AUTOMATIC DETECTION OF TARGETS IN SAR IMAGES

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ABSTRACT:

Military targets in SAR images are not distinguished easily unlike those in optical images, because targets are only dozens of pixels and they have many corner reflectors sensitive to the incidence angle of radar signals. Due to those problems, SAR image analysts have difficulties in recognizing military targets captured by SAR images. Furthermore, manual analysis cannot respond promptly enough to rapidly changing situations such as battle field. We need automated analysis to solve these problems. In this paper, we analyzed algorithms for prescreening of military targets in SAR images. We implemented some prescreening algorithms and tested the algorithms using SAR data. As a result, we will report performance of the tested prescreening algorithms.

KEY WORDS: ATR, SAR, Military Targets, Prescreening.

1. INTRODUCTION

After collapse of Soviet Union, the environment of worldwide military and security changed so that conflicts happen more unpredictably (Delaney, 1995). Radar may have important roles in those conflicts.

Optical images have many restrictions in observation times. Contrarily, Synthetic Aperture Radar (SAR) images can be obtained at any weather conditions. SAR is considered as a useful alternative to observation method.

To use SAR image for a military purpose, we must be able to rapidly recognize existence of military targets and its types in an image. But, military targets in SAR images are not distinguished easily by naked eyes, because the targets are only dozens of pixels in an image that is captured over wide area. There are difficulties in rapidly and precisely extracting targets with human analysts. To solve these problems, we need to develop algorithms that recognize and extract military targets automatically. And the algorithms should increase precision and speed of the work.

For these reasons, Automatic Target Recognition (ATR) system that automatically extracting targets in SAR images has a more important role. There have been many active researches for this system. The purpose of this paper is reporting performance of developed prescreening algorithms, which can be used the first stage of ATR.

In this paper, chapter 2 has a description of the algorithm used in experiments. And we will describe the method and results of experiments in chapter 3. Finally, the performance of the tested algorithm is discussed in chapter 4.

2. ALGORITHM

2.1 ATR Stages

Usually ATR is divided into prescreening stage to find target-shaped images in whole image, and classification stage to distinguish real targets from target-shaped images. We implemented prescreening stage into detection stage and discrimination stage, like the ATR system of Defense Advanced Research Project Agency (Novak et al., 1995).

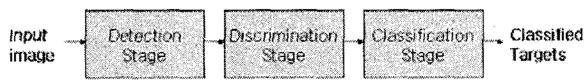

Figure 1. Block diagram of ATR stages

The first step in ATR is 'detection stage'. In detection stage, we extract regions of interest (ROIs) from an input image. ROIs may contain target-shaped images. The second step is 'discrimination stage'. The discrimination stage filters clutter false alarms in ROIs from the detection stage. The final step is 'classification stage'. In the classification stage, we extract ROIs that contains target and classify targets. Figure 1 shows the block diagram of ATR stages that described above.

In this paper, we will discuss about detection stage only.

2.2 Detection Stage

In the detection stage, two-parameter Constant False Alarm Rate (CFAR) detector algorithm is generally used. CFAR detector detects target-shaped images based on contrast and brightness. And the detection progresses on the whole input image. Figure 2 shows the structure of a CFAR detector.

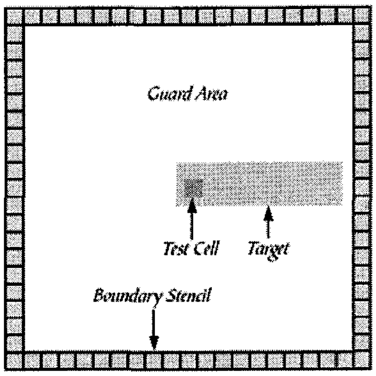

Figure 2. Structure of CFAR detector

Equation 1 shows two-parameter CFAR detector algorithm.

$$\frac{X_t - \hat{\mu}_c}{\hat{\sigma}_c} > K_{CFAR} \qquad (1)$$

In equation 1, X_t is the brightness value of the test cell, $\hat{\mu}_c$ the mean brightness value of boundary stencils, $\hat{\sigma}_c$ the standard deviation of boundary stencils and K_{CFAR} is threshold value. If calculated value of equation 1 is larger than K_{CFAR}, the test cell is considered as a target, otherwise a clutter.

As shown in figure 2, the test cell is located in centre of a detector. Values of boundary stencil are used to estimate the mean and standard deviation. Between the test cell and boundary stencils, there is a guard area. Because of this structure, the test cell does not influence on calculating clutter values.

The size of boundary stencils is determined by the resolution of input image and the type of targets. To detect military targets, boundary stencils for medium resolution (1-m by 1-m) consist of 160 pixels and for high resolution (1-ft by 1-ft) consist of 640 pixels (Novak et al., 1995).

CFAR detector shows constant false alarms by given K_{CFAR} in condition that distribution of clutter brightness value is Gaussian distribution. For this reason, this algorithm is called 'Constant False Alarm Rate (CFAR)' detector. In fact, distribution of clutter in high resolution image is 'almost' Gaussian distribution, so false alarm rate is not always same. However, CFAR detector has been widely used because the detector performs more reliably to find targets with clutters than other algorithms.

Dozens of the test cells that considered as target by CFAR detector makes ROI in size of 128-ft by 128-ft. And these ROIs are passed to next stage (Novak et al., 1995).

In this experiment, we added some algorithms on CFAR detector to make ROIs. The first step is making a binary image with pixels that considered as target and other pixels. And we applied morphology to the binary image to merge blobs locating closely each other (closing method). The next step is tracking boundaries to find isolated blobs. As a result, we got an image with contour of blobs. The threshold is applied to the contour of blobs to remove too small or too big blobs. The final step is making ROIs with centre of gravity of remained blobs. The results of this experiment will be described in chapter 3.

3. EXPERIMENTS

3.1 Used Data

To test detection stage, we used CARABAS-II VHF SAR data. Resolution of CARABAS-II VHF SAR data is 1 metre and the width 2000 pixels and the height 3000 pixels. Shooting height of image is 6.26km and angle of depression is 58 degrees. CARABAS-II VHF SAR data consist of 24 images and we selected 4 images from them. In every 24 images contains 25 targets. Figure 3 shows a CARABAS-II sample image.


Figure 3. CARABAS-II VHF SAR image

3.2 Analysis Method

We got results by defining threshold for the CFAR algorithm and using CARABAS-II VHF SAR data. And we counted numbers of detected targets and false alarms. Performance will be measured by drawing P_d vs. FAR curve. P_d is probability of detection that calculates detected targets divided by the total targets in image. So, 1.0 means all of targets in the image are detected. FAR is false alarm rate. And FAR means numbers of false alarms per unit area (1 km^2). False alarms are calculated from the total number of extracted ROIs subtracts from the numbers of ROIs that contains targets. We get FAR by dividing this false alarm by the area of input image.

3.3 Results and discussion

Figure 4 to 7 shows intermediate result of our detecting algorithms. The algorithm is described in chapter 2.

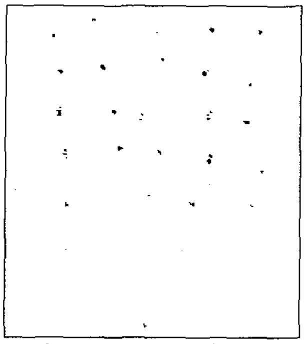

Figure 4. Binary image

Figure 4 is a binary image that made with pixels that considered as target and other pixels.

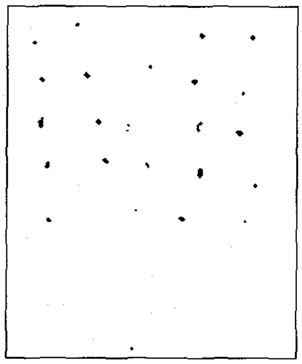

Figure 5. Morphology applied image

After applying morphology to figure 4, we get the image like figure 5. Unlike figure 4, neighbour blobs are merged each other.

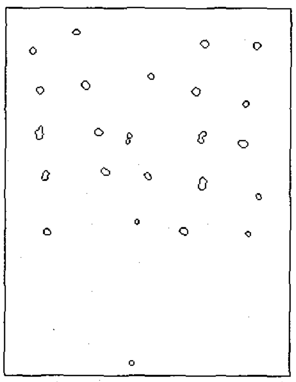

Figure 6. Contour of blobs image

Figure 6 is result of tracking boundary of blobs. In this step, we removed small or big blobs.

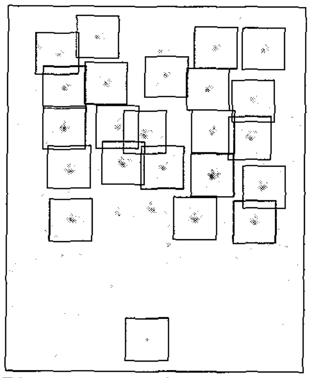

Figure 7. ROI defined image

Finally, we get ROIs. Figure 7 shows defined ROIs by our detecting method.

Based on this result, we drew curve to confirm the performance. Figure 8 shows results of P_d vs. FAR curve.

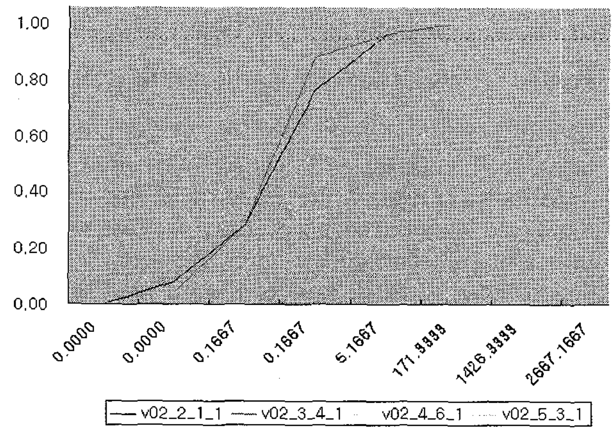

Figure 8. P_d vs. FAR curve

We defined the threshold from 30 to 1 with the threshold interval at 5. If the threshold is closer to 30, detected targets decreased to 0 and false alarms closed to 0. When the threshold goes to 1, all of targets in image are detected but false alarms are dramatically increased.

If we wanted to detect every target, false alarms also increased. To prevent high false alarms, we set $P_d = 0.95$. As shown in figure 8, dotted line means $P_d = 0.95$. Tested images show almost same results of around $P_d = 0.95$ when FAR lies between 5 and 6. Only one image shows a different result around $P_d = 0.95$ when FAR is almost 170.

CONCLUSIONS

An importance of information emphasized in recent conflicts. SAR may have an important role at these kinds of conflicts. The advantage of SAR is that SAR can be acquired at any weather conditions. But, military targets in SAR images are not distinguished easily than in optical images, because targets are dozens of pixels. To solve this problem, we need automated analysis, like ATR system.

In this paper, we analyzed performance of detection stage in ATR system. We used CARABAS-II VHF SAR data to test detecting algorithm. As a result, P_d vs. FAR curve was drawn. If detected targets are to be increased, false alarms are also increased dramatically. We set $P_d = 0.95$ to show high detecting performance and low false alarms. Results show this setting can obtain high performance in detection stage.

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