Ship detection in high spatial resolution remote sensing image based on improved sea-land segmentation

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ABSTRACT

A new method to detect ship target at sea based on improved segmentation algorithm is proposed in this paper, in which the improved segmentation algorithm is applied to precisely segment land and sea. Firstly, mean value is replaced instead of average variance value in Otsu method in order to improve the adaptability. Secondly, Mean Shift algorithm is performed to separate the original high spatial resolution remote sensing image into several homogeneous regions. At last, the final sea-land segmentation result can be located combined with the regions in preliminary sea-land segmentation result. The proposed segmentation algorithm performs well on the segment between water and land with affluent texture features and background noise, and produces a result that can be well used in shape and context analyses. Ships are detected with settled shape characteristics, including width, length and its compactness. Mean Shift algorithm can smooth the background noise, utilize the wave's texture features and helps highlight offshore ships. Mean shift algorithm is combined with improved Otsu threshold method in order to maximizes their advantages. Experimental results show that the improved sea-land segmentation algorithm on high spatial resolution remote sensing image with complex texture and background noise performs well in sea-land segmentation, not only enhances the accuracy of land and sea boarder, but also preserves detail characteristic of ships. Compared with traditional methods, this method can achieve accuracy over 90 percent. Experiments on Worldview images show the superior, robustness and precision of the proposed method.

Key words: ship detection, sea-land segmentation, ship characteristic, mean shift

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1 INTRODUCTION

Alone with the developing of remote sensing technology, abundant data sauces are provided on ship detection. High resolution imaging sensors on satellites are able to offer image data with high spatial, high spectral and high temporal resolution. Owing to the wide observing range and relatively low cost[1], great value is showed in remote sensing. Considering the affluent information in high spatial image, it is widely used in ship target detection. In recent years, the detection results are commonly used to be applied in marine traffic control, fishery management, cargo salvation and naval warfare. Since the extraction of information is slowed down by the tremendous amount of remote sensing images, in order to speed up, plenty of effective algorithms are presented on ship detection. Existing methods focus on shape and texture features, which are exploited to complete the task of ship detection and classification[2]. A shape-based detection approach is presented while the sea-land segmentation contour is obtained using an Otsu threshold[3]; After water and land are segmented based on an active contour model, ships are detected with successive shape analysis, including shape analysis in the localization of ship head and region growing in computing the width and length of ship[4]; Inshore ship in panchromatic satellite images are detected with a framework in which pixels whose gray level is higher than the bottom value between the two peaks of gray-level histogram are classified as land[5]. However, due to the affluent texture features and background noise of the high spatial resolution remote sensing image, land is often recognized as sea incorrectly using traditional sea-land segmentation algorithms, thus results in incorrect ship detection.

False alarm can be reduced if sea and land are separated precisely. Traditional sea-land segmentation algorithms can be divided into two categories: based on gray value histogram or based on texture[6]. In the category based on gray value, all pixels are classified into either sea or land by an appropriate threshold, while the threshold value is usually related to the valley of gray-level histogram curve. The threshold can be also based on some other special parameters, such as the choice of maximum variance in Otsu method and some self-adapt ways. The way to choose threshold value based on the hypothesis that sea area present a relative low gray level and with few texture complex, while a high gray scale is presented in land and ship area. In fact, high spatial remote sensing images shows plentiful texture features. The latter category focuses on texture characteristic. Multiple features are integrated to separate sea from land[7]. The threshold can be determined according to the adaptively established statistical model of the sea area, and the incorrectly classified lands are removed according to the difference of the variance in the statistical model between land and sea[6]. Zhou[8] et al adopts two strategies, by which the existing mean shift algorithm for segmenting high resolution remote sensing imagery is improved. Mean Shift segmentation results in homogeneous regions, the sea and land area cannot be distinguished well.

This article mainly proposed an algorithm based on improved sea-land segmentation to detect ship target, which preserves the robustness of ship detection in high spatial resolution image. This paper is organized by three sections: proposed algorithm, experiment and conclusion. Experimental results show that the improved sea-land segmentation algorithm on high spatial resolution remote sensing image with complex texture and background noise performs well in sea-land segmentation, not only enhances the accuracy of land and sea boarder, but also preserves detail characteristic of ships.

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2 ALGORITHM

The complete proposed algorithm on ship detection is showed in Figure 1. The algorithm includes three parts. Firstly, high resolution optical remote sensing images should be preprocessed to eliminate noise and smooth the image. Secondly, an improved sea-land segmentation method is applied to separate the land and sea. Thirdly, ships are detected by their shape characteristics based on the result of sea-land segmentation.

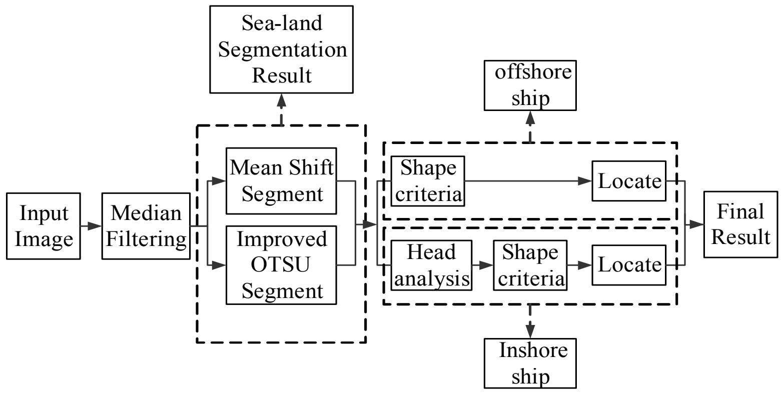

Figure 1 Basic structure of ship detection algorithm

2.1 Image preprocess

High spatial resolution remote sensing images are easily affected by weather, sea conditions, parameters of imaging sensor and other factors[9]. For a better consequence, the image preprocessing is necessary. The filtered image possesses better quality for the upcoming segmentation and feature observation. CCD detector will generate the salt and pepper noise[10]. Salt and pepper noise can be effectively removed by the median filter without obscure their edge or angular details.

Median filter can replace the value of any pixel in the image to the median value of several pixels nearby. Thus noises are eliminated and particulars are preserved effectively. In the automatic calculation of the computer, we can construct a sliding window which traverses all the pixels in the entire image, its output formula is showed in equation 1:

$$g(m,\ n) = med\{f(m-i,\ n-j),\ i,\ j,\ j \in W\} \qquad (1)$$

Where, $f(x,\ y)$ presents the original image, $g(x,\ y)$ presents the image processed by median filtering. W is a template used in the calculation, which is usually 2×2, 3×3 area. In this paper, the applied template is 5×5.

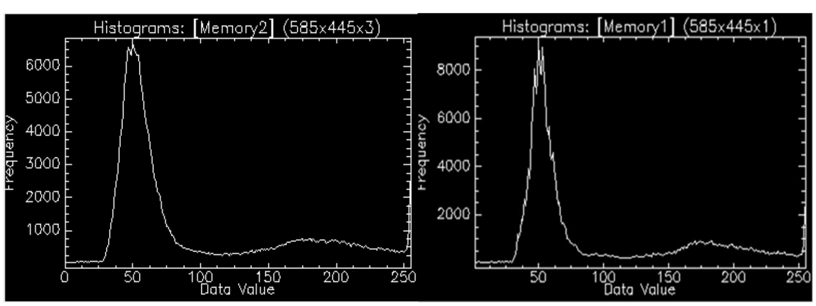

Figure 2 Histogram information before and after image pretreat

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Figure 2 shows the salt and pepper noises were eliminated effectively by median filter. It can be found out that the histogram curve is gentler before image pretreatment. After pretreatment, the histogram curve was serrated shaped, gained more troughs. The image layering was more obvious, which is conducive to further processing.

2.2 **Improved sea-land segmentation**

Remote sensing images used in ship detection usually contain land. As the land part's component is usually complicated, and it results in testing time increase and reduced detection efficiency. So sea area should be isolated from land in order to improve testing speed and quality. In relevant papers, the hypothesis is that sea area presents a low gray level and gently changes, and the threshold value is usually related to the bottom value between the two peaks of gray-level histogram. In fact, high spatial remote sensing images shows plentiful wave texture features. Gray scale histogram distribution of a Worldview remote sensing image is showed in Figure 3.

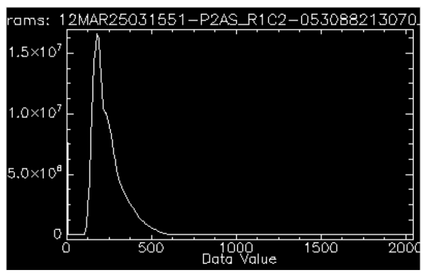

Figure 3 Gray scale histogram distribution of Worldview

This paper proposed an improved sea-land segmentation algorithm. Firstly, using Mean Shift algorithm to divide the given image into several homogeneous areas, it shows robustness when there are sea waves. Secondly, using a modified OTSU method to select the appropriate threshold in order to divide land and sea .At last, combine Mean Shift result and improved OTSU segmentation to get the final result.

2.3 **Mean Shift Segment**

Mean shift is a nonparametric estimator of density which has been applied to image segmentation. Image segmentation refers to identifying homogenous regions in the image. Kernel density estimation is used in the algorithm. It can be used on unsupervised image segmentation. Iterative formula of mean shift is as follows:

Given n data points $x_i, i = 1, \ldots, n$ in the d-dimensional space R^d, the multivariate kernel density estimator with kernel $K(x)$ and a symmetric positive definite $d \times d$ bandwidth matrix H, computed in the point x is given by[11]

$$f(x) = \frac{1}{n}\sum_{i=1}^{n} K_H(x - x_i) \tag{2}$$

Where

$$K_H(x) = |H|^{-1/2} K(H^{-1/2}x) \tag{3}$$

Employing only one bandwidth parameter, the kernel density estimator becomes the expression

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$$\hat{f}(x) = \frac{1}{nh^d}\sum_{i=1}^{n} K(\frac{x-x_i}{h}) \tag{4}$$

While Mean Shift algorithm is used for segmentation, appropriate color space and bandwidth should be selected, and the minimum number of pixels of divided region should be set. Since the use of the spatial relationship between pixels, areas with similar texture can be divided into homogeneous regions

2.4 **Improved OTSU Segment**

Otsu threshold method was proposed by the Japanese Otsu in 1979 is commonly used segmentation algorithm. The image pixels are divided into gray target and background, the maximum variance value between two classifications is taken as the threshold value.

$$\sigma^2(k) = w_1(u-u_1)^2 + w_2(u-u_2)^2 = w_1 w_2 (u_1-u_2)^2 \tag{5}$$

k ranges from1~M, take k value which makes $\sigma^2(k)$ reaches its maximum

While the image has complex characteristics, the center is not ideal, resulting in poor segmentation. In this paper, we applied an improved Otsu method by Fu Zhongliang, which replaces the mean variance instead of maximum variance value method. Expression of optimum threshold T^* is:

$$T^* = Arg \max_{0 \le T \le L-1} [P_0(\sigma_0^2 - \sigma^2)^2 + P_1(\sigma_1^2 - \sigma^2)^2] \tag{6}$$

where $\sigma_0^2 = \sum_{i=0}^{T-1}(i-u_0)^2 p_i / P_0, \quad \sigma_1^2 = \sum_{i=T}^{L-1}(i-u_1)^2 p_i / P_1, \quad \sigma^2 = \sum_{i=0}^{L-1}(i-u\ )^2 p_i$

Experimental results show that the improved Otsu method has better adaptability, and is not affected by changes in linear translational changes in gray value.

After threshold segmentation, some of the land area is divided wrongly into water. These mistaken areas are first morphological processed to remove the "glitches", and then through an empirical parameter - water proportion to determine the threshold value (area of more than 10,000 pixels).

2.5 **Ship identification and location**

Ideal shape of large vessels is relatively symmetrical. However, due to the accuracy of the extracted image, marine and coastal adhesions in the ship often cause irregularity vessel shape. In the spatial image with given resolution, the size of the ship has a range of values. This feature is used to screen out ineligible connected region. On the basis of suspected area of the ship, this paper defines width, length, ratio range, shape parameter and a series of indicators to filter and locate the real ship.

The ratio is defined as: $Ratio = \min\{w/l, l/w\}$, where l is the length of the long axis of the ship, w is width.

Shape parameters are defined as: $F = \|B\|^2 / 4\pi A$, where B is the perimeter of the area and A for acreage.

Shape parameters reflect the compactness of the region. It has no dimension of scale, and is not sensitive to changes in rotation. It does not have a fixed range of values, the greater the value, the less shape compactness. When the choice of parameters is reasonable, it is possible to remove false alarm, preferably selected real ship area.

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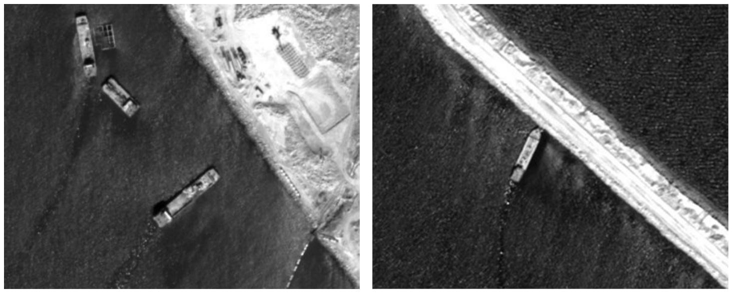
3 EXPERIMENT

In this paper, WorldView-1 data with spatial resolution of 0.5 meters is used to verify the experiment. WorldView is the US Digital Earth company's commercial remote sensing satellite. The detection area in this article locates near the Laizhou seaport of Shandong Peninsula in Shandong Province, the main scene of WorldView-1 image contain both land and sea areas, which meet the needs of experiment. Figure 4 shows 2 pieces of the original remote sensing data, Figure 5 and 6 shows the effeciency of improved Otsu segment.



(a) (b)

Figure 4 pieces of original remote sensing data

Figure 5 Otsu segment

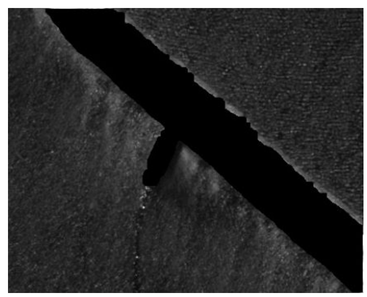
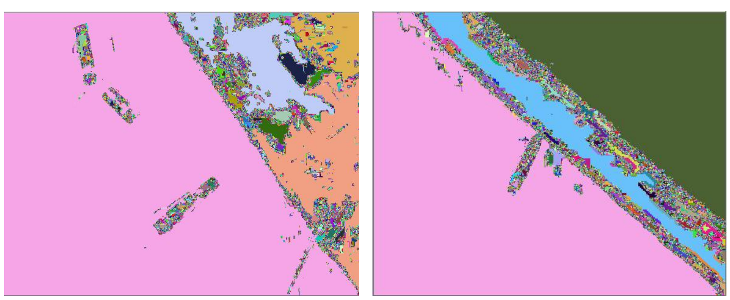


Figure 6 Improved Otsu segment



(a) (b)

Figure 7 Mean Shift segment

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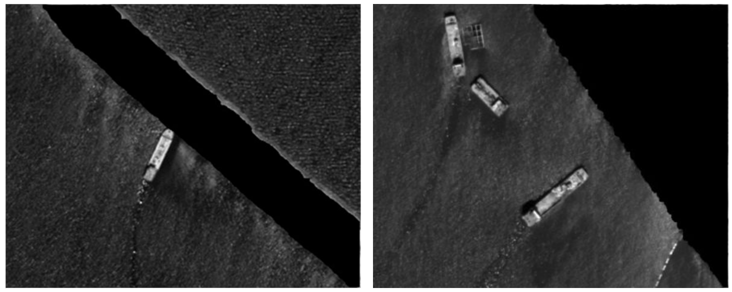
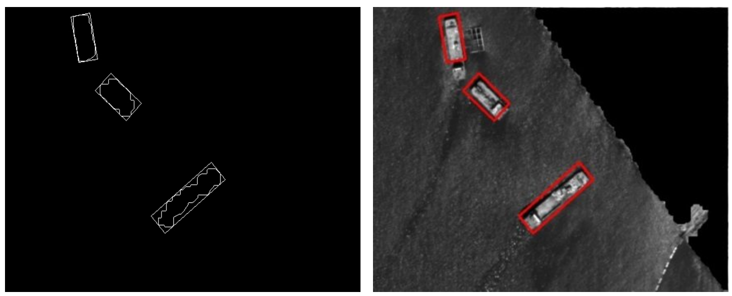


(a) (b)

Figure 8 Sea-land segment



(a) (b)

Figure 9 Ship Detetion

Here comes to final part: ship detection, experimental parameters are set as: the length of ship ranges from 50 to 200 pixels, the width of ship ranges from 10 to 500 pixel, the range of aspect ratios is $2 \le Ratio \le 10$, and the regular shape index $F \le 6$. The parameters above are determined by visual interpretation and experiments beforehand.

The results were shown in the following table:

Table 1 Ship detection result

Otsu	Improved Otsu	Our Algorithm
76.80%	89.50%	92.70%

4 CONCLUSION

Ship detection on images with complex coastal land and sea waves is relatively difficult, a new segment method which combined improved Otsu algorithm and Mean Shift algorithm is proposed in this article. The two kinds of segmentation methods were combined to give a better land and sea segmentation result. The new method is able to handle the presence of sea waves and it has strong robustness and accuracy.

In this experiment, with complex texture and background noise, the extraction work still achieved ideal results in general. It preserves detail characteristic of ships. Compared with traditional methods, this method can achieve accuracy over 90 percent. Experiments on Worldview images show the superior, robustness and precision of the proposed method.

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