A New Method of Tank Detection for SAR Images

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Abstract

The tank is one of important military targets. Tanks detection is the study focus of the synthetic aperture radar (SAR) image processing currently. But there may be many false alarms existed in the detection result with most of the traditional tank detection methods affected by the SAR speckle. A new method of tank detection for SAR images based on the features of SAR images is put forward by this paper. It uses Gauss low-pass filtering to smooth the original image and the geometric active contour model based on prediction theory metric to realize automatic segmentation. It detects candidate targets by removing little connected regions. Finally, it further removes the false alarm targets based on the grey characteristic of the shadow regions. Experimental results indicate that the method can effectively and rightly detect tanks of SAR images. Moreover, it is insensitive to the initial contour.

Keywords: Tanks Detection, Synthetic Aperture Radar, The Geometric Active Contour Model Based on Prediction Theory Metric

1. Introduction

Synthetic aperture radar (SAR) is a type of high resolution imaging radar. Environmental monitoring, earth-resource mapping, and military systems require broad-area imaging at high resolutions. Many times the imagery must be acquired in inclement weather or during night as well as day[1]. SAR provides such a capability. SAR systems take advantage of the long-range propagation characteristics of radar signals and the complex information processing capability of modern digital electronics to provide high resolution imagery[2]. Synthetic aperture radar complements photographic and other optical imaging capabilities because of the minimum constraints on time-of-day and atmospheric conditions and because of the unique responses of terrain and cultural targets to radar frequencies. SAR images have wide applications in remote sensing and mapping of the surfaces of both the Earth and other planets[3]. So the study of SAR image processing has become the focus of research on remote sensing image processing.

The tank is one of important military targets. The tank detection is the study focus of the SAR image processing currently. Yang Lujin[4] brought forward a tank detection method in SAR image based on hidden Markov models and chain code. However, there is the shadow of the target in the experimental result. Mao Liangjin[5] proposed an improved two-parameter constant false alarm rate tanks detection algorithm in SAR Images. But the noise of experimental images is low. The method may not be robust in strong noise. Kong Yingying[6] put forward a new tank detection algorithm based on the Gibbs-Markov random field mode. However, there is a lot of holes in the detection result. In this paper, we propose an effective method of tank detection for SAR images.

2. Preprocessing

Because the detection result is affected by speckle noise in SAR images, the image preprocessing is necessary. The surface of tank is rough. So the tank cause diffuse for SAR. No matter how the antenna depression angle changes, the echo is strong. The tank is light in SAR images.

A low-pass filter is a circuit offering easy passage to low-frequency signals and difficult passage to high-frequency signals[7,8]. It can restrain the noise and retain the even regions in the SAR image. So
Gauss low-pass filter is used to preprocess the SAR image. In Fig. 1, (a) is a MSTAR SAR image; (b) is the result of Gauss low-pass filtering of the original image.

3. The geometric active contour model based on prediction theory metric

Romeil Sandhu\textsuperscript{[9]} proposed a geometric active contour model based on prediction theory metric. Let $\phi : \Omega \rightarrow \mathbb{R}$ be a level set function (LSF) defined on a domain $\Omega$. The curve evolution equation is as follows:

$$\frac{\partial \phi}{\partial t} = \nabla \cdot E_{\text{image}} + \lambda \cdot \nabla \delta(\phi) \cdot \text{div} \left( \frac{\nabla(\phi)}{\left| \nabla(\phi) \right|} \right)$$  \hspace{1cm} (1)

They proposed the following energy functional:

$$E_{\text{image}}(z, \phi) = \sqrt{E \left( \log \frac{p_{\text{in}}(z, \phi)}{p_{\text{out}}(z, \phi)} \right)^2 - E \left( \log \frac{p_{\text{in}}(z, \phi)}{p_{\text{out}}(z, \phi)} \right)^2}$$  \hspace{1cm} (2)

where $E \{ f(z) \}$ is the expected value of the functional $f(z)$ with respect to the random photometric variable $z \in Z$, $p_{\text{in}}$ is the probability density function inside the curve $C$, and $p_{\text{out}}$ is the probability density function outside the curve $C$. The formula definition is as follows:

$$p_{\text{in}}(z, \phi) = \int_{\Omega} \frac{K(z - I(x)) H_\varepsilon(-\phi)}{H_\varepsilon(-\phi)} \, dx$$  \hspace{1cm} (3)

$$p_{\text{out}}(z, \phi) = \int_{\Omega} \frac{K(z - I(x)) H_\varepsilon(\phi)}{H_\varepsilon(\phi)} \, dx$$  \hspace{1cm} (4)

where $K(z - I(x)) = \delta_\varepsilon(z - I(x))$. $H_\varepsilon : \mathbb{R} \mapsto \{0,1\}$ denotes the smoothed Heaviside step function with the corresponding derivative $\delta_\varepsilon$. The formula definition is as follows:
\[
H_{\epsilon}(\phi) = \begin{cases} 
1 & \phi > \varepsilon \\
0 & \phi < -\varepsilon \\
\frac{1}{2}(1 + \frac{\phi}{\varepsilon} + \frac{1}{\pi} \sin(\frac{\pi \phi}{\varepsilon})) & \text{otherwise}
\end{cases}
\] (5)

\[
\delta_{\epsilon}(\phi) = \begin{cases} 
0 & \phi > \varepsilon, \phi < -\varepsilon \\
\frac{1}{2\varepsilon}(1 + \cos(\frac{\pi \phi}{\varepsilon})) & \text{otherwise}
\end{cases}
\] (6)

The gradient \( \nabla_{\phi} T \) can be computed using the calculus of variations.

\[
\nabla_{\phi} E_{\text{image}} = -\frac{\delta_{\epsilon}(\phi)}{E_{\text{image}}} \left[ \epsilon \{B \cdot G\} - \epsilon \{B\} \cdot \epsilon \{G\} \right]
\] (7)

with \( B \) and \( G \) given as:

\[
B = \log \frac{p_{in}(z, \phi)}{p_{out}(z, \phi)}
\] (8)

\[
G = \left[ \left( \frac{1}{A_{in}} + \frac{1}{A_{out}} \right) - K(z - I(x)) \left( \frac{1}{A_{in}p_{in}(z, \phi)} + \frac{1}{A_{out}p_{out}(z, \phi)} \right) \right]
\] (9)

where \( A_{in} \) is given by \( \int_{\Omega} H_{\epsilon}(\phi) \, dx \).

In Fig.2, (a) is the initial contour chosen in Fig1.(b); (b) is the median contour of the evolution; (c) is the final contour of the evolution. The geometric active contour model based on prediction theory metric is effective in searching for segmentation contour. The tank and the shadow of the tank can be distinguished by the method, as shown in Fig2.(c).

![Figure 2. The evolution result](image)

4. Post-processing

After the above experimental steps, there are many false alarm targets in the background region. In order to remove the false alarm targets, we can segment the image with the final contour. Due to the influences of speckle noise, there are still some false alarm targets in the background region. We can remove some little false alarm targets by searching for connected regions, and then judge whether the
candidate target is the real target. Because the shadow region is dark in the image, the tank is light in the image. If the mean grey level of the candidate target is less than the threshold, then the candidate target is the shadow of the tank.

In Fig.3, (a) is the segmentation result of Fig2.(c); (b) is the detection result with the proposed method. This method is available, as shown in Fig3. It can detect candidate targets effectively.

![Figure 3](image)

**Figure 3.** The detection result of Fig.1(a) with the proposed method

### 5. Experimental Results

In proof of the efficiency of the proposed method, we use this method in another three SAR images. In Fig.4, (a) is another MSTAR SAR image; (b) is the initial contour chosen in the result of Gauss low-pass filtering of the original image; (c) is the median contour of the evolution; (d) is the final contour of the evolution; (e) is the final contour shown in original image; (f) is the segmentation result of Fig4.(d); (g) is the detection result with the proposed method.
In Fig. 5, (a) is the initial contour chosen in the result of Gauss low-pass filtering of Fig. 4(a); (b) is the median contour of the evolution; (c) is the final contour of the evolution; (d) is the final contour shown in original image; (e) is the segmentation result of Fig. 5(c); (f) is the detection result with the proposed method.
Figure 5. The detection result of Fig 4.(a) with the proposed method

In Fig 6, (a) is the SAR image of the M-47 tanks provided by Sandia National Laboratories; (b) is the initial contour chosen in the result of Gauss low-pass filtering of the original image; (c) is the median contour of the evolution; (d) is another median contour of the evolution; (e) is the final contour of the evolution; (f) is the detection result with the proposed method.
6. Conclusions

Through the above experimental results, we can see that the proposed method is effective in tank detection for SAR images and insensitive to the initial contour.

Li Chunming\textsuperscript{[10]} proposed the distance regularized level set evolution (DRLSE) method. In Fig.7, (a) is the initial contour chosen in the result of Gauss low-pass filtering of Fig1.(a); (b) is the median contour of the evolution; (c) is the final contour of the evolution.
But the DRLSE method is sensitive to the initial contour. In Fig. 8, (a) is the initial contour chosen in the result of Gauss low-pass filtering of Fig. 1(a); (b) is the median contour of the evolution; (c) is the final contour of the evolution. So the DRLSE method is not suitable to SAR images.

A method of tank detection for SAR images based on the features of SAR images about tanks is put forward. It uses Gauss low-pass filtering to smooth the original image and the geometric active contour model based on prediction theory metric to realize automatic segmentation. It detects candidate targets by removing little connected regions. Finally, it further removes the false alarm targets based on the grey characteristic of the shadow regions. Experimental results indicate that the method can effectively and rightly detect tanks of SAR images. Moreover, it is insensitive to the initial contour.

7. Acknowledgement

This paper is supported in part by National Natural Science Fund under grant No. 60873107, Space Fund under grant No. 20081397, and the Fundamental Research Funds for the Central Universities, China University of Geosciences (Wuhan) under grant No. CUG100708.

8. References


