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Island instantaneous coastline extraction based on the characteristics of regional statistics of multispectral remote sensing image

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Abstract: This study adopted IKONOS remote sensing images and selected spectral characteristic areas, through regional pixel statistics and calculating weight coefficients of each band, processed the images with the spectral normalized method, which made the features of islands, land and water features more obviously in the images. On this basis, the OTUS was used to determine the optimal segmentation threshold, and the normalization image binarization was made, thus the island coastline was extracted. This method used the characteristic curve method to separate the land and water, obtained the binarization images and maintained the original edge effectively. The coastline that was extracted by Binary Morphology was continuous, reliable and high signal-to-noise ratio. The results showed that this method could extract the coastline fast, simply and effectively, which had the practical value.

Keywords: coastline extraction; islands; spectral characteristics of regional statistics; Binary Morphology; IKONOS

Introduction

China is rich of islands, therefore protection and management of the island has become increasingly important. Island coastline, a basic feature of the island, is the boundary between island and seawater, and coastline data play an important role in the management of island security. In the implementation of island monitoring and surveillance, the most direct method is making use of remote sensing image to extract the island instantaneous coastline, which can be extracted whether by the artificial judgment or

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by the computer automatic processing. Artificial judgment is time-consuming, laborious and be likely influenced by subjective factors, while the computer automatic processing is relatively fast and objective, so, finding an effective method of automatic extraction of island coastline is important for promoting work efficiency and data accuracy.

At present, automatic extraction method is more suitable for mainland coastline, and mature algorithms mainly take the threshold segmentation method based on gray histogram statistics [1], segmentation method based on region growing [2], and segmentation method based on gray level co-occurrence matrix feature description method [3], and most of these methods are for the single band remote sensing image (grayscale image). The multispectral remote sensing image coastline extraction method has drawn more attentions from various scholars, and the application of spectrum characteristic curve comparison and multiband superposition of edge information method appear constantly [4-6]. This paper puts forward the island instantaneous coastline extraction method of multispectral remote sensing image, based on the typical image of sea and land statistics, which is realized by the normalization of multiband image superposition.

1 Experimental data and research area

The research area is located at the Qianhai bay in Shenzhen of Guangdong province in China: Dachan Island, Mazhou Island and the nearby sea area, as shown in Fig. 1. The topography of Dachan island is low mountain and hills with lush vegetation and part of the island land has been developed by human. There is about 1 km from the south of Mazhou Island to Dachan Island. Dachan Island is supposed to have 2 independent small islands, which has been developed completely and combined as one island. Remote sensing image of the research area as shown in Fig. 2, which is the wavelength synthetic images of the IKONOS red, green and blue, was taken at 03:11 on Jul. 27, 2008 in GMT.

This paper takes IKONOS satellite remote sensing image as the data source to research. IKONOS satellite was launched on Sep. 24, 1999, and it is the first in the world to provide high resolution satellite images of commercial satellite remote sensing with the acquisition 1 m resolution panchromatic and 4 m resolution multispectral imaging, IKONOS satellite images band information as shown in Tab. 1.

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Fig. 1 Research area(which is surrounded by the square)

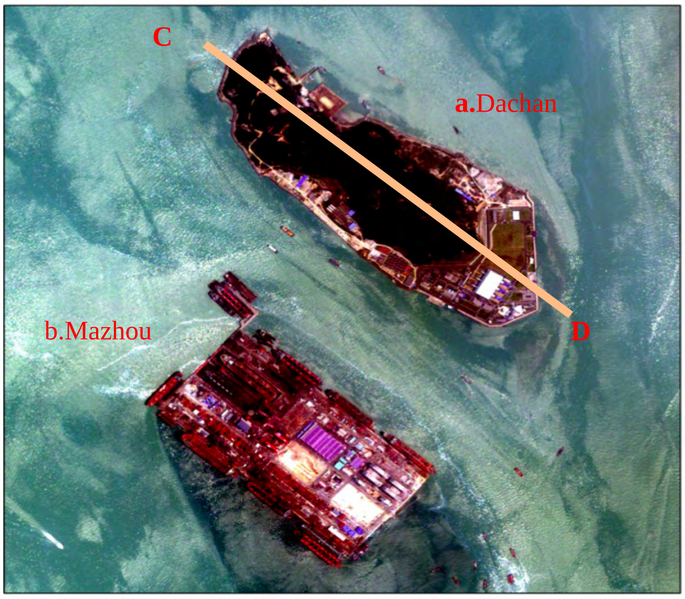

Fig. 2 IKONOS Image(a. Dachan Island and b. Mazhou Island)

2 Remote sensing data preprocessing

The aim of preprocessing is to restrain or eliminate the distortion and degradation in the image, and to enhance some characteristics of image. The preprocessing results affect the subsequent remote sensing image processing and analysis directly. The preprocessing steps include: atmospheric correction, image enhancement and geometric precision correction.

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Tab. 1 Spectral information of IKONOS image

Band	Spectral value / um	Resolution / m
Blue	0.45 - 053	4
Green	0.52 - 0.61	4
Red	0.64 - 0.72	4
Nir	0.77 - 0.88	4
Pan	0.45 - 0.90	1

2.1 The atmospheric correction

Atmospheric correction is primarily to eliminate the material influence of water vapor in the atmosphere, oxygen, carbon dioxide, methane and ozone on clutter reflections, eliminate the influence of atmospheric molecules and aerosol scattering and obtain real reflectance data of the features [7].

This article uses the dark-object methods for atmospheric correction. The basic principle of this method is to assume that the dark-object area exists in the remote sensing image for the correction, and the island surface has lambertian surface reflection and atmospheric properties. To ignore the atmospheric multiple scattering irradiation effect and adjacent pixels, and under the premise that the diffuse emission effect can be ignored, the brightness values of dark-object relatively increase because the dark-object with low reflectivity or radiation brightness is influenced by the atmosphere, and this part can be thought as the brightness of the increase due to the atmospheric path radiation. Dark-object methods are used to calculate the path radiation and applied in the appropriate atmospheric correction model, to obtain the real emission rate by the calculation after getting the corresponding parameters [8].

Using this method to assume there is small DN value (approximately 0) dark-object in the remote sensing image but the DN value is relatively increased by the influence of atmosphere, thus it could be agreed that the number of DN value is decided by the atmosphere. Therefore, using the other pixel minus DN value of dark-object to reduce the influence of atmosphere on the remote sensing images could realize the atmospheric correction indirectly.

2.2 Image enhancement

Gaussian filter is a kind of linear smoothing filter, which is used for eliminating the Gaussian noise, and widely used in noise reduction during the image processing. Smoothing filter uses the filter mask scanning each pixel in the image, with a mask to

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identify the average grey value within the neighborhood pixels instead of each pixel value of the image. Gaussian filter has fast speed of calculation, but it could cause blur while removing the sharp noise, especially in reducing the extraction accuracy of coastline. Gaussian filter is the filter with weight, and the weight in the center is greater than that in the adjacent pixels, so that it could overcome the boundary effect to enhance the accuracy of island instantaneous coastline extraction in this article.

Furthermore, the mask center has the biggest pixel weight so that the farther the position is from the center, the smaller the effects will be. The coastline in the research area is much more smooth, thus this article uses the ENVI image platform to process the IKONOS image of each band by the size of Gauss "7" x 7" low-pass filter to enhance and denoise the processing, which could improve the accuracy of instantaneous coastline extraction and also reduce the blur of image.

2.3 Geometric precision correction

Under the influence of imaging projection method, exterior orientation element changing, the uneven of sensing medium, earth curvature and topography change, and earth rotation et al., remote sensing image has geometric deformation, and the process to eliminate the geometric deformation is called geometric correction.

Geometric precision correction uses (Ground Control Point, GCP) to correct any geometric distortion which is caused by various factors. The principle is to use GCP data to simulate the geometric distortion process of original satellite images, establishing a distortion of the original image spatial domain geographic space corresponding relationship between the national standards, using the corresponding relationship to transform all the elements of the distortion of space to the corrected image space [9]. Therefore, the accuracy of GCP affects the precision of geometric correction directly.

Due to environmental restrictions, it is difficult to obtain more GCP in water and island area, and the result is not satisfactory by using general method for correction. The IKONOS remote sensing image has RPC files and DEM data. This paper adopts Rational Function Model (RFM) with selecting a few control points to realize the essence of remote sensing image geometric correction.

3 Instantaneous coastline extraction method

3.1 Analysis of IKONOS multispectral band characteristics

Each brightness value of the pixels in the remote sensing image represents the

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average radiation value of the ground object, and it changes with the composition, texture, conditions, surface characteristics, and the use of electromagnetic wave varies.

Sunlight absorption, reflection and transmission of water are changing with the wavelength. Generally, absorption is greater than the reflection and transmission [10, 11]. The reflection of water is very low in the visible area normally, and the maximum transmission wavelength of light is about between 450 nm - 550 nm in the clear water, and peak wavelength is about 480 nm. The water spectral attenuation characteristics is shown in Fig. 3. In blue and green wavelengths, seawater has the feature of the weakest scattering least attenuation coefficient, and strongest penetration. Therefore, in the shallow area, blue and green wavelengths can be transmitted through water, reflect the bottom. The reflectivity of water further is reduced with the increase of wavelength, and water is almost fully absorbed to near infrared band. So, on the satellite images of near infrared wave band, the color of water is dark generally.

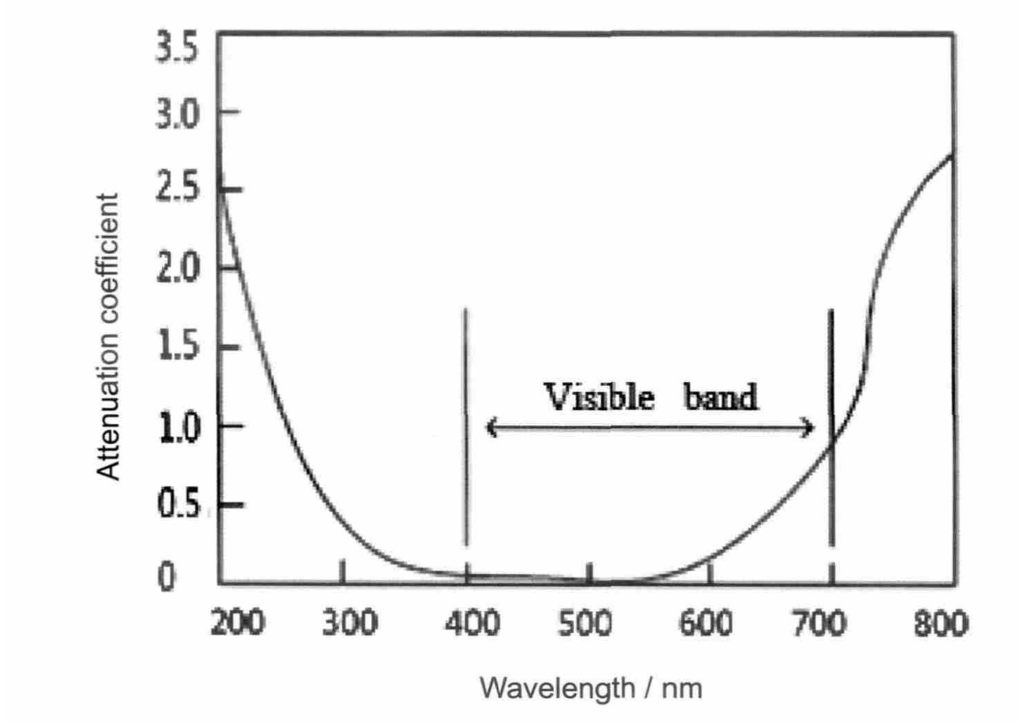

Fig. 3 Attenuation curve of the water spectral characteristics

To compare and analyze the radiation luminance values of IKONOS in four band [6], it is found that near the land and sea borders, the changing ranges of radiation brightness values are different, and the changes of near infrared band and red band changes are great, as Fig. 4 shows. To calculate the change rate of radiation brightness values of four band that near the land and sea borders, the results are related with radiation values from

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seawater to island, and with the island and water rate respectively. The greater rate of change indicates the radiation change from seawater to island is bigger, and island and sea borders are more obvious.

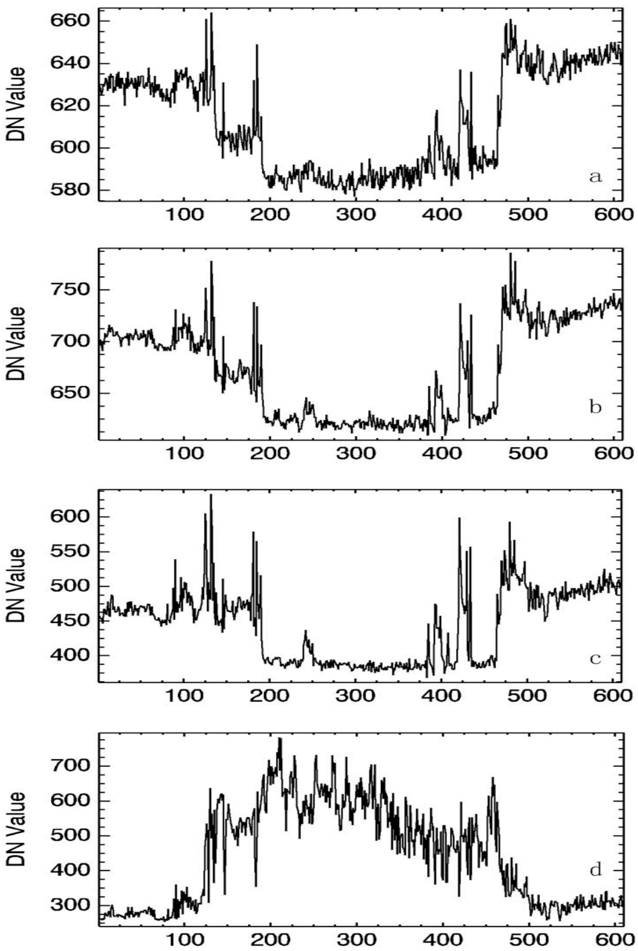

Fig. 4 Spectral band radiance profiles of the IKONOS image

(a-d denote the blue band, green band, red band and near infrared band of C-D respectively)

3.2 The image spectral normalization

According to the analysis results of the section 4.1, the greater radiation brightness value means more successful of the separation of land and water in the band. Method for the weight calculation of IKONOS in 4 bands: selecting 2 reference areas (A and B) on both sides of the island and sea in band i , A is located in the island area, and B is on the sea area. Supposing that the average radiation intensity values are $L_A(i)$ and $L_B(i)$, the

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change of radiation intensity values is as follows:

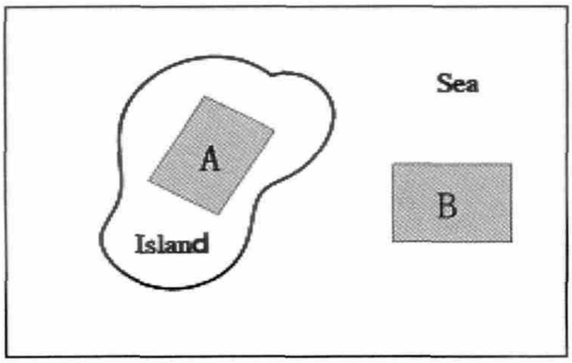

Fig. 5 Schematic diagram of the selected reference area

$$VL(i) = L_A(i) - L_B(i) \qquad i \in [1, 4] \tag{1}$$

Corresponded weight of i band:

$$W_i = \frac{VL(i)}{\sum_{n=1}^{4} VL(n)} \qquad i \in [1, 4] \tag{2}$$

To make full use the information in each band, the images in different bands are processed normalizedly, which could enhance the diversity of spectrum characteristics and popularize the algorithm. The normalized spectrum *E* is calculated by the following formula (0.3), *M* and *N* represent data tag horizontal and vertical size of the matrix.

$$E(x, y) = \sum_{i=1}^{4} L_i(x, y) \times W_i \qquad x \in [1, M] \qquad y \in [1, N] \tag{3}$$

3.3 The normalized spectrum image binarization

The image contains the target, background and noise, and we could set a threshold as T for extracting the target from the multiple-valued image directly, and divide the image into two parts: one group of pixels (target) greater than the threshold T and the other group of pixels (background and noise) less than the threshold T.

Otsu algorithm was proposed by Otsu in 1979, and this method was derived by the analysis and judgment which is an automatic threshold segmentation method without parameters unsupervised. Its principle is to use the image histogram to separate the image into 2 parts, target and background, and use the maximal variance to determine the optimal segmentation threshold for obtaining the corresponding binary image. Otsu algorithm is very simply, clear and fast, and it is also sensitive to the noise and target size. In this article,

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we also use the Otsu Method to process the remote sensing images.

3.4 Using the binary morphology method to detect the coastline

The original idea of Binary Morphology is to extract corresponding shapes to analyze and recognize the image [4]. Binary Morphology is composed by a set of morphological operations, and there are four basic operations: dilation, erosion, opening and closing, and its operation object is the collection. To determine the structure of the image, we must consider the relationship between the various parts of the image, and develop the collection of images and elements for the image processing, meanwhile we have to notice the size of structure elements and images.

After the binarization, we get the binary image of land and water. The coastline essence images (A) are extracted from the binary images, and β(a) is the edge detection. Usually, the erosion operation between b and a is used, then we get β (a) by the difference set of erosion result and a:

$$\beta(A) = A - (A \Theta B) \tag{4}$$

Extracted edge could maintain the correct position of images, but also need further refining 2 pixels of the edge. After obtaining the image edges, we check the connectivity of edges and exclude the outlier noise, then refine the edges and ultimately get the coastline [5].

4 Research area coastline extraction

First, the ENVI software is used to preprocess IKONOS remote sensing images by the method that is mentioned in Part 2. And then, a typical area in the image is selected, such as rectangular region in the Dachan Island and Mazhou Island (L1 and L2 as shown in the Fig. 6). The area L1 is totally covered by the vegetation which is the typical natural land in the island. L2 as a typical area of artificial facilities, has land features with high brightness and low brightness area also. There are 3 selected sea areas in the image, S1, S2 and S3, S1 in the high brightness of sea area, S2 in the low brightness and S3 in the medium brightness of sea area

After selecting a typical areas on land and sea, we start to complete the statistics and calculation of sea multi-band pixel value and weighting factor, and the result is shown in Tab. 2. It shows that island area and sea have the smallest difference of mean pixel in the blue band with the minimum weight coefficient of 0.050, and there is little difference on the brightness in each pixel elements in the typical area. On the contrary, in the near-infrared

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band, there is the maximum weight coefficient 0.682 between island area and seawater. Tab. 2 also shows a trend that with the increasing wavelength, land area and seawater pixel gap become increasingly apparent.

After obtaining the weight coefficient for each band in typical areas, we preprocess spectral image for the normalization. The results are shown in Fig. 7. The processed image is more distinct and has less affection from the noise. The spectrum normalized contrast images of island area and seawater are more obvious, which partly reduces the impact of noise points.

The Otsu variance method is used to calculate the gray histogram first, and then we figure out the interclass variance of each grey level, and determine the optimal threshold finally. The results of normalized spectral image binarization are shown in Fig. 8. The island profile is presented clearly, and we can also find the outline of the ship on the sea. Finally, the binary morphology and visual interpretation are used to extract island instantaneous edges and delete isolated noise from ships, and we can see the final coastline in Fig. 9.

Tab. 2 The weight coefficient statistics for each band of IKONOS image

Band	Island area		Sea area		Weight Coefficient
	Mean	Stdev	Mean	Stdev	
blu	630.348731	27.874797	617.6549	9.593752	0.049676524
grn	708.245658	53.441319	682.6947	19.62781	0.099992185
red	484.165526	68.959783	441.2513	29.00228	0.167942509
nir	439.29722	129.9064	264.9268	40.11173	0.682388781

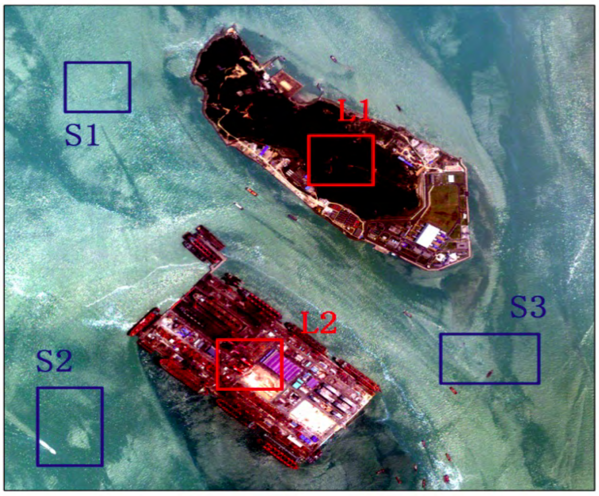

Fig. 6 Typically selected areas

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Fig. 7 Normalized image

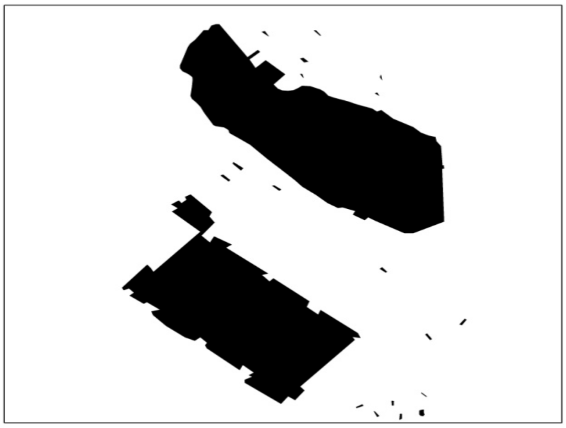

Fig. 8 Binarized image

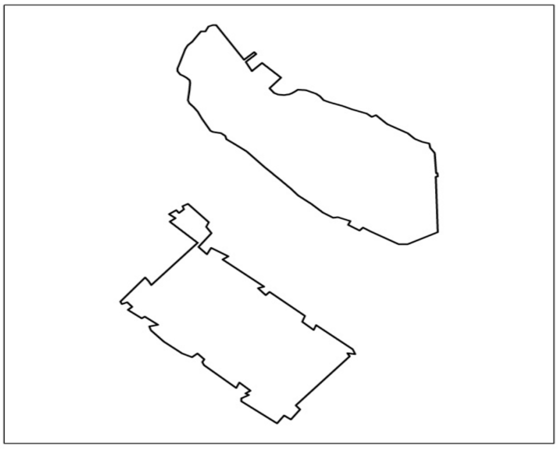

Fig. 9 Result of the island coastline

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5 Conclusion

The results show that separating the land and water by the method of characteristic curve could maintain the effective edges of original images, and extracted coastline is more reliable and has high signal to noise ratio by using the binary morphology. Experimental results show that the algorithm proposed in this article is very simple and fast, and it could extract the coastline effectively in the case of much spectral information and enhance the efficiency. In the remote sensing image, near-infrared (0.76 - 3.0 μm) is the main band of water analysis. Thus in the experiment, we can obtain the best accurate results after having near-infrared information.

The coastline mentioned in the article is not the same in the chart, but it is referred to instantaneous and distinctive coastline boundary in the remote sensing image [14-16] . The coastline extraction model uses the unique advantages of spectral information and morphological characteristics of the image for extracting the edge information of multispectral and hyperspectral remote sensing image effectively. Furthermore, the algorithms mentioned in the article is very simple and efficient, and it could also be adopted in the engineering calculations for the practical value.

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基于特征区域统计的多光谱遥感影像海岛瞬时岸线提取

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摘 要：本研究采用 IKONOS 遥感图像，选取波谱特征区，通过区域像元统计并计算各波段权重系数，将影像进行波谱归一化处理，使归一化的影像岛陆与海水特征更明显。在此基础上，采用最大类间方差法确定最佳分割阈值，对归一化的影像进行二值化，从而提取海岛岸线。该方法采用特征曲线法进行水陆分离，得到的二值图像保持了原图的有效边缘，采用二值形态学提取的海岸线连续可靠、信噪比高。结果表明，该方法简单、快速，能有效提取海岸线，具有实用价值。

关键词：岸线提取；海岛；波谱特征区域统计；二值形态学；IKONOS

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