Significance based Ship Detection from SAR Imagery

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***Abstract*— Synthetic Aperture Radar images have potential applications in the surveillance scenario and hence automated target detection algorithms prove to be a useful tool in monitoring and crime control as well as in marine traffic management. The advancements in marine trade have lead to the increase in the number of ships in the world waters. The usage of satellite-based radar images have become well known for maritime surveillance as ship detection is relatively simple and independent of the climatic conditions. Ships can be easily discerned in the SAR images due to their bright intensity which results due to the strong radar backscatter from their metal surface. These are the significant pixels in an image which can be gathered to detect the ship targets. During heavy sea state conditions and presence of speckle noise, sea ice and coastline structure, the ship detection process is affected since these non-ship features in the sea also exhibit high intensities in the SAR image. These false alarms have to be reduced. So, in this work a Significance based ship detection algorithm followed by a discrimination stage using ensemble classifier is proposed to differentiate the ship and non-ship targets. To enhance the ship detection process, the images are subjected to ridgelet transform based despeckling. The efficacy of the proposed Significance based target detection is proved by the obtained results.**

Keywords: **Target Detection, Ridgelet Transform, Significance, Ensemble classifier.**

I. INTRODUCTION

Target Detection in Synthetic Aperture Radar (SAR) images has been a long research topic and has many applications, such as monitoring of fishing activities and oil pollution, marine traffic management and crime control. Among this, marine traffic represents a basic human activity which leads to the presence of millions of vessels navigating daily on the world seas for different purposes. Migrant flow exploitation, unauthorized fishing and environmental pollution are a few examples of the issues that are related to current illegal ships traffic. This provokes the need for vessel monitoring systems from space with imaging sensors. Two types of airborne and satellite borne imaging sensors are used namely, the optical sensors and imaging radars. The biggest advantage of radar data over optical data is that it is not affected by weather conditions and can see through cloud cover [1]. SAR is a form of radar that is used to create two dimensional images of the earth structures or three dimensional reconstructions of objects on earth. SAR focuses radar antenna over a target region to provide finer spatial resolution than regular beam-scanning radars.

SAR images when acquired, suffer from patterns of constructive and destructive interference of backscattered signals from multiple distributed objects. This disturbance called as speckle noise being the largest source of noise in SAR images, results in bright and dark spots in the image, provoking complications in image interpretation, like failure to extract bright spots which can be possible targets or giving false alarms by identifying other disturbances as targets. Speckle noise is a locally correlated noise in multiplicative form due to which the image processing techniques sense great difficulties when applied on SAR imagery. The heterogeneity of sea clutter, different weather conditions and the unclear appearance of targets caused by different imaging angle in SAR imagery also adds to the difficulty in image interpretation [2]. In SAR oceanography, speckle noise is caused by the ripples and other objects on ocean that produces scattering. So the effect of speckle noise has to be reduced, in order to enhance the subsequent processes such as identification and characterization of the marine targets. A variety of methods have been attempted for despeckling by many researchers.

Ships are metal structures consisting of sharp edges that reflect radar signals intensively, that can be detectable as bright spots on SAR images. A typical target detection system consists of the detection and classification stages. The detection stage is to find regions of interest in SAR image that contain the potential targets points. Classification is done to differentiate whether the detected region is a true target or not. Target detection from SAR images has been explored by many researchers in recent years. Among their contributions, the Constant False Alarm Rate (CFAR) detectors having Cell-Averaged CFAR (CA-CFAR) and the Order statistic CFAR (OS-CFAR) are widely used [3,4]. The CFAR detectors adaptively determine the detection threshold by using the statistics estimated from the boundaries of the detecting window. The background clutters are usually modeled by Rayleigh, Weibull, Non – Gaussian, K, Gamma and Alpha-stable distribution, are recommended by different researchers [5 – 10]. For these types of methods, it is computationally expensive to

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estimate the distribution parameters of complex distribution models and the accuracy of parameter estimation also has significant influences on the final detection results. Furthermore, the pre-specified distribution models of background clutters may not fit the actual data well, especially in complicated scenes, which will degrade the detection performance. Another type of target detection method relies on the information extracted by image decomposition or transform, rather than statistical distribution models [11]. Genetic programming was also introduced for target detection from SAR images by making use of human vision system approach to identify regions that are distinct from their surroundings [12, 13]. Based on the diverse characteristics of ship and sea clutter, heterogeneity based target detection has also been done in literature [14]. Most of the target detection algorithms are computationally difficult and requires intense processing. So a simple target detection algorithm consisting of extracting the significant points in the image to identify the potential target pixel followed by pixel wise classification of the identified ROI pixels using an ensemble classifier to detect the valid ship pixels is proposed in this paper.

The paper is organized as follows: The proposed method is described in Section 2 with results using SENTINEL-1A SAR data and discussion found in Section 3, followed by a brief conclusion.

II. Proposed Ship Detection Algorithm

A significance based ship detection method is proposed in this work as shown in Figure 1. The potential target pixels obtained by extracting the significant points in the image which are then discriminated as ship pixels and non-ship pixels using an ensemble classifier to improve the precision of the algorithm.

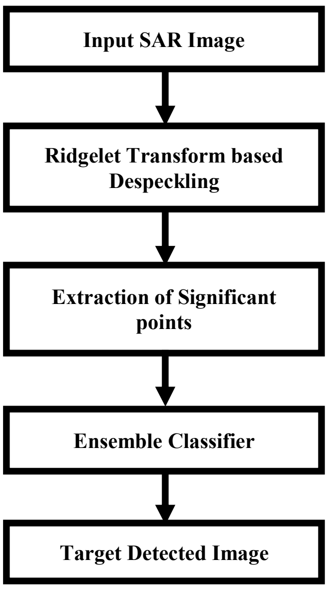


Fig.1 Proposed Target Detection Method

Adhering to the fact that, the ship pixels appear to be brighter than the background clutter pixels in the oceanographic SAR images, the target detection algorithm is proposed to capture the significant pixels as the potential target points. The background clutter, ocean waves, ship wakes and other structures in the ocean may also appear as bright points. So, an ensemble classifier is used to discriminate the ship and non-ship pixels based on their features. Prior to target detection, Ridgelet transform based despeckling is performed to enhance the further processing.

A. Ridgelet Transform based Despeckling

The most common type of noise present in SAR images is Speckle noise, caused by coherent processing of backscattered signals from multiple distributed targets, the gravity-capillary ripples and other elementary structures on the ocean waters [15]. Speckle noise reduces the contrast of the images, which makes it difficult to perform further image processing operations like segmentation, edge detection, etc. Despeckling can improve the quality of the image for better image interpretation. In our work Ridgelet transform based despeckling is used.

The Ridgelet transform can effectively handle the line singularities. It utilizes the radon transform to convert the line singularities into point singularities. Wavelet transform is then applied to deal with the point singularities. Ridgelets are more powerful in handling directions and are highly anisotropic. Discrete Ridgelet Transform can be a near-optimal method for denoising [16], since it provides near-ideal sparsity representation for objects with both edges and smooth regions. The ridgelet transform based image denoising involves partitioning the image into overlapping blocks and applying ridgelet transform on each block. The Ridgelet coefficients obtained are thresholded with minimax thresholding technique. The denoised image is then obtained by taking inverse Ridgelet transform of the thresholded coefficients.

B. Significance based Ship Detection

Ship detection in SAR images is usually affected by some environmental factors such as waves, coastline structures, light reflection from water, waves, etc. Ship detection in calm sea conditions is computationally simple whereas in rough sea state and high wind speeds, the complexity increases drastically [17]. The proposed significant based ship detection can produce relatively good performance at heterogeneous sea state and is simple and fast to implement. The Significance points are the points of interest in an image. In this method, the valid target points are first identified by collecting the significant pixels in the image [18]. The significant pixels, S in the image are found using the formula given by,

$$S = \frac{(x_t - \mu_b)}{\sigma_b} \tag{1}$$

where, x_t is the pixel intensity, μ_b is the mean of the image and σ_b is the standard deviation of the image.

The obtained significance image is then thresholded such that, when $S > t$, the corresponding S pixel is a valid target pixel. The value of t is chosen as, $t = 0.25*max(max(S))$. This process identifies all the potential target points in the image. The false alarms generated in the detection process due to the non ship pixels can be reduced during the discrimination phase. While using an individual classifier for discrimination, there is a possibility that some of the features may remain unlearnt by the classifier leading to unacceptable performance. So, in the proposed work an ensemble classifier of Logit boost algorithm is trained with the features of both ship and non-ship regions. This group of classifiers can improve the algorithm performance and produce better results than the single classifiers [19]. Statistical features such as mean, standard deviation and the texture features given in equation (2) to equation (6) are used as the discriminating features.

$$\text{Contrast} = \sum_{i,j=0}^{N-1} I_{ij}\,(i-j)^2 \tag{2}$$

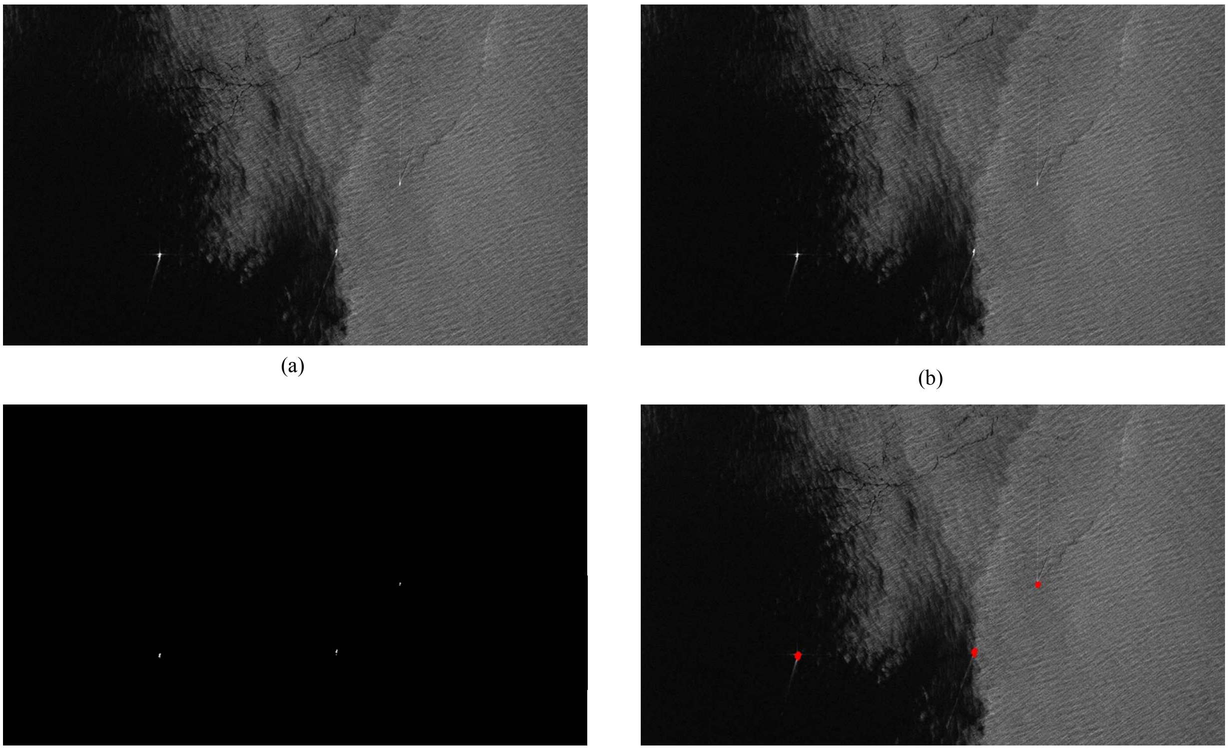
$$\text{Energy} = \sum_{i.j-0}^{N-1} (I_{ij})^2 \tag{3}$$

$$\text{Homogeneity} = \sum_{i,j=0}^{N-1} \frac{I_{ij}}{1+(i-j)^2} \tag{4}$$

$$\text{Cluster Shade} = \sum_{i,j=0}^{N-1} (i+j-2\mu)^3\, I_{ij} \tag{5}$$

$$\text{Cluster Prominence} = \sum_{i.j=0}^{N-1} (i+j-2\mu)^4\, I_{ij} \tag{6}$$

where, I_{ij} is the pixel value at position (i, j) of the image.



(a) (b) (c) (d)

Fig.2 (a) Input SAR Image; (b) Despeckled Image; (c) Significance Image; (d) Target Detected Image

These statistical and texture features extracted from 100 patches each of both ship and non ship regions are trained to the ensemble of classifier, which then differentiates the pixels as ship pixels and non ship pixels. The patches from background sea clutter, the dark region in the SAR image created due to ocean currents and winds were trained as non ship regions.

III. Experimental Reults And Discussions

The experimentation of the proposed work was carried out using seven SENTINEL 1A SAR images. These are VV polarized, Ground Range Detected, Strip Map products acquired at high resolution mode. These images have 23 x 23 (rg x az) m resolution.

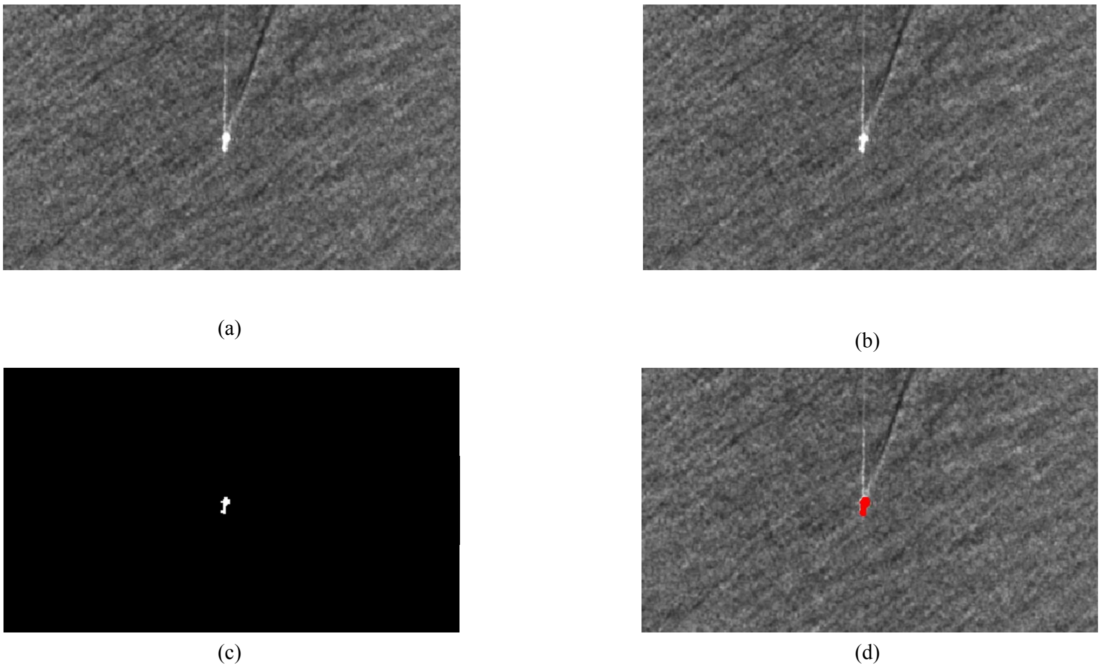


Fig.3 (a) Input SAR Patch; (b) Despeckled Patch; (c) Significance Patch; (d) Target Detected Patch

An image of size *1714 x 2927* consisting of three ships used for experimentation of the proposed algorithm is displayed in Fig.2 (a). The SAR image is first subjected to Ridgelet transform based despeckling followed by Significance based target detection. The despeckled image is shown in Fig. 2 (b). The significant points in the image are first extracted using the equation (1). The significance value is the mean value subtracted from each pixel value and divided by the standard deviation of the image. The obtained Significance image is shown in Fig.2 (c). Then a *3 x 3* patch is extracted around each pixel in the significance image for extracting the texture and statistical features. If the ensemble classifier classifies it as ship, then the corresponding centre pixel is retained as a valid ship pixel, else the process is continued for the next significant point. The target detected image is shown in Fig.2 (d). Based on visual examination, three ships are identified in the SAR image, therefore all the targets are detected correctly, proving the effectiveness of the proposed algorithm. Figure 3 shows the enlarged patch of a single target present in the right side of the image and the corresponding despeckled, region grown and target detected images.

To make further assessment of the proposed algorithm, the images in the database were put to target detection using the conventional CFAR detector. The target detected SAR images using the proposed method and CFAR detector are shown in Fig. 4 (a) and Fig.4 (b) respectively. It is clearly shown that the proposed method produces much better target detection results as CFAR produces more false alarms.

CONCLUSION

Significance based target detection algorithm proposed in this work was able to produce good results. The algorithm is simple and easy to implement. To reduce the complexity of target detection process, only the significant points which are the brightest points in the SAR image are identified and used for discrimination process, thus strengthening the efficacy of the proposed algorithm. Also the Ridgelet transform based despeckling and ensemble classifier helps in reducing the false alarms by discriminating the ship pixels from non-ship pixels.

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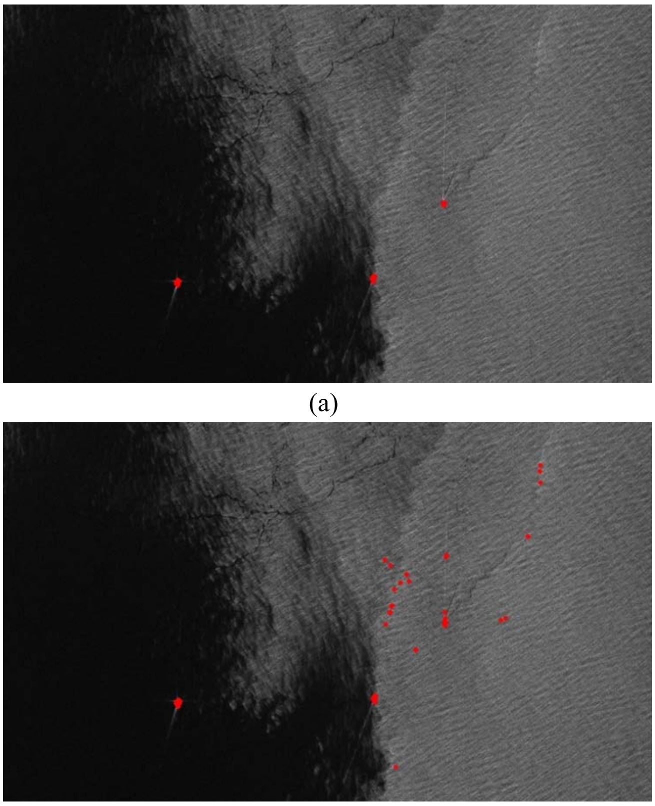

(a)

(b)

Fig.4 (a) Significance based Target Detected Image;
(b) CFAR based Target Detected Image

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