Development of Green Tide Monitoring with Satellite Image

Wang Ruifu, Zhang Ya, Li Jiagui, Zhao Wei, Wang Fangzheng, Cao Hongjun, Duan Yaping

Shandong University of Science and Technology, Qingdao, 266510, China. Email:wrf@sdust.edu.cn

Abstract

Since the large-scale bloom in 2008, green tide, as a marine natural disaster, happens every year along the coast of Qingdao. It brings huge economic losses to society every year. Therefore, it is urgent to monitor the green tide in real time to obtain its dynamic information. Generally, researches on green tide are mainly focused on the coverage area. For Operational Application of Disaster Emergency Response, the influence range of the green tide is what people is concerned about. The influence range of the green tide can not only give information about the gaps between small green tide patches but also show the trend of development of greed tide. Our research is mainly about the influence range of the green tide. We designed an algorithm for extracting the green tide distribution boundaries automatically. Principle of the algorithm is based on mathematical morphology dilation/erosion operation. This paper mainly improves in the following aspects: the partition of the green tide blocks, the accurate and efficient extraction of the distribution range and distribution contour of the green tide, and the filtering of the island. Since green tide mainly bursts along the Qingdao Coast and there is no established system so far, a system for monitoring green tides is established. On the basis of IDL/GIS secondary development technology, the system integrated environment of RS and GIS. It can be used for remote sensing monitoring and information extraction. Optical sensor data and microwave sensor data are used in this system. Special processing flow and algorithms for extracting information are designed on the basis of the different characteristics of these data. Without using this system, a complete data process from beginning to ending needs 2 hours, but it can be finished in 10-15 minutes now in our system. The system runs smoothly and successfully in the State Oceanic Administration for three years till now.

Introduction

At present, since remote sensing developed rapidly, it has been the supreme means of carrying out long-sequence marine monitoring because of its natural advantages of large scale, multi temporality and high efficiency. (Wang et al., 1998). While with a power capabilities of spatial data organization and management, spatial analysis and visual expression, GIS can perform spatial analysis and statistics on any type of green tide data at any period. Meanwhile, spatial analysis technology is very effective in extracting the distribution range of green tide and the contour of its range.

At present the green tide monitoring method which combines remote sensing and GIS is multifarious. But most of the methods rely too much on professional software and operation level of users with a low degree of automation, therefore they are very inefficiency. There lacks researches on automatic, functions integrated system which is needed in green tide monitoring process. An operational system for green tide monitoring is designed in this paper. The system has functions of data preprocessing, acquisition of green tide dispersion points and envelope extraction.

Two main issues are solved in this paper:

(1) An integrated green tide monitoring system is designed. It deals with multi-source data, packages and calls the algorithm to extract the green tide information. This makes it possible to process multi-source data, extract the green tide information in one system automatically.

(2) Improve the efficiency and accuracy. Unsmooth envelopes problems are very prominent in using general algorithm. We combine the Euclidean distance analysis with the principle of mathematical morphology dilation/erosion to achieve a better efficiency and accuracy.

Objective

Countries close to the ocean are affected by the green tide, a marine disaster which is caused by the explosive propagation of algae, for instance Ulva and Enteromorpha. It is a harmful marine ecological phenomenon (Hiraoka et al., 2004; Nelson et al., 2003). Since the 21st century, the green tide has continuously erupted along the coast of China, leading to huge economic losses and environmental pollution in the aquaculture industry and tourism, which has received widespread attention from the society. This phenomenon is particularly serious in the Yellow Sea(Hu et al., 2008; Liu et al., 2016; Liu et al., 2009). In addition, the green tide of corruption will also generate harmful gases and pollute the marine ecological environment. (Quillien et al., 2015; Jeffrey et al., 1993).

Research Contents

(1) Integration functions of GIS processing and RS processing

According to previous methods, first, remote sensing images is subjected to a sequence of pre-processing operations and then algorithms are used to extract coverage information. Afterwards, spatial analysis of the results is performed in the GIS environment. These methods are cumbersome, time-consuming and inefficient, usually manual operations are required.

We integrate the functions of GIS and remote sensing algorithm into one system, and make the whole process automatically. This greatly improves the work efficiency.

(2) Green tide envelope extraction

The envelopment of the green tide is needed to extract because the bi-value images extracted by green tide coverage information extracting algorithm does not contain the precise contour. The influence area also cannot be extracted via this sort of images. Our system combines buffer analysis based on Euclidean distance and morphology closed operation (dilation/erosion) to extract accurate influence range of green tide discrete points.

Integrate the interaction function of GIS and RS

Two main software platforms are used in this system: the ENVI/IDL platform, which is used to extract green tide coverage information; the GIS platform, which is used to manage the data from ENVI/IDL module, and make and visualize the products.

For the purpose of implementing better fusion of GIS and ENVI/IDL, efforts are made as the following aspects including packaing and calling of remoting sensing image processing, unified naming rule and data format,unified image property setting and unified management mode. Packaging and calling of remote sensing image processing modules is the main part.

The image processing modules, which are developed in ENVI/IDL, are sealed as EXEs、such as MODIS.exe, hj,exe,Radasat.exe,TerraSAR.exe and Cosmo.exe. In this paper, data for five sensors including optical sensors and microwave sensors is selected as the source data. In the light of the different demands of the data, this system corresponding related data preprocessing modules for preprocessing operations which generally include radiometric calibration, geometric correction, cloud detection, atmospheric correction, false color synthesis. After these operations, NDVI images、calibrated SAR images、cloud images and false color images are obtained. Next, we use the new extraction algorithm module for further process. A sequence of operations are realized in this module, such as querying interpreted image data, drawing area of interest according to cloud images and land images, cutting the input images with the area of interest, defining threshold based on preprocessing results histogram, image segmentation using threshold etc. Finally, we can obtain a bi-value image, which is the green tide coverage information in ROI.

Algorithm Introduction

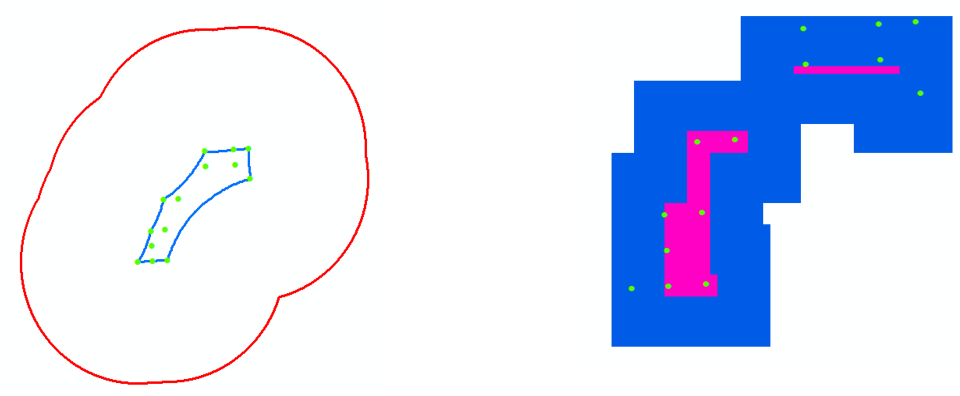
At present, there is no mature method for extracting distribution contour from scatter data, but there are some methods that can be used for reference, such as Euclidean distance buffer method and morphological closed operation method. Euclidean distance buffer method is a commonly used neighborhood analysis method, which chooses a distance as the buffer radius, and processes points and lines separately. For a point, a circle with buffer radius is generated by taking the point as the center of the circle. While for a line, a parallel line is generated, and the distance between parallel lines is the buffer radius. This method is simple and needs to deal with the shape of the inflection point.

Morphology method mainly studies the morphological and geometrical features of images. It can transform a large number of complex image processing operations into a simple combination of shift and logic operations. Morphological closed operations are typically used to fill voids in objects, connect adjacent objects and smooth their boundaries without significantly changing their area. The morphology closed operation is defined as:

$f \cdot b = (f \oplus b) \ominus b$

Here, f dilates based on b and the subsequent result is eroded by b.

The results of two methods are shown as figure 1.



(a)Buffer Scheme (b)Closed Operation Scheme

Figure 1.The Effect Diagram of Buffer Scheme and Closed Operation Scheme

Green Tide Distribution Extraction Method

We designed a new spatial contour extraction algorithm, which contains the merits of the buffer analysis and the morphology closed operation, overcomes the shortcomings of the two methods. The rendering of this algorithm is shown as figure 2.

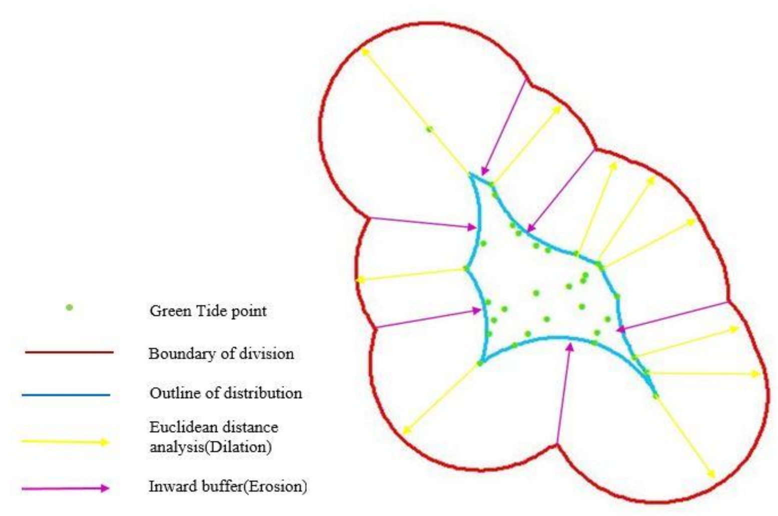


Figure 2.The Rendering of Green Tide Envelope Extraction Algorithm

Algorithm Implementation

All the procedures of green tide envelope extraction algorithm are described as follows, including four parts. And the verification of the algorithm is shown as figure 3.

(1)Data input and parameter setting

Read in the discrete vector points or bi-value images, import the mask shapefiles like land data, cloud data, and then input the pivotal parameters included in the algorithm.

In order to improve computational efficiency, Divide the green tide discrete points into blocks first, and then obtain the green tide distribution range based on the types of the results.

(2)Green tide blocks division

Distance analysis: First, the green tide discrete points file or bi-value image are input. And then the cell size of the output raster is set, meanwhile, the key parameters, the farthest distance, is set as fusion distance. In the end, a gray image whose grayscale value is the linear distance is obtained.

Condition analysis: In this image, the areas expressed in grayscale are divided green tide blocks. Judging pixel by pixel with condition analysis tool, the bi-value image which shows green tide blocks partition is obtained.

Raster-vector conversion: In order to run buffer analysis, the vector file expressing green tide blocks division is transformed from the bi-value image by the raster-vector tool.

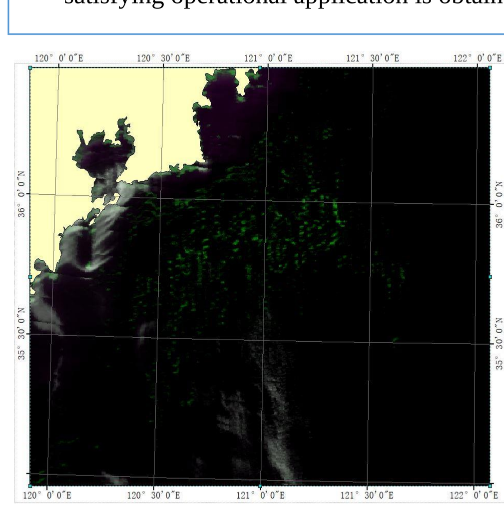
Inward erosion: If the dilative radius and erosive radius are equal, isolated green tide scatters will be lost, so the erosive radius should be slightly less than the dilative radius (generally half the size of the image pixel).

(3)Getting basic distribution contour

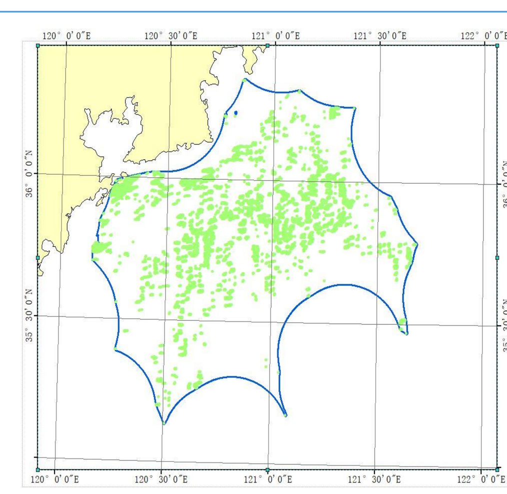
Dilative and erosive operations are performed based on the zoning blocks. The dilation operation is based on the calculation of raster data, while the erosion operation is based on the results of raster-vector conversion, and the basic influence range of green tide is obtained by fusing the results of each block.

(4)Acquisition of accurate envelope of green tide

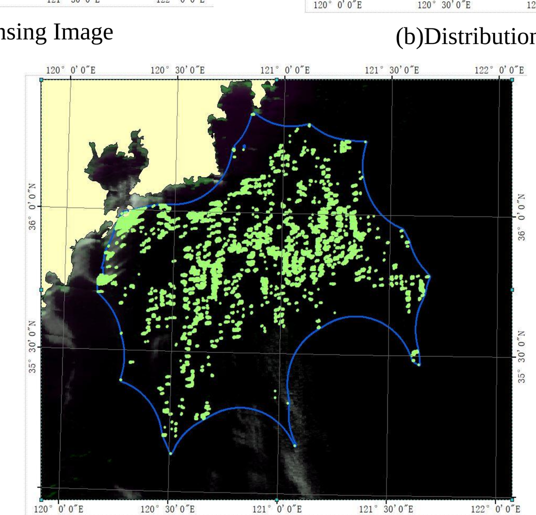
So as to satisfy the need of spatial constraint and business practice, the green tide distribution is masked by land files and cloud files. Features such as "islands" and "rings" are filtered out via merging the polygons. In the end, accurate distribution range is extracted and the vector file satisfying operational application is obtained.



(a)Remoting Sensing Image



(b)Distribution Information Map



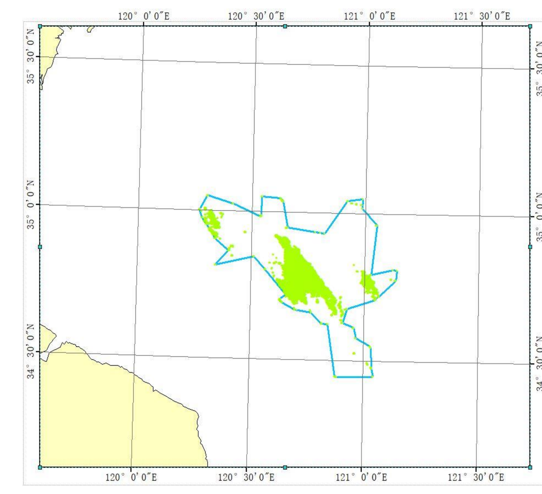
(c)The Sketch Map of Overlaying

Figure 3. The Verification of Green Tide Envelop Extraction Algorithm

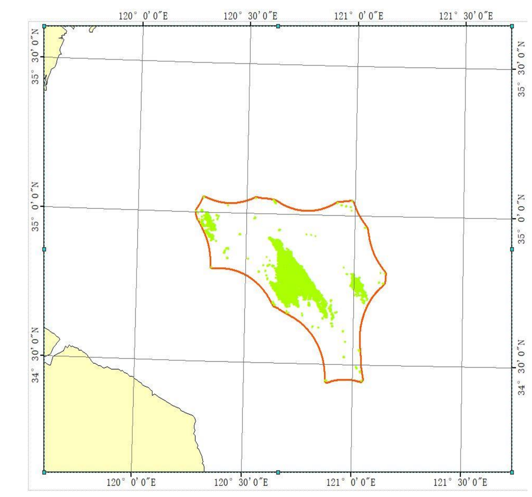
Result

As shown in Figure 4, three methods are used to obtain the envelopes of green tide: mapping manually, buffer analysis based on ArcGIS platform and the green tide remote sensing monitoring system respectively. The time-consuming and detected distribution areas of the three methods are shown in Table 1.

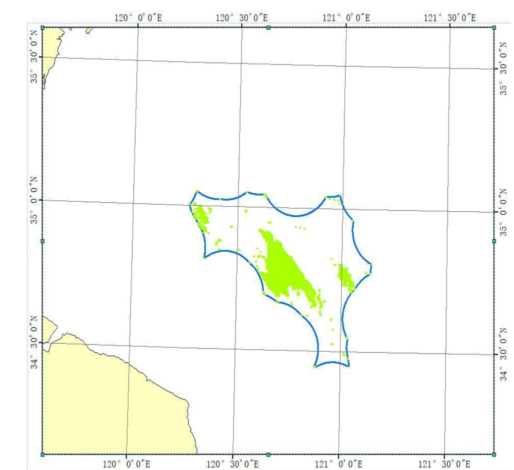
Although the results extracted manually have higher accuracy, it is more obtrusive and time-consuming. It is not conducive to the batch processing, and the efficiency is low. In contrast, the envelopes are acquired by buffer analysis or by our system are smoother, and the efficiency is high. In comparison to buffer analysis by ArcGIS, the efficiency of our system has improved by nearly 16 times. The influence range results are almost similar to the manual results. In addition, the system also solves the problem of the omission of outliers and the filtration of "islands", which makes the influence range more accurate.



(a)Envelop of mapping manually



(b)Envelop of buffer analysis based on ArcGIS platform



(c)Envelop of the green tide remote sensing monitoring system

Figure.4 Results of three algorithms

Table 1 .*Efficiency and Accuracy Parameters for Different Method*

	Mapping Manually	Buffer Analysis	Extraction via Monitoring System
Time (s)	600	378	37.56
Area (km^2)	2304.17	3004.07	2571.88

System Advantage

As shown in Table 2, compared to traditional method, the efficiency of our Green Tide Monitoring System has improved about 10 times. This improvement may come from the following work: First, based on the development of ENVI/IDL, independent modules of the system become possible. Modules on data analysis, geometric correction, radiometric calibration, atmospheric correction, image segmentation and other algorithms are developed for our system. Integrated data processing is achieved in this system. It will save time on data input and parameter adjustment. It is also independent to remote sensing software. Second, software for data processing is packaged to EXEs. This can avoid the frequently switching between ENVI/IDL and GIS, and then improve the efficiency of our system.

In the process of extracting the distribution contour, the traditional method may lead to omissions in isolated points and the connections of adjacent block boundaries are not broken. These are solved in our algorithm. First, the system makes a change that the corrosion distance is slightly smaller than the expansion distance because the equality of the expansion distance and the corrosion distance causes the omission of isolated points. Secondly, since the connection between similar green tides points still exists in the process of erosion after expansion, the system carries out the case that divides the green tide points and then processes them block by block.

However, it needs to be repeated after the points are divided so it will take time as twice as long if it is processed in order and block by block.

After the optimization mentioned above, the system algorithm promises a better efficiency and the accuracy.

Table 2. *Time Parameters of Traditional Methods and the Green Tide Monitoring System*

	Data Preprocessing	Extracting Green Tide Points	Extracting Envelope
Traditional manual method	35min	4.31s	600s
Green tide remote sensing detection system	3min	1.38s	37.56s

Conclusions

In this paper, the system integrated RS and GIS environment via calling sealed modules to preprocess several different kinds of optical sensor images and microwave sensor images and extract green tide coverage information. And this paper explored a new algorithm combining buffer analysis based on Euclidean distance and morphology closed operation to extract green tide envelope efficiently. The system is able to realize an integration of RS data processing and GIS which has a power capabilities of spatial analysis and visual expression.

The algorithm used in this paper saves the time required for the extraction process and the extracted results are more accurate. Finally, the user can perform data processing with a click and quickly make decisions based on the results of the system. Currently, this system has been extensively applied in commercial areas. From now on, we will optimize these used algorithms and expand relative functions of our system.

Main Reference

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