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Novel Segmentation Technique for Target Tracking in Synthetic Aperture Radars

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Abstract: This paper under take the system which is automatically extracts the regions in Synthetic Aperture Radar (SAR) images by speckle noise reduction and regions extraction using segmentation. SAR images are inherently affected by multiplicative speckle noise due to coherent nature. Noise concentration has been eliminated by using Adaptive frost filter. Multilevel threshold based improved hybrid PSO technique is proposed for the image enhancement for segmentation. Experimental result shows that the proposed method can effectively reduce the speckle noise and enhance the edge features.

Keywords: denoising, multilevel threshold, synthetic apertute radar, speckle noise, segmentation.

1. INTRODUCTION

Synthetic aperture radar (SAR) images are inherently affected from speckle noise because it's coherent nature. Though multi look averaging is the general method to reduce the speckle noise at the cost of reduced special resolution. It faces the difficulties due to the multiplicative nature of the speckle noise in the analysis of images by reducing the edges and small disorders in the image. This result an image with poor quality is possible. It is more advantageous to develop suitable filtering techniques. Although the classical filters such as Weiner filter [1], Lee filter [2], and Kuan filter [3] which reduces the noise in SAR images in special domain by recalculating the center pixels of the filtering windows based on the local scene heterogeneity, work well in stationary image area, they tend to either preserve speckle noise or erase a weak scene signal. This necessitates efficient techniques to enhance the image and isolate the regions in the Image. After the image segregation we can find the number of objects or special regions in the Image. The manual detection is the difficult task to differentiate the similarly or typical region in the image, it makes the strain on human eye. In order to conquer the problem in image capture, an enhanced system with denoising filters and segmented algorithms is proposed.

In this paper, several methods for speckle denoising have been proposed. Wavelet based threshold techniques are effective used for speckle denoising. But it has high computational cost. Adaptive threshold techniques [4-8] proposed by Sforza et. al., to detect the grey area from noisy image. Delsanto et. al., proposed Automatic segmentation for artery segmentation. An optimal threshold method is proposed by Geo et. al., proposed for image segmentation based onpartical swarm optimization [9]. The reorganization rate is increased by using the region growing methods but less sensitive to noise. Giordano et. al., and Osowski proposed efficient image preprocessing techniques [10]. Multi frequency techniques [11-14] for image enhancement were introduced by Casciaro et. al., After that level set methods[15] based active contour segmentation is introduced by Chan and Vese.

2. SPECKLE NOISE REDUCTION IN SAR IMAGES

The functional block diagram of processing system is shown in Figure 1. Basically it consists of two stages, one is preprocessing stage and the second one is object identification stage. Different noise eliminating filters are used in the preprocessing stage to remove the speckle noise from the input image which is a noisy SAR image. Region of Interest (ROI) has been separated from input image and the filtering techniques are applied on the image. Image segmentation is done in the object identification stage using the proposed techniques. This is followed by the feature extraction and classification.

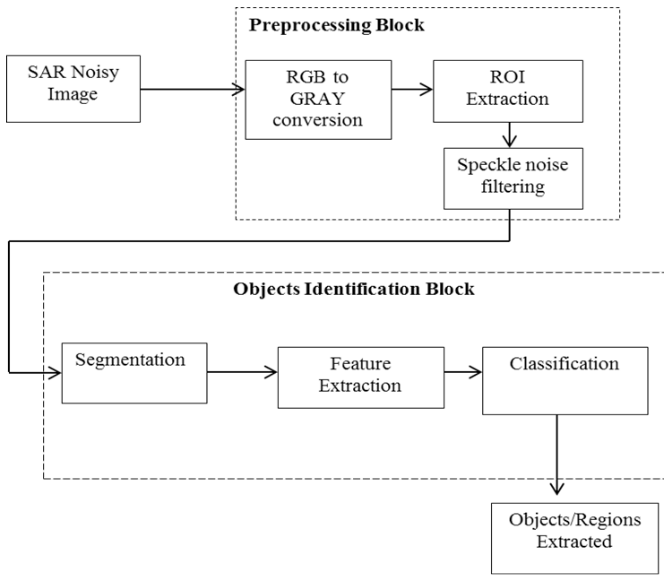


Figure 1: Block diagram of Automatic Object detecting system

Due to the multiplicative nature of Speckle noise the automatic detection of regions in the SAR image is a challenging task. To overcome this problem Adaptive frost filters were introduced. The performance of these filters are evaluated based on specific parameters namely Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Maximum Difference (MD), Normalized Cross Correlation (NK), Absolute Difference (AD), Structural Content (SC) and Normalized Absolute Error (NAE) as specified in Table 1. In the below equations I and I′ represent the noisy and noise free image respectively. X, Y represents the rows and columns in an image. In this paper we proposed a new approach for removing the noise in SAR images for proper segmentation.

Table 1
Performance Metrics

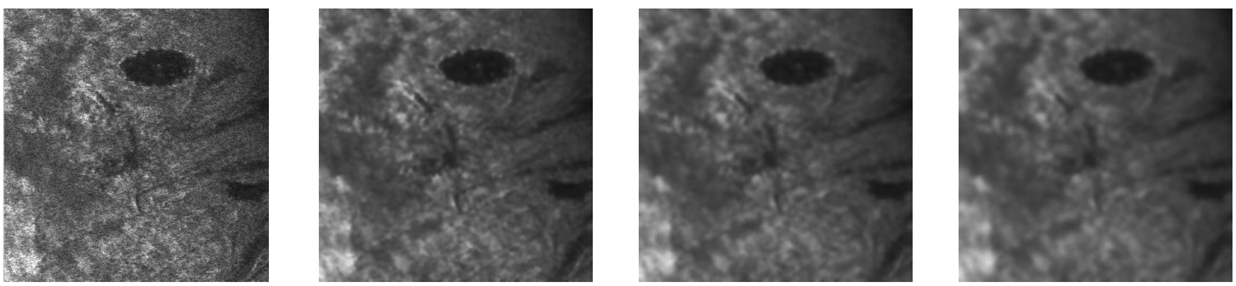
PSNR	$PSNR = 10 \log 255^2/MSE$
MSE	$MSE = \frac{1}{XY}\sum_{l=1}^{X}\sum_{m=1}^{Y}(I(l,m) - I'(l,m))^2$
AD	$AD = \sum_{l=1}^{X}\sum_{m=1}^{Y}(I(l,m) - I'(l,m))/XY$

PSNR	*PSNR = 10 log 255²/MSE*
SC	$SC = \sum_{l=1}^{X}\sum_{m=1}^{Y} I(l,m)^2 \Big/ \sum_{l=1}^{X}\sum_{m=1}^{Y} I'(l,m)^2$
NK	$NK = \sum_{l=1}^{X}\sum_{m=1}^{Y} (I(l,m)\, I'(l,m)) \Big/ \sum_{l=1}^{X}\sum_{m=1}^{Y} I(l,m)^2$
MD	$MD = \max(\lvert (I(l,m)) - I'(l,m) \rvert)$
NAE	$NAE = \sum_{l=1}^{X}\sum_{m=1}^{Y} \lvert (I(l,m) - I'(l,m)) \rvert \Big/ \sum_{l=1}^{X}\sum_{m=1}^{Y} \lvert I(l,m) \rvert$

A. Adaptive Frost Filter

This filter enhances the Quality of the image for accurate segmentation. Frost filter is the combination of Frost filter and Hybridized wiener filter [1]. The blur noise is eliminated by the wiener filter and the resultant image is convolved with spatially-varying Frost Kernel as specified in (1).

$$\bar{G}(e, f) = g(e, f) \cdot v(e, f) \tag{1}$$



(a) Input noisy image **(b) Adaptive frost 3x3** **(c) Adaptive frost 5x5** **(d) Adaptive frost 7x7**

Figure 2: Denoising of Synthetic aperture sonar image for different filter widths

Figure 2 (a)-(b) Shows the de-noising the synthetic Aperture Sonar Image using Adaptive frost filter for different window sizes.

In this paper we have considered three images and the performance parameters are presented. Minimizing the MSE, NK, SC, NAE, AD and MD maximizing the PSNR values results the enhanced de-noising filter. From the Table 2 it is observed that proposed filter shows the better response with decrease in smoothing parameter '*h*'.

Table 2
Performance Metrics for Diferent De-Noising Filters for Sas Image

Filter	*Smoothing parameter/ Window size/ frequency*	*Performance Metrics*						
		AD	*MD*	*MSE*	*NAE*	*NK*	*PSNR*	*SC*
Proposed Filter P1	h=0.3	0.107	27.679	4.763	0.023	0.996	41.352	1.007
Proposed Filter p2	h=0.5	0.138	31.596	10.547	0.035	0.994	37.899	1.011
Proposed Filter P3	h=0.7	0.168	37.713	18.586	0.046	0.991	35.439	1.015
Adaptive Frost Filter AF3	3x3	–0.007	63.000	97.100	0.095	0.982	28.259	1.023
Adaptive Frost Filter AF5	5x5	0.014	82.000	137.574	0.111	0.976	26.745	1.030
Adaptive Frost Filter AF7	7x7	0.018	91.000	168.209	0.122	0.972	25.872	1.035
Optimum Value		–0.134	27.679	4.763	0.023	0.936	41.352	1.007

B. Proposed Hybried Paritical Swam Optimization (PSO) Method for Segmentation

The original PSO is developed by Eberhart and Kennedy. Swarm intelligence basic concept for PSO [16-17]. Proposed hybrid PSO technique is the combination of basic PSO, DPSO and Fractional Order PSO. In which some swarms using Darwin's survival of the fittest principle and convergence of control depending on fractional calculus. It increases the ability of PSO algorithm. It will escape from local minima by running the different PSO having different swarms. It discarded the searching area and another area is searched when it is optimum. By this approach at each step swarm extend the particle life and delete the particles. Griinward-Letnico FC defines the fractional differential concept with α, to control the particle convergence rate it should be $0 \leq \alpha \leq 1$. Each particle P, with each swarm S move in multi dimensional space according to the space $(H_p[t])$, $0 \leq H_p[t] \leq M-1$, and velocity $w_p[t]$. The velocity and position moves are highly dependent on local best $(\dot{H}[t]_p)$ and global best $(\dot{G}[t]_p)$. According to this local best and global best, the coefficients u, β_1 and β_2 controls the inertial influence when the new velocity is determined. Based on the various values of "cognitive" and "social" components β_1 and β_2 the results can be changed and the value of inertial influence will be slightly less than 1. For each value of the particle P of the swarm S the velocity and position vector are defined as

$$w_p^s[t+1] = \alpha w_p^s[t] + \frac{1}{2} w_p^s[t-1] + \frac{1}{6}\alpha(1-\alpha) w_p^s[t-2] + \frac{1}{24}\alpha(1-\alpha)(2-\alpha) w_p^s[t-3]$$
$$+ \beta_1 q_1 (\dot{K}[t]_p^s - \dot{H}[t]_p^s) + \beta_2 q_2 (\dot{G}[t]_p^s - \dot{H}[t]_p^s)\dot{K}[t]_p^s, \left| w_p^s[t+1] \right| \leq \Delta w \tag{2}$$

$$H_p[t+1]^s = H_p[t] + w_p^s[t+1], 0 \leq H_p[t] \leq M-1 \tag{3}$$

Weights and mean value of components are calculated using the value of $H_p[t+1]^s$ when pixels of image divided in to n classes.

The weights
$$u_j^b = \begin{cases} \sum_{m=0}^{t_j^b} x_j^b, & j = 1 \\ \sum_{m=t_{j-1}^b+1}^{t_j^b} x_j^b, & 1 \leq j \leq n \\ \sum_{m=t_{j-1}^b+1}^{M-1} x_j^b, & j = n \end{cases} \tag{4}$$

and the mean values
$$\mu_j^b = \begin{cases} \sum_{m=0}^{t_j^b} \frac{x_j^b}{w_i^c}, & j = 1 \\ \sum_{m=t_{j-1}^b+1}^{t_j^b} \frac{x_j^b}{w_i^c}, & 1 \leq j \leq m \\ \sum_{m=t_{j-1}^b+1}^{M-1} \frac{p_j^b}{w_i^b}, & j = m \end{cases} \tag{5}$$

An efficient approach for getting the optimum threshold value is that maximizes the between class variance of each component defined as:

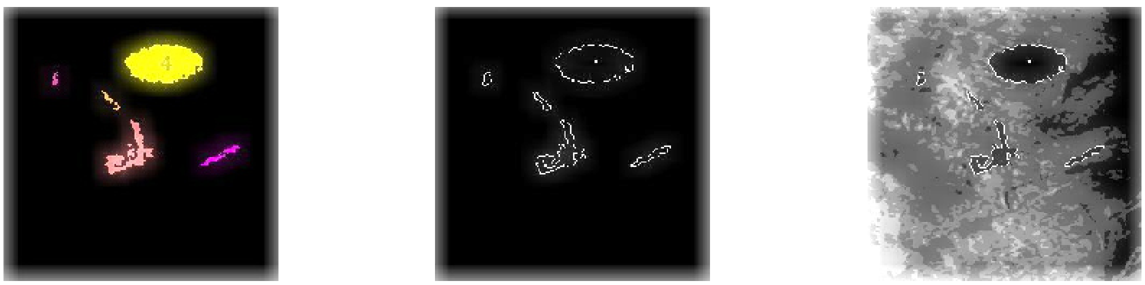
$$\sigma_R^{b2} = \sum_{j=1}^{n} w_j^b (\mu_j^b - \mu_T^b)^2$$

The optimum solution to find the thresholds that maximizes the fitness function of each image component is:

$$\varnothing^{b} = \max_{1 < t_j^b \ldots < t_{m-1}^b < M-1} \sigma_R^{b2}(t_j^b) \tag{6}$$

Based on this optimum solution the swarms fitness may increase or decrease.

(a) Synthetic Aperture Sonar Image **(b) Binary mask of Image** **(c) Area of Extracted Objects**



(d) Result of counted objects **(e) Result of Edge Detected Image** **(f) Overlaid on Original Image**

Figure 3: Segmentation is performed by proposed Hybrid PSO Method

The objects are extracted after completion of number of iterations. Figure 3(c) is the extracted regions after inserting and removing the swarm particles. This technique finds the effective regions where the area is around hundreds of meters. The proposed method extracted the objects effectively from complex condition with lee time through more exactness that matched better with prediction by human experts.

3. EXPERIMENT RESULTS

Here Figure 4 presents the results for three input images which are under tested with proposed technique. Here the three input figures are of different categories like sonar image, volcano effected areas and terrain regions. With the proposed method the calculated number, location and boundary of the regions extracted accurately. During training phase the image characteristics are analyzed and the classifier organizes the data into different tables. In the testing phase all the features are calculated. On the Basis of size of the object or the region and location, observer may come in to conclusion about the area.

Table 3
Result of Regions Extraction by Proposed Method

Method	*Follicle*	*Area*	*Perimeter*	*Major Axis*	*Minor Axis*	*Eccentricity*	*Extent*	*Circularity*
Proposed Method	1	63	42.97056	14.15816	7.863413	0.831585	0.583333	0.428754
	2	84	54.18377	24.58032	5.390268	0.975659	0.260062	0.359543
	3	692	259.1787	54.93315	32.27879	0.809151	0.294468	0.129455
	4	1893	208.3087	70.93147	34.57128	0.873184	0.710586	0.548209
	5	171	92.42641	42.34395	6.026283	0.989821	0.243243	0.251544

Human experts identifies the number of objects and effected regions and area of the effected regions shown in Figure 4. Table 3 represent the testing results of Sonar image and its detected object features.

The SAR Images used in this experiment are collected from the POLSAR Database. The proposed algorithm discussed here is tested with several images. The algorithms are implemented in Matlab software. From the results the performance of proposed algorithm is elevated based on the number of objects extracted, location of objects and it's size. To discuss the performance of automatic object detection system the first processed unit is pre processing unit which is applied to the input sample images. Segmentation methods are evaluated in the second stage with noise free image. The implementation and performance analysis of segmentation algorithm are shown in the above figures. The proposed Hybrid PSO method extracts the various regions in image shown in Figure 3. The proposed methods gives the effective results in terms of all the features of extracted objects which can match the information identified by human expert.

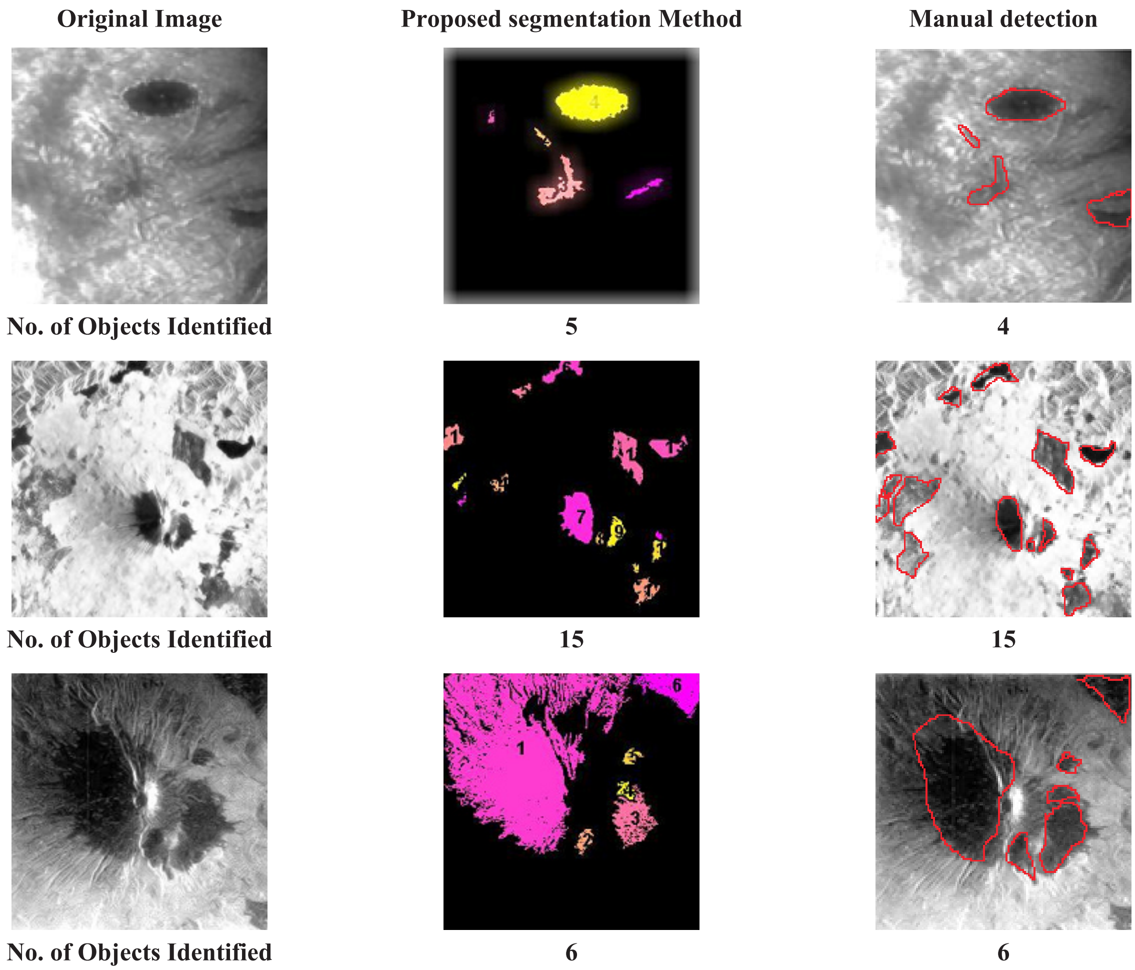


Figure 4: Difference in region extraction of proposed method with three different category of images

4. CONCLUSIONS

This paper presents the efficient system that automatically detects the objects and segmented areas in SAR images. The SAR images are denoised efficiently by using adaptive frost filter and the filtered images are segmented for detecting the special regions by hybrid PSO algorithm. This proposed technique performs more speed and accuracy to meet the specific requirements. Therefore this automatic detecting system embedded with

Geo graphic analyzer that avoids the painful observation of scientists, extracted object or region features more accurately. Hence the this system is an efficient technique for analyzing the SAR image to study the ground condition, icebergs sizes in the sea etc.

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