Cross - Calibration and Normalization for Speckle Noise Reduction in SAR Images

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ABSTRACT— *Speckle noise in SAR is generally more serious, causing difficulties for image interpretation. Reduction of speckle noise is one of the most essential tasks to add up the quality of radar coherent images. Filtering is one of the common methods, which is used to lessen the speckle noise. Several adaptive filtering methods have been documented to deal with this issue such as Kuan, Lee, MMSE and Frost filters. They degrade the spatial resolution of the image and also smooth the details while significantly decreasing the speckle noise level. There are also other filters such as Enhanced Lee and Gamma Map but they could not adequately suppress speckle noise. In this paper, a innovative approach for speckle reduction has been suggested and then its performance on simulated imageries with other existing filtering methods has been compared. The results have been presented by filtered output images, statistical tables and bar charts. The implementation of de-noising technique with enhancement technique as a whole is the proposed method. All the simulation is done with the help of MATLAB R2012a environment.*

Keywords—despeckling, enhancement, SAR image, flood maps, filters.

1. INTRODUCTION

Speckle noise is commonly seen in almost all imaging systems which make use of coherent mechanism to capture images. Therefore, imaging techniques such as laser imaging, acoustic imagery and synthetic aperture radar, which generate coherent images, are subject to the phenomenon of speckle noise. Speckle noise often cause adverse effects and gives a grainy appearance to SAR, MRI as well as ultrasound images.

SAR is an active remote sensing system, which is used to obtain high resolution images. SAR images are widely used in remote sensing applications. SAR is a type of a sensor, which is also called coherent microwave sensor. SAR images are mostly corrupted by speckle noise and this type of noise is produced due to the coherent nature of scattering phenomenon, so the removal of speckle noise from the SAR images without the loss of structural features and textural information becomes very necessary.

SAR has high penetration power and due to this property it acquires high resolution images in almost all atmospheric conditions but the automatic interpretation of SAR images is often difficult due to interference of speckle noise. SAR de-noising procedure is aimed to remove the noise without losing the important information and try to retain the structural features and textural information of the image as much as possible. For making the visual impact of SAR image more effective, after the de-noising process, the three enhancement techniques are applied one by one.

Obviously, it is seen that to interpret radar imageries correctly one has to reduce (ideally remove!) the effect of speckle noise. However, as the speckle noise removal process changes the image as well, one should use proper filter to keep the image degradation minimum. For the past two decades, several speckle reduction techniques have been developed for removing speckle and retaining edge details. However, it is still an unresolved problem and in most of the speckle reduction techniques studied by the researchers, there is no comprehensive method that takes all the constraints into consideration.

2. MATHEMATICAL MODEL OF SPECKLE NOISE

The speckle noise of SAR images is usually modeled as purely multiplicative noise process of the form given in equation (1) below. For SAR, the noise n is assumed to have a mean value $\bar{n} = 1$. The pixel values returned by the radar imaging process g are the product of the true radiometric values f and the speckle noise n.

$$g = f.n \qquad (1)$$

In practice, a digital image generated from the SAR echo returns is represented by spatial variations of pixel intensities. The speckle noise model may be approximated as multiplicative and is given by

$$D_{m,n} = S_{m,n}.U_{m,n} + V_{m,n} \qquad (2)$$

Where, $R_{m,n}$ is the noisy pixel, $S_{m,n}$ represents the noise free pixel, $U_{m,n}$ and $V_{m,n}$ represent the multiplicative and additive noise respectively and m, n are indices of the spatial locations. Since the effect of additive noise is considerably smaller when compared to that of multiplicative noise, (2) may be written as

$$D_{m,n} = S_{m,n}.U_{m,n} \qquad (3)$$

Logarithmic compression is applied to the noisy signal which affects the speckle noise statistics and it becomes very close to white Gaussian noise. The logarithmic compression transforms multiplicative noise form in (3) to additive noise form as

$$log(D_{m,n}) = log(S_{m,n}) + log(U_{m,n}) \qquad (4)$$

The term $log(D_{m,n})$, which is the SAR image after logarithmic compression is denoted as $G(m,n)$, the term $log(S_{m,n})$, which is the noise free pixel after logarithmic compression is denoted as $R(m,n)$ and the term $log(U_{m,n})$, which is the noisy component after logarithmic compression is denoted as $N(m,n)$ respectively.

$$G(m,n) = R(m,n) + N(m,n) \qquad (5)$$

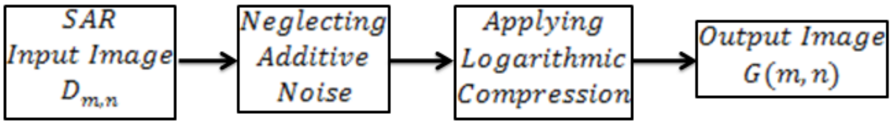

Figure.1 Steps Involved in Noise Modeling

3. REVIEW OF THE ADAPTIVE SPECKLE FILTERS

3.1 Lee Filter

The Lee filter [4] 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, smoothing will not be performed. The equivalent number of looks (ENL) is a parameter used to estimate noise variance and it effectively controls the amount of smoothing applied to the image by the filter. A smaller ENL value leads to more smoothing; a larger ENL value preserves more image features. The main drawback of Lee filter is that it tends to ignore speckle noise in the areas closest to edges and lines.

3.2 Kuan Filter

The Kuan filter [1] is used primarily to filter speckled radar data. It is designed to smooth out noise while retaining edges or shape features in the image. The filter size can be specified through the filter size parameters. Different filter sizes will greatly affect the quality of processed images. If the filter is too small, the noise filtering algorithm is not effective. If the filter is too large, subtle details of the image will be lost in the filtering process. A 7x7 filter usually gives the best results.

3.3 Frost Filter

The Frost filter [2] uses an adaptive filtering algorithm which is an exponentially damped convolution kernel that adapts itself to features by using local statistics. The frost filter differs from Lee and Kuan filters by the fact that the image reflectivity is estimated by convolving the observed image with the impulse response of the SAR system.

3.4 Mean Filter

Mean filtering [3] is a simple, intuitive and easy to implement method of smoothing images that is, reducing the amount of intensity variation between one pixel and the next. It is often used to reduce speckle noise in SAR images. The idea of mean filtering is simply to replace each pixel value in an image with the mean value of its neighbours, including itself.

3.5 Median Filter

The median filter [6] replaces each and every pixel in the input image with the median of gray levels in the neighborhood. This filter is a type of smoothing spatial filter.

The filtering procedure consists of three steps:

- Arrange the pixel values in the window in increasing or decreasing order.
- If the window size S is odd, the middle value is the median. If the window size S is even, the average of the two values in the middle is the median.
- Now, each and every pixel in the image replaced by the median

Median filter provides less blurring than linear filters. As the median filters have excellent noise reduction capability, they are used to reduce impulse noise, which is also known as salt and pepper. Median filter is used in the SAR filters and textures program. Sometimes, to get better image quality, it may be useful to filter the same image two or three times. The main drawback of the median filter is the extra computation time needed to sort the intensity value of each set.

4. PROPOSED METHOD

The proposed method includes several sequential steps used to generate fast-ready flooded maps: filtering, histogram clipping and equalization and RGB composition.

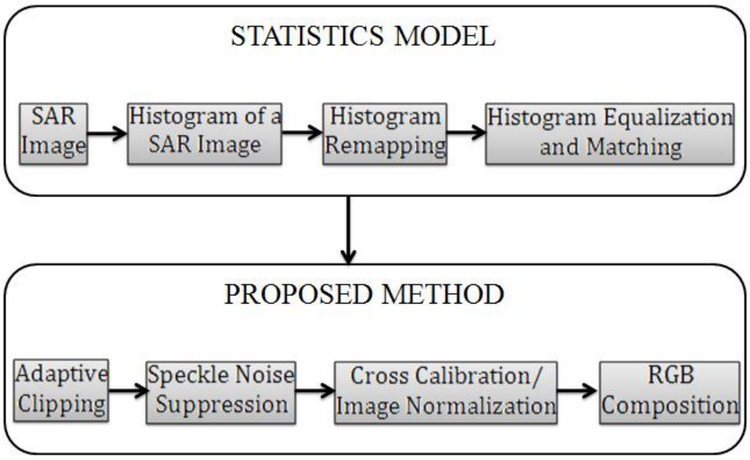

Figure.2 Block Diagram of Proposed Method

4.1 Filtering

The filtering step reduces the granularity due to the speckle present in SAR images and makes it possible to obtain better results. Different filters have been proposed in the literature, including the Lee, Frost, Mean and Median filters [5] and more recently, the SRAD filter [13]. The filters in image processing have a vital role in improving the image appearance. These filters not only reduce the effect of noise present in the satellite images

4.2 RGB Composition

For the numerical fusion of multidimensional data, color pseudo-composite images of available channels are widely used to integrate and enhance image content. RGB composition can be used to enhance regions of interest and as a preprocessing step intended to aid in identification. RGB composition is used as a preliminary step before a change detection process used to map flooded areas. In the monitoring of flooded areas, the satellite data has been widely used. A color composite image is often used first to obtain rapid results. All of these techniques make it possible to quantitatively analyze flood and no-flood areas and to quickly obtain results for flooded areas.

4.3 Histogram of a SAR Image

It is well known that SAR images are always very dark and poorly contrasted even if they are generated using 2 bytes per pixel (Bpp). The aim of this technique is to improve contrast and allow for a visual interpretation process.

Histogram of an image normally represents the gray values of all the pixels present in the image. This makes the classification of the pixels very easier. With the help of the histogram the dark and bright pixels can be easily identified. The task of finding out the dull pixels and applying the manipulation becomes simple.

4.4 Image Normalization

Image normalization makes it possible to increase the contrast between the flooded and dry areas as compared to the permanent water, thus making it easier to identify damaged areas. As a result better visualization interpretation and better results are possible than would have been achieved using the original images.

The steps involved in the whole process are meant for enhancing the image and to bring out the edge information and feature information in such a way that the processed image becomes better than the original image. The normalization process is normally done in order to increase the intensity of the pixels present in the image. Each and every pixel in the SAR images may contain essential edge information and feature information. Hence careful attention should be given while using the manipulation for highlighting those dull pixels.

4.5 Histogram Equalization

The equalization step in image enhancement produces a uniform histogram with pixels occupying the entire spectrum. In histogram equalization process, the whole spectrum of gray scale is fully utilized. This technique thus provides a good visual effect to the output image. When all the above techniques combined together and applied during the processing of the image, that will produce an image with all requirements satisfied.

Histogram equalization technique is widely used method, especially when there is need to make the darker part of the image brighter. Thus equalization technique with all other technique makes proposed technique that makes the input image worthy to be used during the hazards and disasters.

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5. EXPERIMENTAL RESULTS

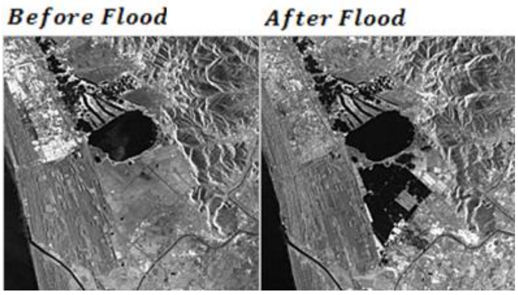


Figure.3 Original Image

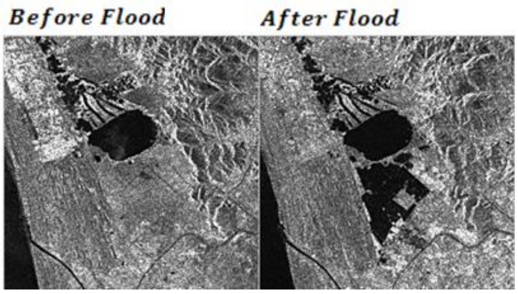


Figure.4 Image with Speckle Noise

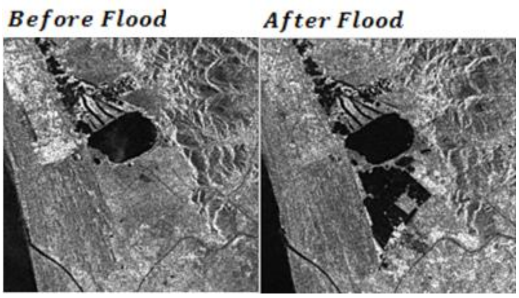


Figure.5 Output of Mean Filter

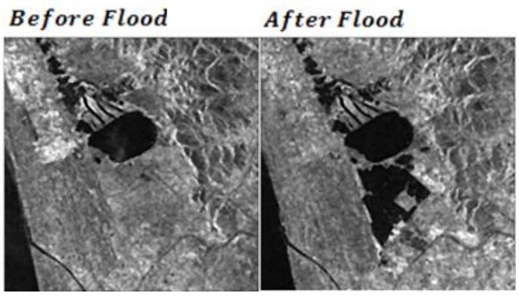


Figure.6 Output of Median Filter

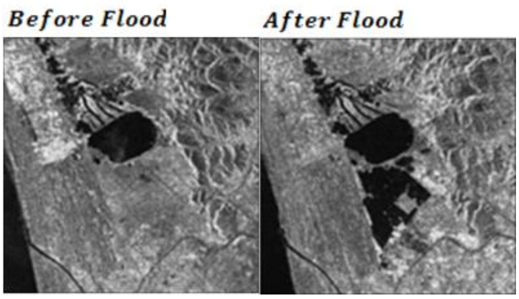
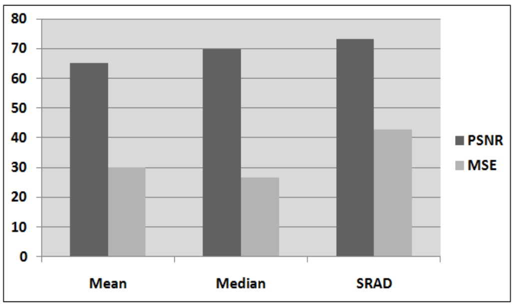


Figure.7 Output of SRAD Filter



Bar Chart.1 Performance Assessment

VI. CONCLUSION

Despeckling is carried out for SAR image using the different standard speckle reduction filters like Mean filter, Median filter and the proposed SRAD filter. Simulations are carried out in MATLAB. The performance of different despeckling filters in terms of PSNR and MSE are compared in Bar Chart -1. Simulations results show that the proposed filter yielded better PSNR and MSE when compared to other filters. The proposed filter takes into account the speckle noise model for SAR images and outperforms existing filtering methods on simulated images.

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