ISAR Target Multi-Threshold Value Segmentation Algorithm Based on Quantification Energy Band

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Abstract

ISAR image segmentation is the key step from ISAR image processing to ISAR image analysis. Since in ISAR target there is vast difference between the energy amplitudes of strong and weak scattering points, with the traditional image segmentation algorithm the strong and weak scattering points are suppressed evenly, resulting in for the geometry structure of the target the weak scattering point performance ability suppressed. In the article the author proposes based on the ISAR target chief axe and the target energy band analysis, using the different segmentation threshold value to carry on the segmentation for the different energy band region. The ISAR target segmentation result indicated that the method in the article has given dual attention to strong, and weak scattering regions, and protected the weak scattering spots effectively.

Keywords: ISAR imaging; image segmentation; target axis; quantitative energy band; multi-threshold

1. Introduction (Heading 1)

In the study of ISAR image, people tend to only certain parts of ISAR image are interested in, these targets usually occupy a certain region, and their some features (such as gray scale, contour, etc.) are different from those of the images around. And these parts are often referred to as ISAR targets or foregrounds (other part is called the background). In order to identify and analyze the targets, they need to be separated and extracted, and then it will be possible to further use the targets. The process of separation and extraction is the image segmentation. ISAR image segmentation refers to the process of separating ISAR image into regions each with a characteristic and extracting the interesting ISAR targets [1].

Currently, many methods have been proposed for SAR image segmentation, including the threshold segmentation method and the clustering method, the mixed method with edge detection and region mergence, the method based on Markov (MRF), watershed segmentation approach, etc.; for ISAR image...
segmentation there are not many open literatures for reference, the threshold segmentation method and the edge detection one are mainly used at present [2].

In ISAR target there is vast difference between the energy amplitudes of strong and weak scattering points, with the traditional image segmentation algorithm the strong and weak scattering points are suppressed evenly, resulting in suppressing the weak scattering points more and the weak scattering point performance ability to the geometry structure of the target suppressed.

Shown in Figure 2, Figure 1 in ISAR target weak scattering points were obviously inhibited, in the weak scattering point region the target geometry shape obviously weakened. (Figure 2-(a) the nose and belly section of the target; Figure 2-(b) the nose and wing section of the target).

![Figure 1 ISAR target under the two dip angles](image1)

![Figure 2 ISAR target automatic threshold segmentation results under the two dip angles](image2)

Combination of geometric moment invariants and with the determination of the target axis and quantitative energy band, we propose ISAR target multi-threshold segmentation algorithm based on quantitative energy band.

2. ISAR target axis and quantitative energy band analysis

In Literatures [4,5] it’s thought that the strong scattering points in ISAR image distributes mainly near the target axis, we also proved it by experiment. In Figure 3 - (a) the strong scattering points of ISAR target can be seen to distribute mainly along a certain axis.

![Figure 3 Amplitude of ISAR image and energy distribution](image3)
Figure 3 - (b) shows that the literature [4,5] proved along the vertical direction of ISAR target axis, a series of energy fringes exists indeed.

The direction of target axis, the target center, the energy fringes of the target and the major energy distribution are the main features of ISAR image processing. The relationship between them is shown in Figure 3 - (c).[6,7]

Target axis direction is defined as follows:

Suppose there are N points in ISAR image, \( N \cdot 0.01 \) points of the strongest strength are initially selected as the strong scattering points, set the coordinates of these points \((x_i, y_i)\), strength \( f(x_i, y_i) \), \( i = 0, 1, \ldots, N \cdot 0.01 \).

Calculate the covariance matrix of matrix A constituted by these points’ coordinates [6, 7]

\[
\text{COVA} = \begin{bmatrix}
E(X_1 - \mu_1)(X_1 - \mu_1) & \cdots & E(X_1 - \mu_1)(X_N - \mu_N) \\
E(X_2 - \mu_2)(X_1 - \mu_1) & \cdots & E(X_2 - \mu_2)(X_N - \mu_N) \\
\vdots & \ddots & \vdots \\
E(X_N - \mu_N)(X_1 - \mu_1) & \cdots & E(X_N - \mu_N)(X_N - \mu_N)
\end{bmatrix}
\]

The eigenvector that the largest Eigen value of the covariance matrix corresponds with expresses the axis direction of the target.

2.1 Target Center

Target center \((x, y)\) can be obtained approximately by averaging the position of \( N \cdot 0.01 \) points.

\[
x_o = \frac{1}{N} \sum_{i=0}^{N-1} x_i, \quad y_o = \frac{1}{N} \sum_{i=0}^{N-1} y_i
\]

2.2 Target quantitative energy Band

The major axis is defined as the eigenvector that the largest eigenvalue \( \lambda \) of the covariance matrix corresponds with, the width of the band is proportional to \( \lambda \). In the reported experiment, [6,7] selected coefficient \( 10e^{-5} \) as a constant ratio, so six bands can cover most of the target. In each band, the feature \( F \) is defined as:

\[
F_j = \frac{\sum_{i=1}^{M_j} R_i^2 S_i}{\sum_{i=1}^{M_j} S_i}
\]

In the formula (3), \( M_j \) is the pixel number of band \( j \), \( R_i \) is the distance between pixel \( i \) and the axis, \( S_i \) is the energy of the pixel. Here, the pixel gray value is directly used as energy.

2.3 The main range of the target energy distribution

Calculating the length of the major axis and looking for the strong scattering points directly from the target center along the axis, the main range of the target distribution can be determined and so the main range of the target energy distribution can be calculated.
In actual use, the main range of the target energy distribution can be calculated as follows:

1) Post-processing of imaging data, preliminarily determining strong scattering points;
2) for the range of the strong scattering point to carry on binarization, and to determine the foreground range, then recording the coordinates of the target points;
3) Constituting a matrix of the target coordinates;
4) Calculating the maximum feature vector and the size of the covariance matrix that the largest eigenvalue corresponds with;
5) Calculating the center and direction of the major axis, along the scope with the major axis vertical the major axis parted for 6 equal copies and computing the direction of the vice-axis and the intersection of the major and vice-axis;
6) Along the direction of the major axis, according to the vice-axis direction calculated to determine the quantitative calculation of energy fringes of these points.

3. Threshold segmentation

The threshold segmentation for the gray image is first to determine a gray threshold in the taking value range of the image gray, then compare the gray value of each pixel in the image with the threshold, and according to the result of comparison the corresponding pixel is segmented (split) into two categories: the pixel gray value greater than the threshold for a class, and pixel gray value less than the threshold for another (the pixel of gray value equal to the threshold can be classified as either of these two categories). [8]

If using only a single threshold to split it is called single threshold segmentation method; if using more than one threshold it is called multiple threshold segmentation method. Commonly in the threshold segmentation method there are the gray threshold segmentation, the maximum entropy threshold segmentation, the best threshold and the dynamic threshold method, and so on.

We use the histogram threshold method, the automatic threshold and the two-dimensional entropy threshold method to segment the ISAR image in Figure 1-(a), segmentation result shown in Figure 4.

![Figure 4 ISAR image amplitude and distribution of energy](image)

4. Multi-threshold segmentation algorithm based on quantitative energy band

In Figure 4, you can see: when using the histogram threshold segmentation method, due to the threshold selected lower, segmentation result affected the weak scattering points less and the structure of ISAR target weak scattering points region is relatively complete, but the impact of spot noise is obviously; with the automatic threshold segmentation and the two-dimension entropy threshold segmentation the threshold selected is larger, and inhibition of spot noise is clear, but larger threshold inhibited the weak scattering points obviously, the structure of ISAR target has a flaw. This is because the average gray value of the weak and strong scattering points regions is non-uniform. So we propose a multi-threshold segmentation algorithm, by calculating ISAR targets axis and quantification energy band we can obtain the
distribution regions of six quantification energy bands. On this basis, using two-dimensional entropy principle to solve different two-dimensional thresholds of the six quantification energy bands distribution regions, the dynamic threshold segmentation of the different region is achieved. The concrete steps are as follows:

Step 1: for an original ISAR image I to calculate the target center, the target axis and the target quantization energy band;

Step 2: to segment the quantitative energy band and by the classification result, the image I is divided into six regions: $G_i, G_2, \ldots G_6$

Step 3: making curve fitting of the ISAR image I and removing the band noise and spot noise;

Step 4: using two-dimensional entropy principle to the six regions respectively to solve their two-dimensional threshold with Genetic Algorithm.

Step 5: doing multi-threshold segmentation in accordance with the regions of the image.

5. Segmentation result based on quantification energy band multi-threshold segmentation algorithm

![Image of ISAR target multi-threshold segmentation results under two kinds of obliquity](a) (b)

Figure 5 ISAR target multi-threshold segmentation results under two kinds of obliquity

Based on quantification energy band distribution with multi-threshold segmentation algorithm the result of ISAR target segmented under the two kinds of obliquity as shown in Figure 5, comparing the segmentation results of Figure 4 and Figure 5 we can see:

In the two kinds of segmentation calculation all of the stronger scattering points in ISAR target have been reflected. But in the single-threshold segmentation the weaker scattering points were inhibited, the expression of the target structure was weakened obviously. The weaker scattering points of ISAR targets segmented based on quantification energy band multi-threshold segmentation algorithm haven not been weaken excessively, the expression of the target structure has been strengthened obviously and the spot noise effectively and appropriately inhibited.

To sum up, ISAR Target multi-threshold segmentation algorithm based on quantification energy band is suitable for ISAR image with strong and weak scattering points, obvious target axis and energy band.

References


