Ship Target Segmentation and detection in Complex Optical Remote Sensing Image Based on Component Tree Characteristics Discrimination

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ABSTRACT

Under the application background of sea-surface target surveillance based on optical remote sensing image, automatic sea-surface ship target recognition with complicated background is discussed in this paper. The technology this article focused on is divided into two parts, feature classification training and component class discrimination. In the feature classification training process, large numbers of sample images are used for feature selection and classifier determination of ship targets and false targets. Component tree characteristics discrimination achieves extraction of suspected target areas from complicated remote sensing image, and their features are entered to Fisher for ship target recognition. Experimental results show that the method discussed in this paper can deal with complex sea surface environment, and can avoid the interference of cloud cover, sea clutter and islands. The method can effectively achieve ship target recognition in complex sea background.

Keywords: ship target recognition; optical remote sensing image; component tree segmentation; feature selection

1 INTRODUCTION

Automatic ship target recognition in optical remote sensing image has great application value. With the improved resolution of optical satellite images, the outstanding advantages of the ship target classification and recognition in ship investigation, shipping monitoring is attracting the attention of marine monitoring department and domestic-foreign scholars [1]. At present, automatic ship target recognition in optical remote sensing image has become a hot field of remote sensing image processing and pattern recognition.

Among the algorithms of remote sensing ship target recognition, image segmentation based on gray level statistical features is the most classic. Such methods are generally applicable to the situation where the sea is relatively calm, has uniform texture and low gray level of water. While the sea condition become complex, it will produce much missing alarm and false alarm. In addition to the gray statistics, some papers focus on image segmentation based on edge information [2]. These methods make a linear combination of the original gray image and the edge image, then use OTSU to search then use OTSU to search self-adaptive threshold for image segmentation, and combine with simple shape

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characteristics to get the ship target candidate regions. However, in the variable sea surface, large waves and bright wave blocks could bring much interference, leading to failure. With the development of computer vision, some researchers have introduced the characteristics of human visual system (HVS) that could quickly focus on the region of interest (ROI). Paper [3] based on the selective attention mechanism of HVS, obtains ROI quickly by the guidance of gray and area characteristics, and then selects the real ship targets. Although HVS can face complex scene, save calculation resource and reduce the difficulty of analysis, it can also be affected by sea condition, ship target attribute, target motion parameter, sensor parameters and many other factors. To solve the interference of wave, paper [4] has developed a target segmentation algorithm based on characteristic domain. This method makes feature conversion for input image and then gets feature image that highlights targets for recognition. This method can restrain sea wave, cloud shadows, ship wakes and bright band strongly in feature image, but it can also amplify the noise, bring false alarm, in addition, in the process of feature conversion, the object contour and its shape information may be lost.

To solve the above difficulty, we develop a method for sea ship target adaptive recognition that can be suitable for complicated marine environmental conditions and meteorological conditions. We first make a deep study of the target / background characteristics. To search ROI quickly, we introduce the component tree theory for image segmentation based on A-L threshold. Next, local invariant target feature parameters are extracted, overcoming the impact of objective deviation from different circumstances. At last a Fisher classifier is used for automatic target recognition. Experiment results that have been given in this paper verify the performance of our method.

2 ANALYSIS OF TARGETS / BACKGROUND CHARACTERISTIC

Due to the difference of the ship target's speed, color, material and wake, target exhibits uncertainty of gray and diversity of features. It can be seen from Figure 1 that the targets in (c) and (d) have different significantly different wakes, (a) and (b) show the diversity of their targets. The diversity of the target and the uncertainty of gray can increase the difficulty of identification.

The optical remote sensing image can be affected by sea environment, image acquisition time, weather condition (clear or cloudy), imaging perspective, image spatial resolution and many other factors. Variety of factors led to the complexity of the background, shown in Figure 1. Furthermore, sea clutter, sea fog, clouds and islands often have similar gray with ship target, it can cause interference to ship identification. Therefore, the target recognition algorithm must have the ability to resist interference.

(a) interference of islands  (b) interference of sea clutter
3 GENERAL SCHEME

The overall process of ship target recognition in this paper is shown in Figure 2, including feature classification training and component class discrimination.

![Figure 2 The overall process of ship target recognition](image)

(c) interference of clouds

(d) interference of fogs

Figure 1 Optical remote sensing image with different types of interference
In the feature classification training process, we first collect true target and false target regions from large numbers of images as training sample set. Next we extract their geometric feature parameters, choosing the parameters with DB Index criterion. At last a Fisher is used for training the selected feature parameters, and then a classifier with a single threshold is obtained.

On the other hand, in the component class discrimination process, the component tree structure of the input image is established at first, next the candidate target regions are picked up by means of A-L threshold criteria. The candidate target regions are used as unspecified samples, entered the classifier for ship target recognition.

4 IMAGE SEGMENTATION BASED ON COMPONENT TREE

4.1 Component tree construction of input image

Image segmentation is the premise of the image recognition. The front analysis show that traditional image segmentation methods can’t be qualified for the remote sensing image with diverse targets and complex background. Considering the above factors, we propose an image segmentation method based on component tree.

Component tree is a form of expression of a gray image. It expresses the information of each connected region in the input image through establishing the tree structure of the image. The connected region is the region which has a gently gray gradient in the image, such as ship target, island and clouds. Component tree can contain the basic features of an image. It can effectively suppress the interference of sea clutter and noise. Now it has been applied to image filtering and segmentation, video segmentation, image registration, image compression and so on [5]. The component tree structure of an image is as follows:

Tree node represents the connected regions of the image, generated by threshold processing for the image, namely the set of the image pixels greater than a threshold. The leaf node corresponds to the maximum gray-level threshold of the image and the root node corresponds to the minimum gray-level threshold of the image. The connections among the nodes describe the branch and containing relationships among the connected regions in the image. Figure 3 gives the corresponding relation between an image and its component tree. It can be seen from Figure 3 that the connected regions are separated in the high gray level nodes. Create the component tree of input image according to the above procedure, each connected region corresponds to the note is called a component.

![Figure 3 The establishing process of component tree](image-url)
Figure 4 shows the correspondence between different level components and the original image. With the raise of gray level, the component area is gradually reduced, and the connected regions are separated layer by layer.

Figure 5 is the component tree of Figure 4(a). Some special components (the red circles in right figure) are regarded as candidate targets (the red crosses in left figure), and then the primary image segmentation are completed.

Figure 5 The component tree and its special components
4.2 Suspected target segmentation based on A-L criteria

In order to remove the false alarm and extract the suspected target area, an area - gray (A-L) threshold criteria is proposed for component selection. A component tree of original image is created, as shown in Figure 6. According to the target gray distribution characteristic, we choose the components with their pixels gray level greater than 1/2 of the max gray value and their areas in the range of [20,300] as suspected target areas, marked with small red circles in Figure 6. From Figure 6 we can see that after A-L threshold criteria filtering for the component tree, the false alarms of clouds, islands, etc are effectively removed.

![Figure 6 Image segmentation process based on the component tree](http://proceedings.spiedigitallibrary.org/)

(a) original image  (b) the first layer nodes  (c) the second layer nodes

5 COMPONENT CLASS DISCRIMINATION FOR TARGET RECOGNITION

5.1 Component features selection

The properties of the target area can be divided into geometric features and statistical features. As the seriously affect from illumination and sea condition, the target texture feature has a poor stability. Therefore, we extract the geometry feature parameters shown in Table 1 as component properties.

<table>
<thead>
<tr>
<th>Geometric features</th>
<th>Definition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>aspect ratio</td>
<td>$L/W = a/b$</td>
<td>$a$ and $b$ are the major axis length and minor axis length of the ellipse with standard second-order central moment of ROI respectively.</td>
</tr>
<tr>
<td>compactness</td>
<td>$Compactness = (Perimeter)^2/Area$</td>
<td>$Perimeter$ is the regional boundary length, $Area$ is the region area.</td>
</tr>
<tr>
<td>eccentricity</td>
<td>$e = c/a$</td>
<td>$c$ is the distance between the two focus of the ellipse with standard second-order central moment of ROI.</td>
</tr>
<tr>
<td>solidity</td>
<td>$Solidity = Area/Convexarea$</td>
<td>$Convexarea$ is the area of convex</td>
</tr>
</tbody>
</table>

Table 1 Target geometry feature parameters
symmetry

$$SMR = 1 - \frac{|(A_{0/2} - A_{1/2})|}{\text{Area}}$$

$A_{0/2}$ and $A_{1/2}$ are the area of the region in front and back the middle point of the major axis respectively.

covexity

$$\text{Convex} = \frac{\text{Area}}{\text{Area of ellipse}}$$

$\text{Area of ellipse}$ is the area of the ellipse which has the same standard second-order central moment as the region.

However, not all features are beneficial to the target classification, it is very important for classification to select available features. Classifier design with few features can not only improve its overall performance but also simplify feature extraction process, reducing the computing and storage costs of the pattern recognition system.

Generally speaking, the selected available features must lead to a small within-class scatter and a large class separation distance. The DB Index criterion combines within-class scatter and class separation distance \[^6\], so we use it for the criterion of separability on classes. The basic content of DB Index criterion is as follows:

$$J = \frac{1}{k} \sum_{i=1}^{k} R_i$$

$$R_i = \max_{j=1, \ldots, k, j \neq i} \frac{S_i + S_j}{d_{ij}} \quad (1)$$

Which, $k$ is class number (this article is 2), $S_i$, $S_j$ are the within-class scatter of class $i$ and class $j$ respectively, and $d_{ij}$ is the distance between class $i$ and class $j$. For a certain feature, a smaller $J$ usually means a better classification effect.

### 5.2 Component classification algorithm

When dealing with the pattern recognition problem, researchers often face the puzzle called ‘dimension disaster’. For this, we use Fisher for feature compression clustering. Fisher classifier is to find the optimum projection direction, using weight vector $W^*$ to compress the original high dimensional feature space, achieving linearly separability in low dimension. That is:

$$y = (W^*)^T X \quad (2)$$

$X$ is the feature vector, compressed to one-dimensional space by projection, forming the corresponding projection point $y$. According to the distribution of the two classes (ship target class and false target class) in the compressed feature space, a decision function based on a single threshold is used for sample classification.

### 6 EXPERIMENTS

For the imaging difference between QuickBird and OrbView, we choose 80 images of each for training respectively. The images contain 98 ship targets and 103 ship targets respectively. We select the feature parameters by means of the sequential forward search \[^7\], and get the first four feature parameters of minimum $J$ as component properties. That is aspect ratio, eccentricity, solidity and convexity. Then four-dimensional feature vectors are obtained for classification training and ship target automatic identification.
A Fisher is brought for training the two kinds of satellite images. We get the threshold $y_Q$ of QuickBird is 0.0899, the corresponding weight vector $W_Q^*$ is $[1.18 \times 10^{-4}, 0.0191, -0.0302, 0.0612]$; and the threshold $y_o$ of OrbView is 0.0263, the corresponding weight vector $W_o^*$ is $[-1.5602 \times 10^{-4}, 0.0191, -0.0092, 0.0242]$. The region whose $y$ value is greater than the threshold is determined as the ship target. Figure 7 gives part of the ship target recognition results.

![Part of the ship target recognition results](image)

The algorithm in this paper is tested by QuickBird and OrbView image set, containing 80 ship targets, 347 false targets and 86 ship targets, 511 false targets respectively. Table 2 lists the result.

<table>
<thead>
<tr>
<th>Satellite platform</th>
<th>Targets number</th>
<th>Detection number</th>
<th>False alarms</th>
<th>detection rate</th>
<th>False alarm rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuickBird</td>
<td>80</td>
<td>79</td>
<td>31</td>
<td>97.44%</td>
<td>2.57%</td>
</tr>
<tr>
<td>OrbView</td>
<td>85</td>
<td>73</td>
<td>82</td>
<td>88.64%</td>
<td>11.36%</td>
</tr>
</tbody>
</table>

**7 SUMMARY**

Image segmentation is the basis of the image recognition, its significance is to obtain the ROI (the suspected target area) and reduce the number of false target as possible. The image segmentation algorithm based on the component tree for primary screening targets in this paper combine image information with the target gray distribution characteristic...
effectively. Compared with the traditional image segmentation method, the image processed by our segmentation algorithm often has a high target density, in some cases can directly extract the targets, greatly reducing the burden of the subsequent identification.

In the target identification stage, to reduce the computation and storage cost of the classifier, we introduce DB Index criteria to select the feature parameters and use Fisher for dimensions compression clustering, beneficial to real-time processing. From the experimental results, it can be accredited that the classifier designed in this paper has a higher performance, can suppress the interference of cloud cover, sea clutter and islands forcefully. It could be used for practical engineering. The effect of this methods for OrbView images recognition is general, this is because that OrbView images in image database have much interference of cloud, islands, and sea clutter.

REFERENCES


