A Comparative Study on Image Edge Enhancement for Synthetic Aperture Radar (SAR) Images

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Abstract— This paper is based on the glimpse of a comparative analysis of image edge enhancement techniques of synthetic aperture radar (SAR) images. The importance of edge enhancement is very much significant for SAR image recognition and other purposes. The first portion of this paper is based on a novel edge enhancement algorithm based on 2D wavelet transform. This method also signifies the motive to suppress the speckle noise from the image. Relying on the features of wavelet speckle image and log-compressed and transformed image, the result image is normalized, and finally the point wise maximum and multiplication has been taken to get the enhanced edge detection result. The second method is organized by taking sobel edge detection of SAR image. The resultant edge detected image is improved via a fuzzy logic based edge enhancement algorithm. Genetic algorithm based optimization is introduced in the next portion for further modification and enhancement of the edge detected and fuzzy-modified SAR image, which is finally re-enhanced by applying relaxed median filter on the image. Finally, the enhanced SAR edge image outputs for our two approaches are compared with different traditional edge detection techniques and the corresponding Root Mean Square Error (RMSE), normalized absolute error (NAE) and normalized cross-correlation error (NCC) have been computed and the comparative analysis is furnished.

Keywords- edge enhancement, synthetic aperture radar (SAR) image, 2D wavelet transform, Fuzzy Logic based edge enhancement, Genetic algorithmic optimization in edge enhancement

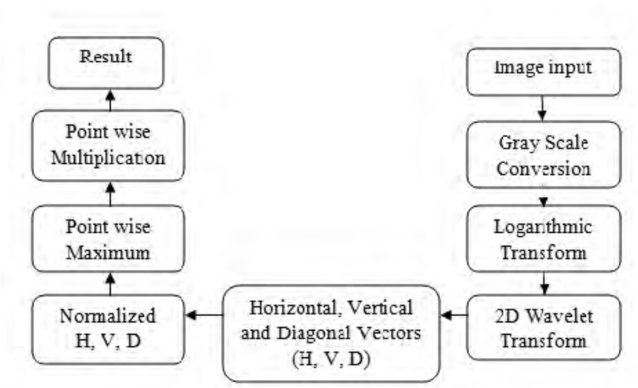
I. INTRODUCTION

A Radar system that generates high resolution remote sensing imagery, using a synthetic antenna installed aboard aircraft or spacecraft. Unlike conventional radar, SAR uses the platform movement to obtain a larger synthetic antenna, with finer azimuth resolution than the real antenna. During the data acquisition process, the target is illuminated by the antenna beam from different positions along its trajectory, resulting in a relatively long synthetic aperture, which yields finer resolution than is possible from a smaller physical antenna. High-resolution synthetic aperture radar is a very effective terrain and sea surface mapping tool. Robust edge detection techniques are essentially based on the following two steps: edge enhancement and decision. Unlike optical images, in SAR data, which is highly heterogeneous, a robust edge enhancement phase is critical in providing acceptable detection rate. This phase is usually performed through traditional techniques that are related to derivation, namely, simple differences, Sobel filter [1], Prewitt filter [2] , morphological gradients, etc, possibly combined with smoothing. These methods are limited to efficiency in SAR applications due to the presence of a speckle which is a multiplicative noise like pattern [3]. Statistically, speckle can be regarded as a random walk process as defined by Goodman [4]. The primary goal of speckle reduction is to remove the speckle without losing much detail contained in an image and resolution. In the past, several multi-scale approaches, relying on the analysis of the information contained in the wavelet domain, have been proposed [7]–[10]. In recent years, wavelet-based de-noising algorithm has been studied and applied successfully for speckle removal in SAR images [5,6]. The wavelet analysis is well localized in time and in frequency, allowing a better representation for non-stationary signals, such as SAR images. This paper aims at presenting two novel methods for edge enhancement in SAR images, of which one is based on the exploitation of the information provided by the wavelet coefficients and another is based on a hybrid fuzzy-genetic optimization approach. The first method proposed in this paper is based on a different way of managing multi-scale data. For instance, the study in [11] or [12] proposes an edge detector based on a threshold operation of wavelet coefficients. Despite a low computational cost and a good contrast, detected edges are too thick. This approach proposed in this paper will tackle at the same time the robustness as well as the precision issues of edge enhancement and detection. The second method generalizes the use of hybrid fuzzy logic and nature inspired genetic algorithm based optimization for image edge enhancement for reducing the false edges and effective enhancement. Most of the traditional edge-detection algorithms in image processing typically convolute a filter operator and the input image, and then map overlapping input image regions to output signals which lead to considerable loss in edge detection [16]; however there is no such loss in the fuzzy based method [17]. Local smoothing filter like median filter used to solve edge preserving and noise removal problem [18]. Root Mean Square Error (RMSE), normalized absolute error (NAE) and normalized cross-correlation error(NCC) have been computed on our two proposed method in correspondence with the traditional edge detection methods and it has been seen that from RMSE point of view our first 2D wavelet based method has proved more efficient than the second method. A conclusion has been drawn the last portion of our paper.

II. IMPLEMENTATION

A. *First System:*

1. *Block Diagram of the first proposed system:*



2. *Image acquisition:*

SAR image is taken as input for processing

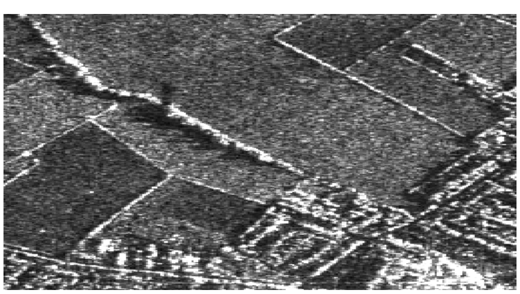


Fig1: Input Image

3. *Logarithm of the image:*

In the field of SAR image processing it is very helpful to take logarithm of the original image to manage multiplicative speckle[13,14].On the other way we can say that this logarithm operation reduce the large dynamic range of SAR image. Hence in the wavelet transform of the of the SAR signal help us to reduce speckle noise. Here the input image is converted into gray scale image at first and then logarithmic transformation is induced.

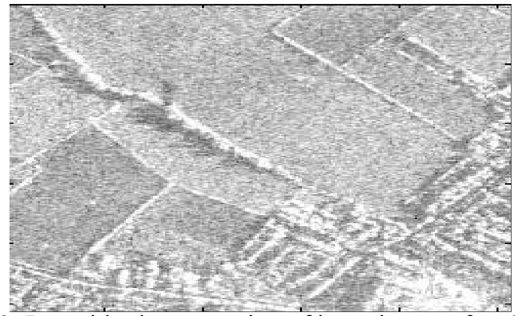


Fig2: Logarithmic conversion of input image after Gray scale conversion

6. *2D Wavelet transformation:*

Fourier transform uses sliding window to find spectrogram, which gives the information of both time and frequency. But length of the window limits the resolution in frequency. This problem is solved by wavelet transform. In this paper 2D discrete stationary wavelet transform (SWT2) and Haar mother wavelet is used. After each iteration, four sub-bands are obtained. The first three bands (i.e.,{H,V,D}) refer to the horizontal, vertical, and diagonal details of the image, respectively. The fourth band contains the low-pass-filtered component of the image. The four sub-bands have the same size as that of the input image. in the proposed method point-wise product is calculated among these four sub-bands to generate the resultant image which is the same size as the input image. So this is the reason for taken SWT2 wavelet transform. As we know that SAR images show a lot of discontinuities due to speckle noise, so we should take a mother wavelet that has small no. of coefficients like haar wavelet. The wavelet transformed output of the logarithmic image is given below.

Fig 3

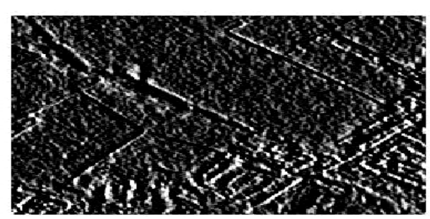


Fig4: Vertical Sub Band

Fig5. Diagonal Sub band

4. *Normalization, Point-wise maximum, Point wise multiplication:*

In this step normalize each sub-band to their maximum and take their absolute value. For better result normalization is done number of times (usually three) the standard deviation. This repeat ion of normalization method ensures low values on the sub-bands Point-wise maximum means taking the maximum value pixel per pixel among matrices. Sub-bands at each iteration create a single image or matrix by using point-wise maximum operation. As a result of this step is minimization of speckle. The point wise maximum operation is carried out with different iteration. Then, the different intermediate maxima are calculated. These are combined through point wise multiplication. Point wise multiplication means for each pixel of the resultant image is the output value corresponds to the product of the values for that pixel of the intermediate maxima matrices obtained previously.

Fig6. Resultant Image of proposed method1

5. *Advantage of the proposed model:*

Simplicity: The proposed technique is simple and its computational cost is low. It is an iterative process. It is an iterative process in which each iteration composes of two operations.

a. Uses of SWT wavelet transform.
b. Evaluation of point wise maxima.

- No pre-filtering process is needed.
- It provides a good output directly in the wavelet domain. It does not require any inversion step like conventional filters.
- Contrast achieved due to the proposed method between edges and background is very noticeable which the main objective of any edge enhancement algorithm.

B. *Edge Enhancement via proposed second method:*

In this method, the image is acquired and sobel edge detection is furnished on the input SAR image. After that, the edge detected image is modified by Fuzzy logic based image enhancement technique. The enhanced image is then enhanced and optimized via Genetic Algorithm. At last, the resultant enhanced edge image is captured by taking relax median filter enhancement.

1. *Sobel Edge detection:*

The Sobel Edge Detection method detects edges using the Sobel approximation to the derivative. It returns edges at those points where the gradient of the input image has maximum. The output of the SAR image after applying Sobel Filter is given below.

Fig7: Image obtained by using sobel edge detection on the input image.

2. *Fuzzy Logic based enhancement of edge image:*

Fuzzy logic based algorithm for detection of Edge has also been applied to the image obtained by Sobel Edge detection technique. The whole test image has been scanned using a 2*2 pixel window.

P1	P2
P3	P4

The different rules which has been used for marking the pixel under consideration as Black, White or Edge has been furnished in Table-1.

Table-1 (Fuzzy Rule Matrix)

Fuzzy Inputs				Fuzzy Output
P1	P2	P3	P4	P4_out
B	B	B	B	B
B	B	B	W	E
B	B	W	B	E
B	B	W	W	E
B	W	B	B	E
B	W	B	W	E
B	W	W	B	E
B	W	W	W	W
W	B	B	B	E
W	B	B	W	E
W	B	W	B	E
W	B	W	W	E
W	W	B	B	E
W	W	B	W	E
W	W	W	B	E
W	W	W	W	W

The output after applying Fuzzy logic based edge detection on the image obtained by Sobel filter is given below.

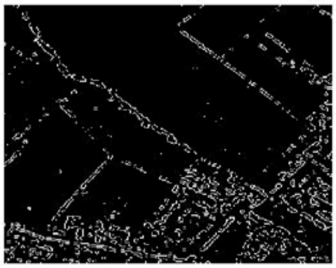


Fig8: Image obtained by applying fuzzy Logic

3. *Optimization of edge using genetic algorithm:*

Genetic Algorithm is a heuristic method used to find approximate solutions of harder problems. In early 1970s, John Holland introduced the concept of Genetic Algorithm [15]. Genetic Algorithm uses an iterative approach for solving a problem. Each iteration produces generations which have been used as parents in the next generation. Here application of Genetic Algorithm provides an image which contains optimized edges which is given below.

Fig9. Edge image enhancement by applying GA

4. *The Genetic Algorithm has been furnished as follows:*

Step 1

Represent the problem variable domain as chromosome of a fixed length and population, with suitable cross over probability and mutation probability.

Step 2

A fitness function has been defined to measure the performance, or fitness of an individual chromosome in the problem domain.

Step 3

An initial population of chromosomes has been generated randomly.

Step 4

The fitness of each individual chromosome has been calculated.

Step 5

A pair of chromosomes for matting from the current population has been selected. Parent chromosomes have been selected with a probability related to their fitness. Highly fit chromosomes have a higher probability of being selected for mating compared to less fit chromosomes.

Step 6

A pair of offspring chromosomes has been created by applying the genetic operators' crossover and mutation.

Step 7

The created offspring chromosomes in the new population have been placed.

Step 8

Steps from 5 to step 8 have been repeated until the size of new chromosome population becomes equal to the size of the initial population.

Step 9

The initial chromosome population has been replaced with the new population.

Step 10

Go to step 4, and repeat the process until the termination criterion is satisfied.

III. RESULTS

The final output result images by our two proposed edge enhancement systems (Figure 6 and Figure 10) has been compared with traditional edge detection methods like Canny, Sobel, Prewitt, Roberts, Laplacian and Zero-cross edge detection algorithms and Root Mean Square Error (RMSE), normalized absolute error(NAE) and normalized cross-correlation error(NCC) have been computed for both the images with a corresponding traditional edge detection method. The table of the error measurement is given below.

Table 2

(Error Measurement of Resultant Enhanced edge images with traditional edge detected image)

Edge Detection Technique	Comparison with proposed enhanced resultant image(given as figure no)	RMSE	NAE	NCC
Sobel	Fig6	191.9353	0.9997	2.5433e-004
Sobel	Fig10	221.4667	0.9998	2.2715e-004
prewitt	Fig6	191.9352	0.9997	2.5474e-004
prewitt	Fig10	221.4666	0.9998	2.2742e-004
roberts	Fig6	191.9661	0.9999	1.1975e-004
roberts	Fig10	221.4931	0.9999	1.0768e-004
laplacian	Fig6	191.8933	0.9994	4.7381e-004
laplacian	Fig10	221.4206	0.9996	4.3561e-004
zerocross	Fig6	191.8933	0.9994	4.7381e-004
zerocross	Fig10	221.4206	0.9996	4.3561e-004
canny	Fig6	191.8600	0.9991	6.4770e-004
canny	Fig10	221.3812	0.9994	6.1387e-004

IV. CONCLUSION

Two methods are proposed for edge detection technique for Synthetic Aperture Radar (SAR) Images. The first method is consisted of 2D wavelet based image detection and second method shows hybrid fuzzy-GA based image edge detection procedure. The comparative study of Root Mean Square Error (RMSE) suggests that its value has been less in case of 2D wavelet based image edge enhancement scheme than that of other approaches. Other quality measures like normalized absolute error and normalized cross-correlation error have been also calculated which suggests that the 2D wavelet based image edge enhancement has been better than other edge detection enhancement methods. This enhancement can be proved to be a boon of efficient edge detection in SAR images. Future works tend to provide more efficient edge enhancement methodologies for SAR image for effective recognition purposes.

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