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SHIP DETECTION IN RADARSAT SAR IMAGERY *

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ABSTRACT

An automatic detection model for ship targets in RADARSAT SAR images is being developed by using statistical methods, Radon transform and other image processing techniques. This paper presents current progress made on the detection model.

Keywords: *K-distribution, Morphological filter, Radon transform, Ship target detection*

1. INTRODUCTION

There have already been considerable works done on ship and other target detection in a radar clutter background (see [6, 9, 10, 11]). In general, ships are identified in the SAR imagery as very bright features because of the corner reflection. In reality, with an appropriate choice of threshold, all visible ships to human eye can be detected. A statistical algorithm for quantifying RADARSAT SAR's ship detection has been proposed by Rey *et al* (see [9, 10]). The Constant False Alarm Rate (CFAR) technique has been used to improve ship target detection performance. The initial ship detection algorithm in the *Ocean Monitoring Workstation* (OMW) is CFAR algorithm based on K-distribution statistical fits, which was developed jointly by the *Defence Research Establishment Ottawa* (DREO) and the *Canada Centre for Remote Sensing* (CCRS).

Our project is an important part of a CRSNG-CSA-Industry research program on the use of Canadian RADARSAT imagery for coastal surveillance. The purpose of this project is detection of ships in RADARSAT SAR imagery by using statistical methods, Radon transform and other image processing techniques. The detection model developed is a modification made on the initial algorithm in [9]. The main work is combination of the Radon transform technique and the K-distribution model to reduce false alarms and the computational time. In this paper, we will describe our detector model for ship targets in SAR images and show two experimental results based on the model.

2. DETECTION ALGORITHM

The basic structure of the detection algorithm is summarized in Figure 1. Different procedures are discussed accordingly in subsequent sections.

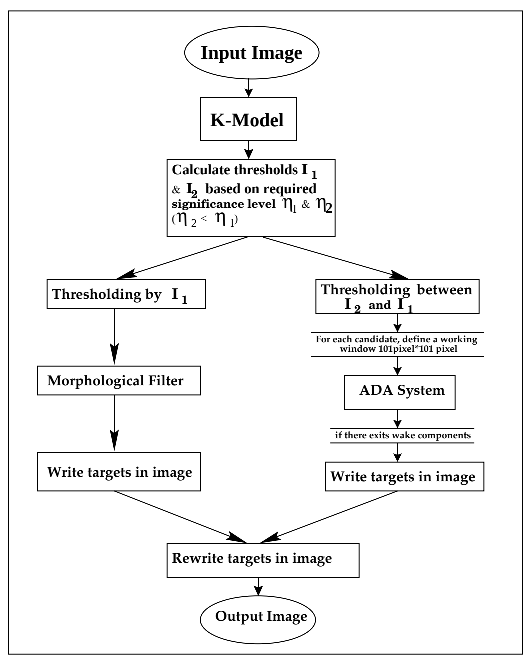

Figure 1: The flow diagram for ship target detection procedure

2.1. K-distribution Model

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In our research work, we still use the multi-look intensity K-distribution to describe the probability density function (pdf) of RADARSAT SAR image intensity (see M. Rey [9]):

$$p(x) = \frac{2}{x\Gamma(\nu)\Gamma(L)} \left(\frac{L\nu x}{\mu}\right)^{\frac{L+\nu}{2}} K_{L-\nu}\left(2\sqrt{\frac{L\nu x}{\mu}}\right)$$

where μ is the image intensity mean, ν is a shape parameter, L is the number of statistically independent looks, Γ is the gamma-function, and $K_{\nu-L}$ is the modified Bessel function. The theoretical expressions for mean and variance are as follows:

$$E[x] = \mu$$

and

$$Var(x) = \left[\left(1+\frac{1}{\nu}\right)\left(1+\frac{1}{L}\right)-1\right]\mu^2 \quad (1)$$

where E is the expectation and Var the variance operator.

The considered density function may be completely specified by the image mean, the number of independent looks, and the order shape. The main problem here is how to estimate these parameters. The number of statistically independent looks in a SAR image is an essential parameter for determining the speckle level in the image. The number of looks L can be either specified by the SAR processor or estimated using statistical methods (see [13]). In our model, for a given data sample sequence $\{x_i\}_{i=0}^N$, we propose to estimate the look number L by

$$\hat{L} = \left\lceil \frac{\left(\frac{1}{N}\sum_{i=1}^N x_i\right)^2}{\frac{1}{N-1}\sum_{i=1}^N \left(x_i - \frac{1}{N}\sum_{i=1}^N x_i\right)^2} \right\rceil$$

based on the condition of $\nu > 0$ and the equation (1). Meanwhile, the parameter estimates of the mean and shape parameter using the first approach of Blacknell (see [3]) can be obtained from the equations:

$$\hat{\mu} = \frac{1}{N}\sum_{i=1}^N x_i$$

and

$$\left(1+\frac{1}{\hat{\nu}}\right)\left(1+\frac{1}{\hat{L}}\right) = \frac{\frac{1}{N}\sum_{i=1}^N x_i^2}{\left(\frac{1}{N}\sum_{i=1}^N x_i\right)^2}.$$

To examine that K-distribution is a suitable probability density function (pdf) for RADARSAT ocean scenes (see [2]), we use the mean-squared error as a goodness-of-fit test. i.e.,

$$\text{Error} = \frac{1}{256}\sum_{i=0}^{255}(h(i)-p(i))^2 \quad (2)$$

where $h(i)$ is the histogram of original image.

2.2. Radon Transform Technique

The Radon transform accentuates linear features in an image by integrating image intensity along all possible lines in an image. This transform is commonly used in algorithms for detecting linear features in an image even in the presence of noise. The Radon transform can be defined as:

$$\check{f}(\rho,\theta) = \int\int_D f(x,y)\ \delta(\rho - x\cos\theta - y\sin\theta)dxdy$$

where D is the entire x-y image plane, $f(x,y)$ is the image intensity (gray level) at position (x,y), δ is the Dirac delta distribution, ρ is the length of the normal from the origin to the straight line, and θ is the angle between the normal and x-axis.

Details regarding the Radon transform is given in M. Rey [8] and Jiang *et al* [1]. In general, an automatic detection algorithm (ADA) developed using the Radon transform involves three consecutive processes: *pre-processing*, *Radon transform*, and *post-precessing*. Here we propose to apply the Radon transform by integrating image intensity along all lines starting from the centre of each ship candidate.

2.3. Ship Target Detection Performance

The algorithm starts with testing the suitability of the intensity K-distribution. When the error calculated by the equation (2) is less than a given value α (usually $\alpha = 0.05$ is selected), we determine a threshold, I_c, by the solution to

$$\eta_c = \int_0^{I_c} p(x)dx \quad (3)$$

where $p(x)$ is a pdf with K-distribution and η_c represents the required significance level. This significance level corresponds to a constant false alarm rate (CFAR) of $(1-\eta_c)$ for the pdf of intensity. Our ship detector model is divided into two parts (Figure 1):

The first part is used to identify almost all visible ship targets in a SAR image. Presently, it uses a threshold I_1 which corresponds to a significance level η_1 (usually $\eta_1 = 0.995$ is selected) in the equation (3) to identify possible pixels and, after that, a morphological filter is applied to eliminate those false ship pixels. The morphological filter is a logical filter which pertains to the structure and shape of objects (see Lin [6]). The filter is a 7 by 7 moving window. Each image pixel is examined by placing in the filter centre. The filter than examines the 48 neighbouring pixels. If more than 7 neighbouring pixels are possible ship pixels, the centre pixel is considered as a true ship pixel.

The second part is mainly to refine some ship targets by using simple thresholding and Radon transform techniques. In fact, we first identify some pixels which have the image intensity between I_1 and I_2 that corresponds to another significance level η_2 (usually $\eta_2 = 0.95$ is selected) and, for each ship candidate, a Radon region (typically 101 pixel square) centred at the ship center is defined for detecting the corresponding ship wake. If there exist wake components, then we will take this candidate as a ship target, otherwise those false ship pixels will be removed.

3. EXPERIMENTAL RESULTS

The model developed is tested on a number of SAR images. The detection results are promising. Two examples are shown in the following. Figure 2(b) presents a result of the detection by directly using a threshold calculated by the equation (3). As can be observed in Figure 2(b), thresholding does not exclude some false ship pixels. Therefore, it is necessary to remove those false pixels by the morphological erosion. The Figure 2(c) is the result of ship target detection in the first part by using morphological filter. Meanwhile, this is also the final detecting result because there is no ship target in the second part by using simple Radon transform. The computational time for this SAR image (374*436 pixels), which is a subimage of the m0109452 provided by DREO, is only 4.2 seconds.

Figures 3 illustrates another experimental result using this model. There exist ship targets in both of two parts. For that SAR image (1121*730 pixels) in Figure 3(a), we only need 13.5 seconds to detect those ship targets shown in Figure 3(d).

4. CONCLUSION AND FUTURE WORK

We have demonstrated one possible method of automatic detection of ships in RADARSAT SAR imagery. Further development is on the way to improve the applicability of our model and to reduce the computational time and false alarms. On the other hand, some experimental results have shown that K-distribution does not always give a good fit. Therefore, it is necessary to choose a new statistical model instead of K-model. There are many statistical models to be used to describe the distribution of SAR image intensities.

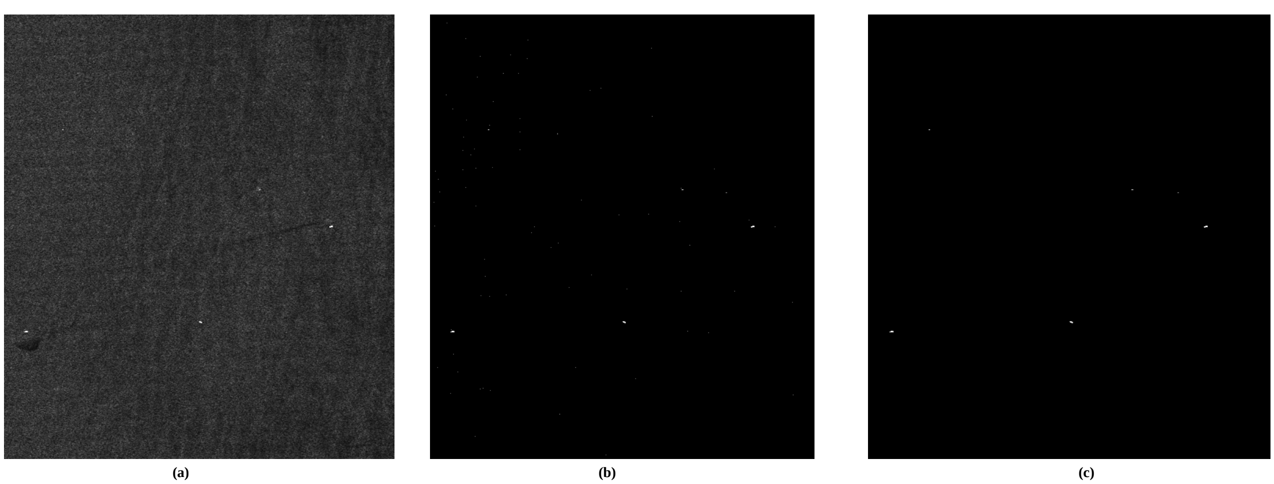

Figure 2: (a) Original image, (b) result using threshold I_1, and (c) result using morphological filter

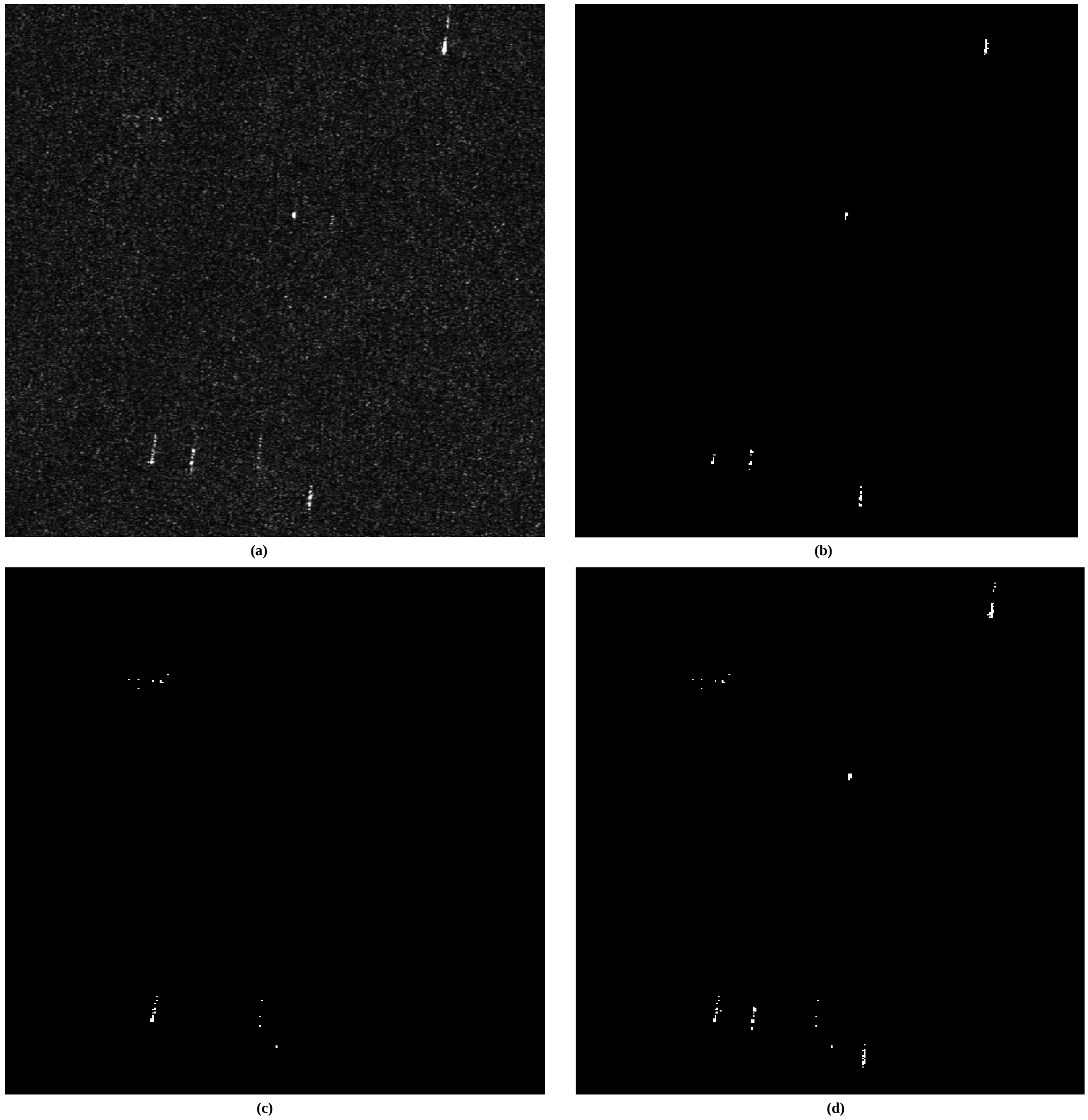

Figure 3: (a) Original image (a subimage of m0114461), (b) result in first part, (c) result in second part, and (d) the final detection result

In our future research work, for example, we will try to use a probabilistic neural networks statistical model (PNN-model) (see [14]) because this model usually makes an excellent fitting for the intensity of SAR imagery.

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