DESPECKLING OF SAR IMAGE USING CURVELET TRANSFORM

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Abstract - *Researchers are striving hard to get rid of noise from images. Medical images and satellite images contain immense noise during capturing and transmission process. Therefore, the reduction of noise is a challenging task for researchers. Several methods have been developed in the past to reduce noise from images. Synthetic Aperture RADAR (SAR) images are generally affected by speckle noise or granular noise, during transmission. The present paper discloses the speckle noise reduction method using Curvelet transform. The Curvelet transform is more effective on the images to restore the edges of the images. The SAR image is used as input image and analysis is carried that shows better performance parameters like Peak Signal-to-Noise ratio (PSNR) and Mean Square Error (MSE).*

Key Words: Curvelet transform, image enhancement, SAR images, speckle noise reduction

1. INTRODUCTION

Last decades, interest has grown among the researchers to capture, store, transmit and analyze image data. Image capturing is one of the effective ways to get data regarding an object, place, condition, etc. Sensing of images remotely is one of the efficient ways to get updates regarding the evolution of the natural phenomenon. This is one of the main reasons behind the increasing interest for remote sensing products in many fields of application, from homeland security to environmental protection or land resource management, just to quote some. The relevant among remote sensors for data acquisition are the Synthetic Aperture Radars (SAR). It is an active coherent sensor which stimulates the scene of interest through electromagnetic waves reproducing it by recording the backscattered signal; such a signal is thus managed by the SAR system in the image processing, in order to obtain the image. The interesting feature of the SAR compared with other sensors such as the optical, one is its microwave nature. This property offers the advantage of working with all weather and illumination conditions [1]. Moreover, varying the working frequency and so the penetration depth of the electromagnetic radiation, the information recorded is about the Earth surface, subsoil, hidden objects.

Although SAR images are a powerful tool, their interpretation is not so easy: in fact, SAR images are affected by a strong noise called speckle, which degrades the performance of many image processing tasks, such as image segmentation, target detection, and classification, or recognition of regions of interest by expert human photo interpreter.

In image processing, removing noise from the original image is still a challenging research. Several approaches have been introduced and each has its own assumption, advantages and disadvantages. The speckle noise is commonly found in the ultrasound medical and SAR images. Various techniques such as Adaptive filter, Partial Differential Equations based filters, Transform domain filters, Non-local restoration filters and Fuzzy logic based filters are used to eliminate the noise in SAR image [2].

Recently, Wavelet transform based approaches are considered as strong tool to recover SAR image from noisy data [3]. But the issue of preserving the edges of images remains unsolved. To overcome the limitation of wavelet denoising of images of exhibiting large wavelet coefficient even at fine scales, along all important edges of image cuvelet transform came into existence. Wavelet transform requires many coefficients to reconstruct an image. With so many coefficients to estimate, denoising of image faces certain difficulties [4].

These considerations motivate the increasing interest in reliable de-speckling techniques which reduce the speckle and at the same time preserve the structures in the images. However, although the image, de-speckling has been an active field of research for almost thirty years, and a large number of algorithms have been proposed, performance assessment is still an open issue for real SAR image because of the lack of a reference which does not allow introducing objective measurement criteria.

I. This paper presents a methodology to enhance the SAR images using Curvelet transform for gray scale images. CURVELET TRANSFORM

Canes and Donoho developed Curvelet transform, a powerful multi-scale multi-orientation image decomposition technique [3]. Basically, Curvelets are like ridgelets that occurs at all scales, locations, and orientations [4]. Curvelet transform solves the problem of curved singularities and varies with scale in the degree of localization in orientation [3]. In Curvelet transform, the combination of multiscale ridgelets and spatial bandpass filtering operation are used for the isolation of different scales.

A discrete curvelet transform (DCT) is performed on 512 × 512 images in 3 steps-

a. Image splitting
b. Performing tiling on sub-bands
c. Performing ridgelet transform on each tile

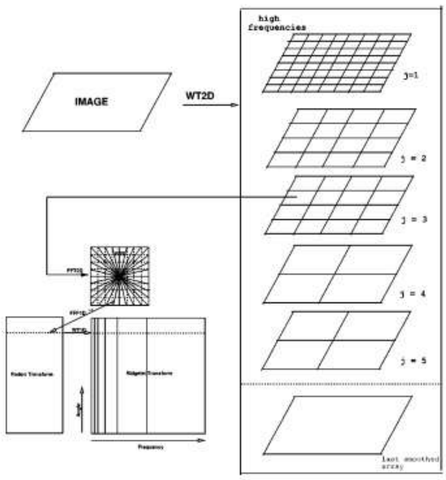

Fig. 1. Illustration of original image decomposition into sub-bands, followed by the spatial partitioning of each sub-band. After sub-band partitioning each block undergoes the ridgelet transform [5].

Image splitting involves splitting up the image in three sub-bands. Then the sub-bands are tiled that involves zooming into the image, so that curved edges are converted into linear singularities. For ridgelet transformation, the image is first transformed into Radon transform and then 1-D wavelet transform is performed.

Cycle spinning is implemented on sub-bands to convert DCT into time invariant curvelet transform. Cycle spinning denoising algorithm is implemented that includes shifting, denoising by applying DCT-thresholding- Inverse Discrete Curvelet Transform (IDCT) and unshifting to obtain denoised image.

II. IMPLEMENTATION

Following algorithm is implemented using MATLAB to analyse the performance of curvelet filter to reduce speckle noise in SAR image-

1. Input the SAR image
2. Add noise to the SAR image
3. Calculate the energy of the empty image
4. Apply the curvelet transform using Atrous algorithm
5. Select a threshold for the curvelet co-efficient and threshold the coefficient below the cut-off
6. Apply inverse curvelet transform
7. Calculate the PSNR and MSE

A flow chart for the speckle noise reduction methodology is as follows-

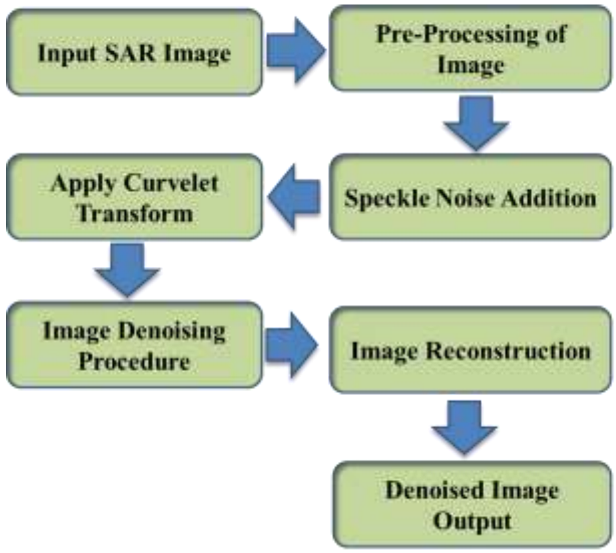

Fig. 2. Flow chart of the proposed methodology

An image of size 512 × 512 was inputted. The noise was added in the image using the random function. The algorithm was implemented for several images in .jpg format. The PSNR and MSE was calculated. The *Fig. 3a, 3b and 3c* shows the input original image, noisy image and output denoised (restored image), respectively. The proposed method performance parameters are compared with conventional methods as mentioned in *Table II*.

Evaluation Parameters

1. *Mean Squared Error (MSE)*
   It is nothing but the quantity of removed noise. It measures difference between the estimator and what is estimated [6].

$$MSE = \frac{1}{k_1 k_2}\sum_{l=1}^{k_2}\sum_{k=1}^{k_1}[X(k,l) - Y(k,l)]^2$$

2. *Peak Signal to Noise Ratio (PSNR)*
   Peak Signal to Noise Ratio is used to estimate the quality of image.

$$PSNR = 10\ log_{10}\frac{255^2}{MSE}$$

Thus, MSE and PSNR of image are calculated to find out the quantity of removed noise and quality of restored image [7].

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 06 | June 2019 www.irjet.net p-ISSN: 2395-0072

III. RESULTS AND DISCUSSION

Following are the screenshots of the image 1.jpg input and output displayed on the monitor. First image is the input SAR image, second is the noisy image obtained after addition of speckle noise in the SAR image and third is the Denoised output image.

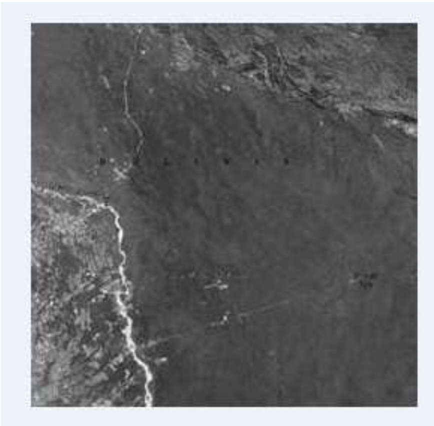

Fig. 3a. Original Image

Fig. 3b. Noisy Image

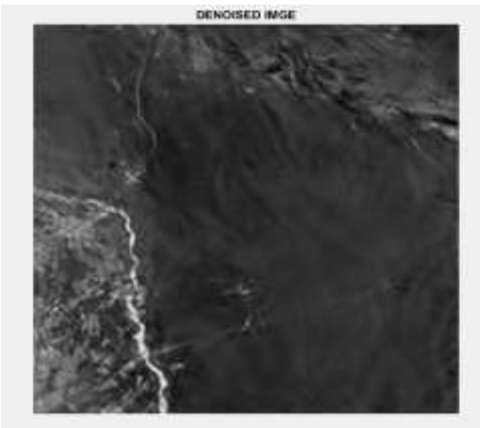

Fig. 3c. Denoised Image

Following are the screenshots of the image 2.jpg input and output displayed on the monitor. First image is the input SAR image, second is the noisy image obtained after addition of speckle noise in the SAR image and third is the Denoised output image.

Fig. 4a. Input gray image

Fig. 4b. Noisy Image

Fig. 4c. Denoised Image

Table I and *Table II* depicted below shows the estimated Mean squared error (MSE) and Peak noise to signal ratio (PSNR) of noisy image and denoised image. From *Table I* and *Table II,* it can be inferred that the quantity of noise has gradually decreased and quality of image has improved.

TABLE I. Image 1.jpg PSNR and MSE for Noisy image and Denoised image

Image 1.jpg	**PSNR**	**MSE**
Noisy Image	21.9383	416.1521
Restored Image	**32.4612**	**36.8952**

Table II. Image 2.jpg-PSNR and MSE for Noisy image and Denoised image

Image 2.jpg	**PSNR**	**MSE**
Noisy Image	21.9383	416.1521
Restored Image	**29.7458**	**68.9451**

A comparative analysis is performed with existing techniques [1] for removing speckle noise from SAR image. Proposed method performance parameters are compared with conventional methods in following table-

TABLE II. Comparison of existing filtering methods with Curvelet Transform for Speckled noise in Urban Area Image

Filter	**PSNR**	**MSE**
Lee [1]	17.94	76.86
Median [1]	17.76	83.44
Mean [1]	17.86	77.79
Frost [1]	18.86	73.95
Proposed Curvelet Method (Image 1)	**32.4612**	**36.8952**
Proposed Curvelet Method (Image 2)	**29.7499**	**68.8791**

The time-invariant curvelet transform denoising for 512 × 512 images was proposed and compared with the conventional filtering methods. The method significantly reduces the speckle noise while preserving the resolution and the structure of the original image as shown in the *Fig. 3c* and *Fig. 4c*. Experimental results given in *Table II* show that the proposed curvelet tranform outperforms the conventional methods giving a good and clean image.

IV. CONCLUSION

In this paper, curvelet transform based denoising technique is implemented. SAR image was used as an input image. Introduced model preserve the appearances of structured regions. The experimental results show that images texture and surfaces have been enhanced. The performance parameters of the Speckle noise reduction model for SAR imagery is well as compared to other conventional methods. It was observed that PSNR ratio of the restored/denoised image has increased and MSE has decreased as compared to the noisy image.

Acknowledgment

We would like to thank Dr. D. N. Kyatanavar and Dr. B.S. Agarkar for providing the required infrastructure and technical support to carry out the analysis.

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