reflected from many elementary scatterers. This effect causes pixel to pixel variation in intensities and the variation manifests itself as granular noise called speckle. SAR speckle statistics are necessary to understand for better information extraction and interpretation by designing algorithms for speckle filtering, ground level classification etc. When radar illuminates a rough surface on the scale of radar wavelength, the returned signal consists of waves reflected from many elementary facets within a resolution cell. The distance between elementary scatterers and radar vary due to the random location of scatterers. The received wavelengths are constructive if waves are strong and out of phase if waves are weak. Fully developed speckle has the characteristics of random multiplicative noise.

2.1 Speckle Statistics for Multilook Processes SAR Image

A common approach to speckle reduction is to average several independant estimates of reflectivity. In SAR processing this is accomplished by dividing the synthetic aperture length into N segments which are known as looks. Each segment is processed to form either an intensity or an amplitude SAR images and N are summed to form an N-look SAR images.

The averaging process is the method that does the average of N independent samples, if samples are assumed statistically independent. The N look processing reduces the standard deviation of as speckle by the factor of$\sqrt{N}$. However this is accomplished with the expense of azimuth resolution which is degraded by the factor of N. In current SAR systems, the data are available either in multi-look or in single-look complex format. The most common N-look SAR images having Gamma distribution with mean R(x, y) and variance R^2(x, y)/N is expressed as

$$\mathbf{p(I/R)}=\frac{N^N I^{N-I}}{N-I\,!\,R^N}\cdot e^{-\frac{I}{R}N}$$

For homogenous area, the intensity of SAR image is

$$\mathbf{p(I)= p(I/R)}=\frac{N^N I^{N-I}}{N-I\,!\,I^N}\cdot e^{-\frac{I}{I}N}$$

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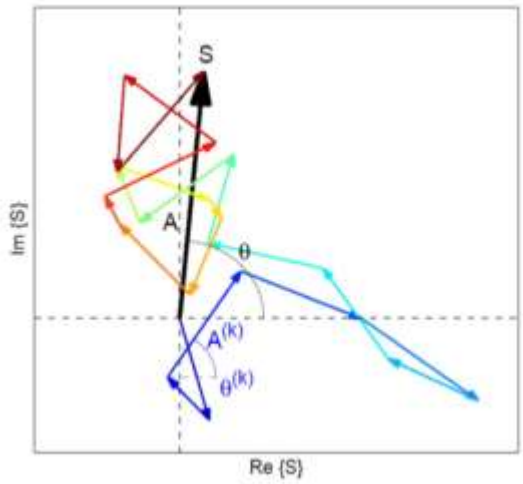

Fig 1.Strong Scattering

(Fully Developed Speckle)

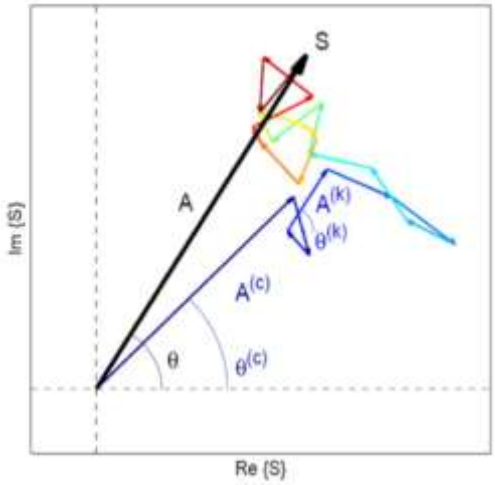

Fig 2.Weak Scattering

(Partially Developed Speckle)

For heterogeneous area, the radar reflectivity R(x, y), is a random process. So the intensity of SAR image is

$$\mathbf{P(I)}=\int_0^\infty \boldsymbol{p}\left(\frac{I}{R}\right).\boldsymbol{p}(\boldsymbol{R}).\boldsymbol{dR}$$

The main aim of this paper is to apply speckle filtering to reduce radar reflectivity R(x,y) noise in heterogeneous area.

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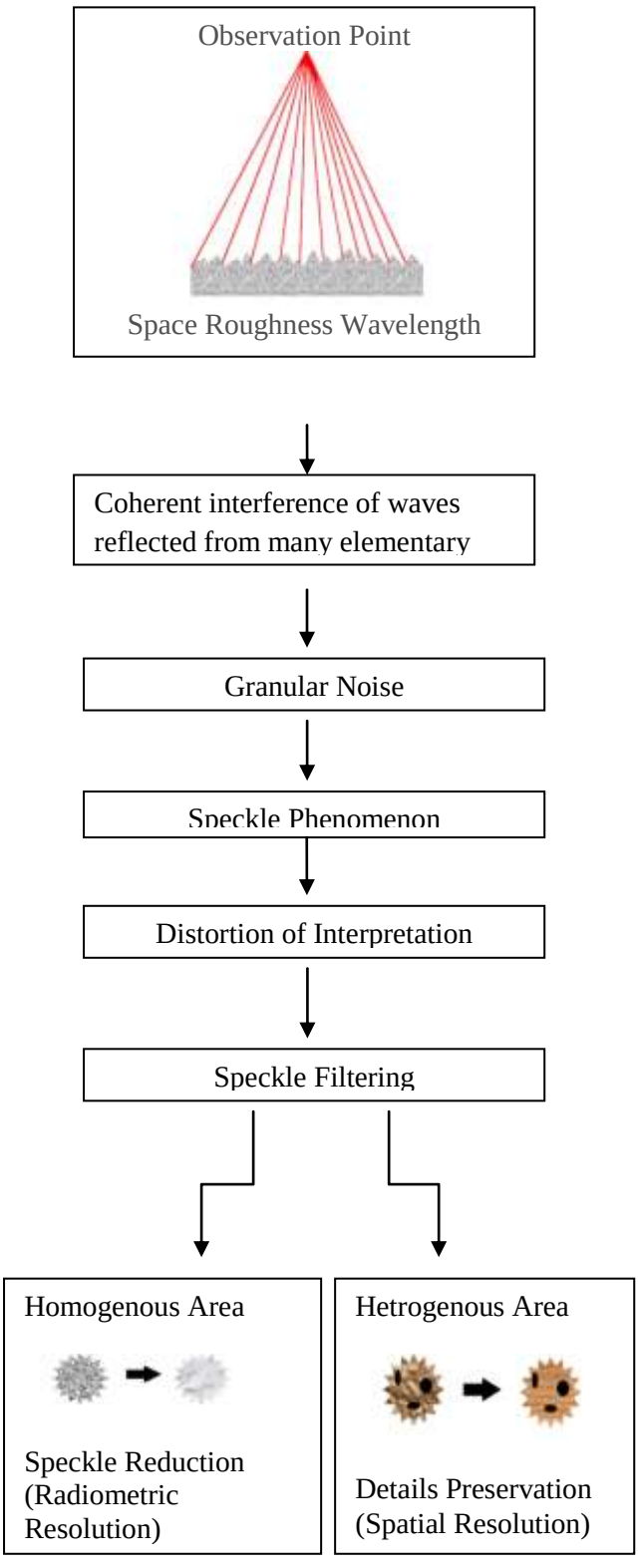
2.2 Speckle Phenomenon



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III.SPECKLE FILTERS

The speckle reduction methods fall into two categories: multi-look integration and post-image techniques. In first category, low pass filter is applied to multi-look processing and box filter and it is known as pre processing. In second category, speckle reduction is carried out and it is known as post processing. Low pass filter is the most basic filtering technique. It is also called as blurring or smoothing filter averages out rapid changes in intensity. The average of pixels for eight immediate neighbors is calculated by simplest low-pass filter. Here post processing category is discussed using various filters.

3.1 Box Filter

A box linear filter is also known as spatial domain linear filter in which each pixel in the resulting image has a value equal to the average value of its neighboring pixels in the input image. It is a form of low-pass "blurring") filter. A box filter is also called a mean filter.
The matlab code used to perform box filter is

B = imboxfilt(A,filterSize)

It filters image A with a 2-D, 3-by-3 box filter with size specified by filter Size.

3.2 Median Filter

Median Filter replaces each pixel with the median value of the surrounding N-by-N neighborhood and it is a nonlinear digital filtering technique mostly used to remove noise from an image or signal and also it preserves edges while removing noise.

The matlab code used to perform median filter is

B = medfilt2(A, [m n])

It performs median filtering, where each output pixel contains the median value in the m-by-n neighborhood around the corresponding pixel in the input image.

3.3 Kaun Filter

The Kaun filter is used to suppress speckle and also smoothes image data without removing edges or sharp features in the original image. The Kuan filter first transforms the multiplicative noise model into a signal-dependent additive noise model. Then the minimum mean square error criteria are applied to the model.
The matlab code used to perform Kaun filter is

B=kuan(I, niterations)

3.4 Lee Filter

Lee filters to smooth speckled data that posses intensity related to the image and that also have an additive or multiplicative component. It preserves image sharpness and detail while suppressing noise. The pixel being filtered is replaced by a value calculated using the surrounding pixels.Each pixel is put into one of three classes, which are treated as follows:

- Homogeneous: The pixel value is replaced by the average of the filter window.
- Heterogeneous: The pixel value is replaced by a weighted average.
- Point target: The pixel value is not changed [6].

The matlab code used to perform Lee filter is

K = Lee_filter_C(I,J,[5 5])

3.5 Frost Filter

Frost filters to reduce speckle while preserving edges in radar images. The pixel being filtered is replaced with a value calculated based on the distance from the filter center, the damping factor, and the local variance... Each pixel is put into one of three classes, which are treated as follows:

- Homogeneous: The pixel value is replaced by the average of the filter window.
- Heterogeneous: An impulse response is used as a convolution kernel to determine the pixel value.
- Point target: The pixel value is not changed [6].

The matlab code used to perform Frost filter is

B = fcnFrostFilter(A,MASK)

It performs the filtering with local statistics computed based on the neighbor's as specified in the logical valued matrix MASK.

3.6 Gamma MAP Filter

Gamma filters are used to reduce speckle for preserving edges in radar images. The gamma filter is similar to the Kaun filter but assumes that the data is gamma distributed. The pixel being filtered is replaced with a value calculated based on the local statistics [6].

The matlab code used to perform Gamma MAP filter is

B=gmap(I, niterations)

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IV. METHODOLOGY

Sentinel SAR (Synthetic Aperture Radar) datasets were used. The Sentinel (SAR) is a dual polarization instrument and operates in VH and VV nodes. Operating in the VH mode, bright targets like vessels are relatively easy to detect, while operating in VV mode oil spills become much more evident. SAR images measure the surface roughness depending on the backscatter. The main mechanism is to detect the characteristics on paddy field using the adaptive filters.

4.1 Tests and Discussions on images

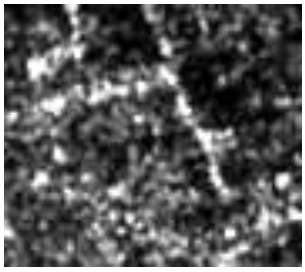

Fig 4.Original SAR Image

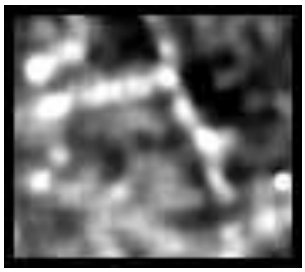

Fig 5. Box Filter

Fig 6. Median Filter

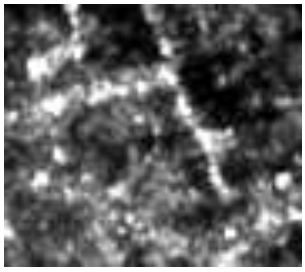

Fig 7. Lee Filter

Fig 8. Frost Filter

Fig 9. Kaun Filter

Fig 10. GMAP Filter

V. EVALUATION OF FILTERS

The performance of all the six above mentioned filters are carried out by comparison of six different speckle filters with six different kernel widow sizes (3*3,7*7,5*5,11*11) with dampening effect of 10 and 5. The dampening factors increases the sharp edges. From the results it is clear that Gamma map performs best with 7*7 window sizes. Lee filter with 3x3 window size (VH and VV polarization, frost filter with 11x11 window size (VH and VV polarization), lee filter 3x3 window size (VH polarization) and frost filter 11x11 window size (VV polarization) perform weak. In addition, the histograms of intensity image in each area in VH and VV polarizations reveal the characteristics of a positive exponential distribution . When comparing the histograms of noisy and filtered images, the histogram of filtered images look smoother than the noisy images because the number of each pixels are recalculated by filter method, so speckle noise of image is degraded. Although, Gamma MAP filter performs better in reducing noise, Gamma MAP blurs theimage. Based on my research and the aforementionedconclusions ofrelated studies found in the scientific literature, it is suggested that Gamma MAP with a window size 7x7 is a robust filter technique for reducing speckle noise in SAR images.

VI. CONCLUSION

Speckle noise degrades the quality of SAR image and also reduces the image contrast. So, before image interpretation, removal of speckle noise from SAR images should be done. To despeckle the Sentinel SAR data, six filter techniques with 5 different spatial kernel sizes were applied and quantitatively compared in order to evaluate the elimination of speckle noise on Sentinel-1A radar image. When compare to other filters the Gamma MAP filter with a 7x7 window size gives the best performance based on experimental results.

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