Synthetic Aperture Radar Image Speckle Noise Suppression and Mine Target Detection

Xiongsheng Yi*, Cailun Huang*
School of Hunan University of Science and Technology, Xiangtan, China

*Corresponding author’s e-mail: 806313410@qq.com, *2016276144@qq.com

Abstract. Synthetic Aperture Radar (SAR) provides a comprehensive, all-weather target monitoring function and is widely used in the military and industrial fields of defense. This article mainly studies a landmine target detection technology based on synthetic aperture radar image processing, shallow buried mines. The detection and identification of military radar has important military significance, which can reduce the casualties caused by landmine explosions. This article first introduces the basic imaging principle of synthetic aperture radar, then introduces the noise processing of SAR images based on the Gamma filter, and finally targets the targets of mine SAR images Features were identified and analyzed.

1. Introduction

Synthetic aperture radar (SAR) is a general method that uses the relative motion of radar antennas and imaging scenes, and uses low-resolution aperture data to generate high-resolution radar maps. Originally conceived in the early 1950s[1], it is widely used to image objects on the Earth's surface and planets[2]. It can be used in terrain surveying, target positioning, electronic charts and other fields. Radar detection technology has the advantages of non-destructive and fast. Synthetic aperture radar (SAR) has an active imaging function, is a high-resolution radar, and has good penetration capabilities. Synthetic aperture radar (SAR) has all-weather observation capabilities, and has become an important tool for microwave remote sensing[3]-[7].

The identification of shallow buried landmine targets not only plays a very important role in reducing the casualties caused by landmine explosions, but also an important technology to improve the military strength of defense and exclude landmines left after the war to protect the people's safety of the territory. Due to the specific natural environment of mountains, such as rock and soil , tree weeds, etc., the process of identifying landmine targets requires filtering and screening of a large amount of noise, filtering out interference information, and obtaining accurate mine target information.

The research object of this article is the problem of mine target recognition based on synthetic aperture radar (SAR). It focuses on the working principle of synthetic aperture radar, the filtering principle of mine target images, and the feature analysis of mine target images. Target detection has a certain practical value in improving the accuracy of mine target recognition.

2. Research and Development Status of Synthetic Aperture Radar

Radar was originally a technology invented to detect enemy fighters during World War II. After continuous development in recent years, radar imaging technology has become increasingly mature.
Synthetic aperture radar is different from traditional electromagnetic wave radar. It uses the principle of Doppler frequency shift to process the radar image, and the radar resolution in the vertical and horizontal directions has been significantly improved. The imaging principle of synthetic aperture mainly includes 3 types: strip mode imaging, spotlight mode imaging and scanning mode imaging, among which spotlight mode imaging has the highest resolution, while scanning mode imaging technology has the widest coverage, and the imaging principle of synthetic aperture radar is shown in Figure 1. Effective coverage of synthetic aperture radar The range is large, and it has advantages when detecting shallow buried mine targets.

![Figure 1. Schematic diagram of synthetic aperture radar imaging.](image)

The signal output by the synthetic aperture radar is a frequency-hopping pulse signal. This signal transmission method has higher obstacle penetration ability. The pulse radar signal is as follows:

\[
f(t) = a(t)\cos\left[\sqrt{2}\pi f_0 t + \phi(t)\right]rect\left(\frac{t}{T}\right)\]

(1)

Among them, \(a(t)\) is the amplitude function of the signal, \(f_0\) is the initial frequency of the signal, \(\phi(t)\) is the phase function, \(rect\left(\frac{t}{T}\right)\) is a rectangular function of the signal, as follows:

\[
rect\left(\frac{t}{T}\right) = \begin{cases} 
0, & |\frac{t}{T}| > 1 \\
1, & \text{other} 
\end{cases}
\]

(2)

The narrow-band energy of the radar signal in one cycle is as follows:

\[
E = \int_{-T}^{T} |f(t)|^2 dt + \frac{1}{2} \int_{-T}^{T} |a(t)|^2 dt
\]

(3)

The analytical signal of the synthetic aperture radar is as follows:

\[
H(t) = T \frac{\sin\pi\left(1 - \frac{|t|}{T}\right)}{\sqrt{2K}} rect\left(\frac{t}{T}\right)\]

(4)

3. Synthetic Aperture Radar Image Speckle Noise Suppression and Mine Target Detection

3.1. Research on Gamma Filter

Speckle noise in synthetic aperture radar (SAR) images is caused by the fading phenomenon of the target echo signal inherent in the radar system. The presence of speckle noise seriously affects the quality of the image, making it difficult to extract internal wave features, which in turn affects the quality and efficiency of image analysis. Therefore, suppressing speckle noise is very important for the accuracy of SAR image feature extraction and recognition.

The original SAR filtering algorithm used traditional image processing filtering methods, such as mean filtering and median filtering. Its advantages are simple calculation, fast speed, and good speckle
noise removal in uniform areas; the disadvantage is that the details are not maintained well, and the edges change Obscured, the point target loss is large, and these shortcomings will become more obvious as the processing window increases.

In order to improve the target detection accuracy of synthetic aperture radar images, this paper introduces a Gamma filtering algorithm. Gamma filtering is a speckle noise suppression algorithm that combines the statistical characteristics of SAR images. Compared with other filters, the Gamma filter considers the first-order and second-order statistical models of coherent speckle noise and target scattering coefficients, and treats them as Bayesian. The reasoning is combined, so it has better texture retention ability while suppressing coherent speckle noise. The model of the filter is as follows:

\[
\text{pixel value} = \begin{cases} 
I & C_i \leq C_u \\
B + D & C_u < C_i < C_{\text{max}} \\
CP & C_i \geq C_{\text{max}}
\end{cases}
\]

(5)

In the formula:

\[
B = A - N_{\text{look}} - 1; \quad A = \left(1 + C_u^2\right) \left(C_i^2 - C_u^2\right); \quad D = I^2 \bullet B^2 + 4AN_{\text{look}}CP \bullet I
\]

(6)

3.2. Analysis of mine target characteristics in synthetic aperture radar images

The synthetic aperture radar image processing is the focus of this study, and it is also based on the difficulty of sar landmine target detection. Figure 2 shows the shallow buried landmine image collected by the synthetic aperture radar.

![Figure 2. Target images collected by synthetic aperture radar.](image)

As can be seen from the figure, in the images collected by synthetic aperture radar, the shapes and contours of landmines are obvious, but due to the variety of landmines at present, in order to more accurately identify the types of landmines and extract richer landmine data, further analysis of The mine sar image is used for feature analysis and extraction. The mine feature information extracted mainly includes the following aspects:

Mine area

In the synthetic aperture radar image, the area of the mine target area is directly proportional to the number of pixels. Therefore, calculating the number of pixels in the mine target area can efficiently and accurately obtain the mine area, as follows:

\[
s = \sum_{i} \sum_{j} L_i \times W_j
\]

(7)

Landmine edge analysis

Edge analysis refers to the optimization and processing of the edge profile of synthetic aperture radar images. The edges of landmine synthetic aperture radar images are mainly divided into three
types: grayscale step edges, pulse signal edges, and landmine shell edges. Among them, the value of the grayscale histogram of the mine target corresponding to the gray step edge will be abrupt, which usually means that the mine target image at this position has distortion problems, and the processing method is direct filtering; the edge of the mine shell is an important image feature, and optimizing the image of the edge of the mine shell is helpful to improve the accuracy of mine recognition.

Mine amplitude characteristics
The amplitude characteristics of a landmine image refer to the change in the gray value of the image. It is assumed that the pixels at any point are \((x, y)\), gray value is \(h(x, y)\), the characteristics of the gray level in a certain target area are as follows:

\[
\delta(x, y) = \frac{1}{2w-1} \sum_{i=1}^{n} f(i+x, j+y)
\]

The process of mine target detection based on synthetic aperture radar image processing is shown in Figure 3.

**Figure 3.** Mine target detection process based on synthetic aperture radar image processing

4. Conclusion
Shallow buried mine target detection and identification technology is an important technical support in the field of war mine removal, military detection and other fields. In order to improve the accuracy of landmine detection and identification, high-resolution synthetic aperture radars have been widely used. The main content of this paper is the feature analysis of synthetic aperture radar images and the extraction of mine targets. The focus is on the detailed research on the suppression of interference spots and other technologies of synthetic aperture radar images. This article is of great significance for improving the radar detection of shallow buried mines and the accuracy of radar image recognition.
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