Performance Comparison of Adaptive Filters for Speckle Noise Reduction in SAR Images

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***Abstract*—Noise is the most common problem in imaging systems that affects the quality of the image. Noise is unwanted data that has the capability to reduce the contrast and deteriorate the object's size and shape in the image. It also blurs the edges or dilutes the fine details in the image. Reducing the noise in images has become very essential in image processing. This paper presents the comparison of Frost and Kaun filter for noise reduction in images. Speckle is a characteristic attribute of SAR(Synthetic aperture radar) and Ultrasonic images. Speckle noise is modelled as spatially correlated multiplicative noise. The speckle noise filters are designed for enhancement of visualization of speckle images. SAR and Ultrasound are the main applications areas for speckle noise filters.**

Keywords—Speckle noise, Kaun filter, Frost filter, MSE, PSNR

I. INTRODUCTION

Synthetic Aperture Radar (SAR) imaging technique can be applied for taking pictures of the earth by the satellites or from the air-crafts.SAR images are helpful in the study of the environment, vegetation and survey of land on that part of the earth.SAR images suffer from the noise-like feature called as a speckle. This work is done to compare the filters that are used to reduce the speckle noise and their performance is studied. The speckle characteristics are analyzed by utilizing its mathematical model and comparing the result of applying two recommended speckle reduction filters used for SAR images. We used synthetic images for testing of spatial filters. Finally, this paper presents a comparative study of the filter functions.

The interference of reflected waves on the transmitted waves causes random speckle noise, making it a difficult task to process the image. Hence it is the most important thing that the speckle noise is filtered in order to improve the quality of the image for post-processing.

The Kaun MAP filter and Frost filter are good at preserving the edges as well as noise removal. These two filters are discussed in this paper. There are partial differentials used in the Kaun Map filter and Frost filter in order to preserve the edges and median or averaging filter is used for speckle noise removal. Kuan and Frost's filters are used for filtering the images.

Information about the speckle noise and its causes are discussed in the paper. Techniques used to reduce the above said noise is also addressed. Statistical parameters like PSNR and MSE for image quality assessment are also discussed. The brightness of the image or the film density is expected to have a uniform value all over the image except the places where the values change. There are several factors that affect the variation in the image brightness even when there are no significant image details. These variations do not follow a single pattern, it has a random value. The quality of the image is reduced considerably when the objects captured are small. If the captured image is a low contrast image, the randomness of brightness is visibly noted. An image is said to be noisy when the image has spots or smears of colours, grains or textures or a snowy appearance.

A speckle is not exactly a noise but it is a noise-like variation in the image. It occurs due to the random variation in the strength of the reflected waves from the objects. It is mostly observed in RADAR and Ultrasonic Imaging.

The paper is organised as follows: Section I gives an introduction to speckle noise and its properties are explained. Section II depicts about noise reduction filters. PSNR and MSE computed in Section III and Section IV. In section V, the result and comparison of two filters are encountered. Section VI concludes the work.

II. NOISE REDUCTION FILTERS

The granular pattern and the inherent property of the ultrasonic image and SAR image are considered to be a speckle noise. Speckle noise is a multiplicative noise. There is always a misconception that many of us do is that we assume that the ultrasonic waves travels in a straight line from the reflecting surface. The portion of ultrasonic sound reflected back by the transducer surface is another source of reverberation. A reliable speckle filter algorithm can be designed only when an accurate and reliable model of speckle formation is done.

The most generalized model of the speckle imaging is

$$g(n, m) = f(n, m)\, u(n, m) + \xi(n, m) \qquad (1)$$

Where the term 'g' mentions the observed image and 'f' represents the original image. The terms, n and m represent the axial and radial lateral values of the image.

The degradation of the SAR image is mainly caused by the speckle noise. This degradation will reduce the efficiency of the image processing system.

The two types of filtering methods used to reduce the speckle noise are, Incoherent processing and Image post-processing.

A. Incoherent processing techniques

Technique of averaging of different images is used in incoherent image processing. The images are obtained by varying two parameters namely view angle, and transducer frequency. This enables the technique to achieve speckle patterns to be independent or partially uncorrelated.

B. Image post-processing:

Image post processing involves adaptive and anisotropic filters to reduce the speckle noise. The hardware for the purpose of image reconstruction system does not require any modification while applying the above said methods of filtering. The images are captured by the usual technique. Image processing techniques like filtering is applied to the captured image.

Speckle is a distinctly grainy appearance due to the characteristic image noise in radar images. The image is formed by a single ground-resolution cell after receiving and adding the signals generated by different obstacles. Change in the direction and the angle of view changes the strength of the aggregate return signal. Constructive and destructive interference can be observed between the individual signals due to the variations in the direction and angle of view. The uniform ground materials and slope in the image will show random variation is brightness which produces a speckled appearance. In some areas such as non uniform areas, the observation of speckle noise is very difficult for the human interpreter to resolve the details in the image.

The mean value is less likely affected by the speckle noise, undiversified areas of the image. Specific properties of speckle noise are utilized in the radar imaging techniques for enabling the system to increase the noise reduction capacity. While processing the SAR images, the aggregate return signal strength is considered to be the true signal. In optical images, most of the noise models are in the form of additive noise. In case of speckle noise in the optical image, it is multiplicative in nature. Here the brightness and the noise are directly proportional; hence the increase in brightness of the target object introduces more noise to the image. The radar filters are designed in order to tackle this property of the speckle noise. The radar filters are fundamentally designed in the principle of adaptive filters. The filters will vary its parameters spatially depending on the local statistical properties of the image. Speckle noise is modeled using a multiplicative model. Adaptive filters preserve the edges and also reduce the spatial resolution loss. The filters can produce optimum results with user-defined parameters. The output of different filters exhibits a slight difference.

III. Speckle Noise Filters

A. Frost

Frost is one of the filters which belong to adaptive filter family which uses local image statistics for filtering purpose. The weighted average of the cells is calculated, the weight of each cell is decided based on the local statistics because it helps in minimizing the error in the processed image. As the variance in the filter window increases the centre cells become heavily weighted. As a result, the filter smoothens the homogeneous areas in the image. It can be observed that the value of the centre cell in heterogeneous areas of the image becomes closer to the signal estimate.

B. Kuan (MAP)

Maximum likelihood probability approach is used in the Kuan Maximum A Posterior filter to find out the true signal value. Speckle noise is assumed to have negative exponential distribution in case of MAP filter. This maximizes the probability function of the centre cell value, standard deviation and local mean. To find the cntre cell true value, the local minimum mean square error is used by the Kuan adaptive noise reduction filter Lee filter uses an approach that resembles the Kuan filter but differs in making some simplification assumptions before calculating the values of the centre cell.

IV. PSNR calculation

A. Algorithm for computing Signal to Noise Ratio (SNR)

Step 1: Find the STD deviation value of noise free signal

Step 2: Find the square of standard deviation to obtain the variance.

Step 3: Noise is added to the image

Step 4: The original image and the noisy image are subtracted using an inbuilt command in MATLAB processing toolbox.

Step 5: Standard deviation of result of step 4 is calculated.

Step 6: Variance is calculated.

Step 7: Calculate the ratio between the results of step two and six.

Step 8: Take log of resultant value obtained in step 6 to calculate the signal to noise ratio in decibels.

B. Algorithm for calculating Peak Signal To Noise Ratio

Step 1: Determine the difference between noisy and noiseless image

Step 2: Find the actual size of the matrix obtained from step1.

Step 3: Calculate the pixel value from the above matrix.

Step 4: Calculate the square of each pixel of the resultant matrix of Step 1 and formed as a matrix.

Step 5: Find the sum of pixels for the image obtained from 4^{th} step.

Step 6: Mean Squared Error (MSE) is calculated.

Step 7: Find the square root for the MSE in 6^{th} step.

Step 8: Taking 1og base 10 of the RMSE divided by 255 and then multiplying the result with 20 gives the value of PSNR.

V. Simulation Results

The filter functions have been implemented in MATLAB software. Two of the existing filters viz. Frost and Kuan filters have been implemented, the output obtained during the simulation process are described and the screenshot of the outputs are provided in the following text.

Fig. 1. Original Image

The output of the Frost filter during the simulation when speckle noise is introduced to the image with the noise variance 0.04 and the output was taken for various values of noise variances.

Fig. 2. Noisy Image

Fig. 3. Filtered image (frost)

Fig. 4. Filtered image (Kuan)

TABLE 1.MSE AND PSNR FOR DIFFERENT NOISE VARIANCES OF FROST FILTER

Noise Variance	Frost		Kuan	
	MSE	PSNR	MSE	PSNR
0.02	136.192	26.7893	115.725	27.4965
0.03	181.413	25.5441	138.390	26.7197
0.04	226.940	24.5717	157.567	26.1561
0.05	274.377	23.7473	177.792	25.6317
0.06	318.489	23.0998	198.165	25.1605
0.07	362.624	22.5362	217.847	24.7493

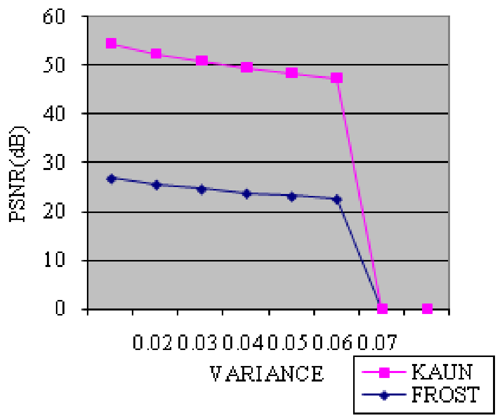

Fig. 5. Comparison chart of PSNR values of Frost and Kuan filters

VI. CONCLUSION

Analysis of two filters is done in the work, which involves, Frost and Kuan filters. These two filters are suitable for removing speckle noise from SAR images. The experimental results show that, the Kuan filter gives better result than the Frost filter. The filters have the main property to preserve the edges which are the sharp details in the image.

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