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The Extraction Algorithm of Ocean Surface Oil Spill in Gulf of Mexico based on MODIS Data

Yuanfang Sun[1st]
The institute of Ocean-graphic Instrumentation of Shandong Academy of Sciences, Qingdao, China
sunyuanfang1987@126.com
Bin Zhou[2nd]
The institute of Ocean-graphic Instrumentation of Shandong Academy of Sciences, Qingdao, China
Yingying Gai[3rd]
The institute of Ocean-graphic Instrumentation of Shandong Academy of Sciences, Qingdao, China
Yan Zhou[4th]
The institute of Ocean-graphic Instrumentation of Shandong Academy of Sciences, Qingdao, China
Wenwen Li[5th]
GeoDa Center for Geospatial Analysis and Computation, School of Geographical Sciences and Urban Planning, Arizona State University, Tempe AZ 85287

***Abstract*—This paper extracted oil spill which happened in Gulf of Mexico using two images obtained from MODIS on May 17,2010 and May 24,2010, and then analyzed the accuracy of extraction results based on the confusion matrix. It was conducted with eigenvectors built by multi-spectral information and spectral matching with the texture characteristics to recognize targets in consideration of mix points phenomenon between oil slick and sea water. Meanwhile, it also made comparisons with minimum distance algorithm and support vector machine to extract oil slick. The contrast among these three algorithms showed that the improved spectral angle mapper (SAM) algorithm had good effect of monitoring the oil spill area than others. Then confusion matrix was used to verify the result accuracy. Results showed that the overall accuracy were up to 90%, and they could meet the extraction accuracy requirement, which could be used in oil spill dynamic monitoring and could provide technical support for oil spill trend and oil sea pollution response.**

***Index Terms*—MODIS, Gulf of Mexico, oil spill, texture feature, SAM.**

I. INTRODUCTION

Over the years, marine oil pollution becomes more and more serious. According to statistics, there were about 2635 oil spill accidents from 1973 to 2006[1].Whether it could accurately and timely monitor oil spill is of great significance to prevent the pollution expansion of oil spill and take prevention measures after the spill[2]. The traditional tests are time-consuming, and the detection result has low accuracy. In recent years, remote sensing has become an effective method for monitoring oil spill with the development of satellite remote sensing technology[3-5]. Foreign started ocean oil spill monitoring using remote sensing technology in the early 1960 s and early '70s[6]. There were many ocean oil spill successful cases at home and abroad based on remote sensing methods, and many studies were based on SAR data, LANDSAT TM data, NOAA, and so on. In consideration of MODIS multispectral, short cycle, and freely available, MODIS data are chosen to conduct oil spill extraction in Gulf of Mexico in this paper. Bari university researched the trend of oil spill development based on MODIS/MERIS data and SAR data. Some researchers in America conducted oil spill identification and analysis to extract oil position, oil diffusion, and so on based on MODIS data. All these researches had achieved good results.

In order to better to distinguish oil spill from water, this paper made the best use of field spectra information to extract oil spill based on spectral angle mapper algorithm. In view of some different features have similar spectrum, so this paper added texture features on the original algorithm in order to improve the interpreting accuracy. This improved algorithm could provide technical support for subsequent dynamic monitoring and oil spill spread trend.

II. DATA SOURCES

This paper acquired two MODIS L1B images on May 17,2010 and May 24,2010 of Gulf of Mexico (as shown in Fig.1, and Fig.2).According to previous researchers' research experience, this paper chose MODIS L1B level data with 7 bands and 500 m resolution to extract oil spill.

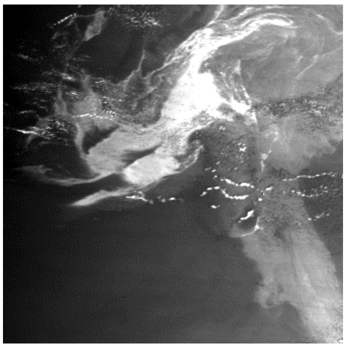

Fig. 1.Oil spill image of Gulf of Mexico on May 17, 2010

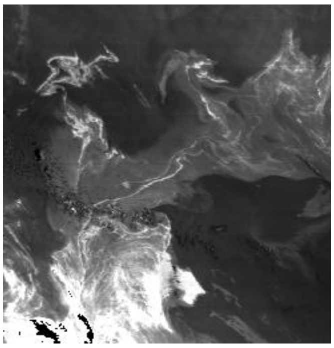

Fig. 2.Oil spill image of Gulf of Mexico on May 24, 2010

III. OVERVIEW OF THE OIL SLICK

Gulf of Mexico locates in the North America mainland southeast coastal waters, and part is surrounded by land, about 1609 km long, 1287 km wide, and has an area of 154.3 square kilometers. The Gulf of Mexico is one of the important oil-producing region. In April 2010, BP's deep water horizon rig exploded and caused the fire in the Gulf of Mexico, which caused oil spill to be up to 5000 barrels a day, and the extent of the oil slick expanded further on the basis of statistics of 9900 square kilometers on April 30, 2010.

IV. Data Processing and Methods

A. Data Preprocessing

MODIS L1B level data have been calibrated, but stripes exist on images, so they needs to deal with the stripes before using the images[7]. And they also hierarchically stores geographic coordinates information, so they need to be geometric corrected and bow-tie removed.

B. Target extraction algorithm

This paper used spectral angle mapper with texture feature added to extract oil spill. Firstly, it added one or more texture features to the original bands. Secondly, it built referenced spectral library according to the prior knowledge and visual interpretation. Lastly, it judged pixels belongings according to spectral angle between them with referenced spectrum curves[8].

1) Texture information extraction

Texture is a change in the image pixel grayscale or color. The images texture features play an important part in pattern recognition of remote sensing. Eight kinds of texture features commonly used include mean, variance, homogeneity, contrast, dissimilarity, entropy, second moment, correlation.

Gray-level co-occurrence matrix has been widely used in digital image processing as a traditional method of texture analysis. This paper used gray-level co-occurrence matrix to extract images texture features. Gray-level co-occurrence matrix collects simultaneous occurrence probability for pixels of gray value 10 when the distance was d, and the direction was θ from the pixel for (x, y) with gray level as i, just as shown in formula1:

$$p_{ij} = \frac{p(i, j, d, \theta)}{\sum_i \sum_j p(i, j, d, \theta)} \quad (1)$$

Comparing eight texture features between oil spill and the sea (as shown in Fig.3), it found that mean could be better to extract target of oil spill. Therefore, this paper add mean to original bands in order to build spectral library.

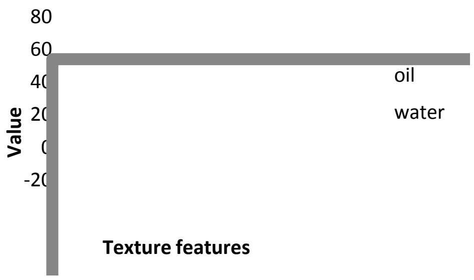

Fig. 3.Comparison of the common used eight texture features between oil slicks and seawater

2) The improved spectral angle mapper algorithm

The so-called spectral angle mapper classification algorithm (SAM) judges each object belongs according to comparing the angle between waited feature vectors recognition and the reference objects vectors. The principle of SAM [8] is shown in Fig.4.

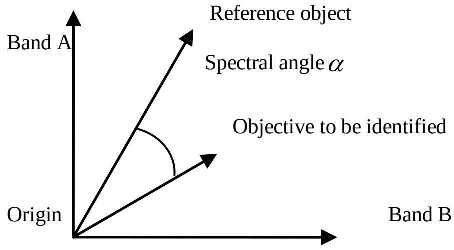

Fig. 4.Two-dimensional space of spectral angle

$$\cos\alpha = \frac{X \cdot Y}{\|X\| \cdot \|Y\|} = \frac{\sum_{i=1}^{n}(x_i \cdot y_i)}{\sqrt{\sum_{i=1}^{n} x_i^2} \cdot \sqrt{\sum_{i=1}^{n} y_i^2}} \quad (2)$$

$$\alpha = \arccos \frac{\sum_{i=1}^{n}(x_i \cdot y_i)}{\sqrt{\sum_{i=1}^{n} x_i^2} \cdot \sqrt{\sum_{i=1}^{n} y_i^2}} \quad (3)$$

Equation 2 and equation 3, n: bands number. $X = (x_1, x_2, \ldots, x_n)$ and $Y = (y_1, y_2, \ldots, y_n)$ respectively represent spectral response value of two spectral vector on the n bands. α : spectral angle.

Different terrain types have different characteristics in the spectral curve, and the faint difference could also show up on the spectral curve. Just because it was difficult to distinguish thin oil slicks and seawater, this paper analyzed the radiance comparison between thin oil slicks, thick oil slicks and seawater.

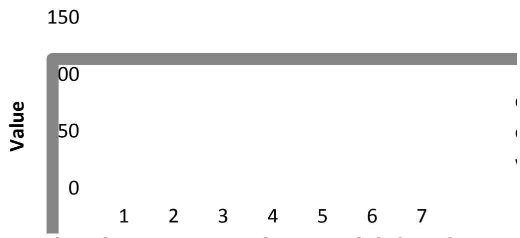

Fig. 5.The radiance comparison between oil slicks and seawater

It could be seen form Fig.5, the radiance spectrum curve shape of the oil slicks and sea water had the same trend. The radiance values of oil slicks were higher than sea water. Therefore, this paper chose 50 oil slicks samples and 50 sea water samples and calculated theirs ratio in order to better distinguish oil spill from sea water. It is shown in Fig.6.

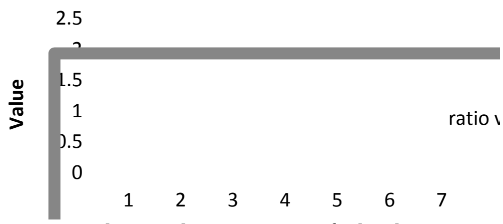

Fig. 6.Radiance value ratio curves of oil and sea water

Just as shown in Fig.6, each ratio value of oil slicks and sea water in 7 bands was greater than 1, and the maximum ratio value was in band7, band6, band5 and band2. Therefore, it referenced to synthetic false color images of these four bands.

The reference spectrum curves of oil slicks and sea water are shown in Fig.7.

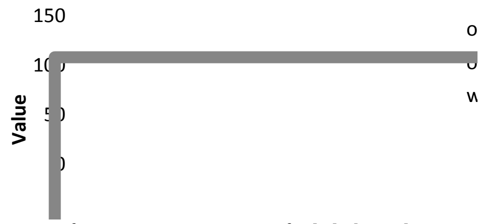

Fig. 7.Reference spectrum curve of oil slicks and sea water

This paper added the mean of texture to the original bands, after building referenced spectral library, it carried out the improved spectral angle mapper with no threshold. It judged the pixels belonging according to the angles between pixels and the referenced spectrum curves and the mean of texture. (Fig.8). α_o represented angle between pixels and oil spectral library, and α_w represented angle between pixels and sea water spectral library.

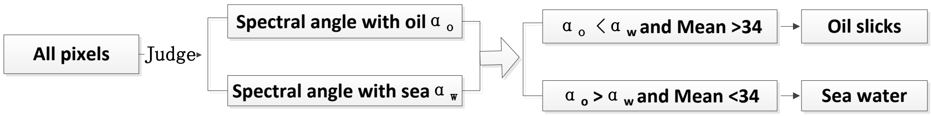

Fig. 8.Improved spectral angle mapper algorithm flow

3) Technical Route

Technical process is shown in Fig.9.

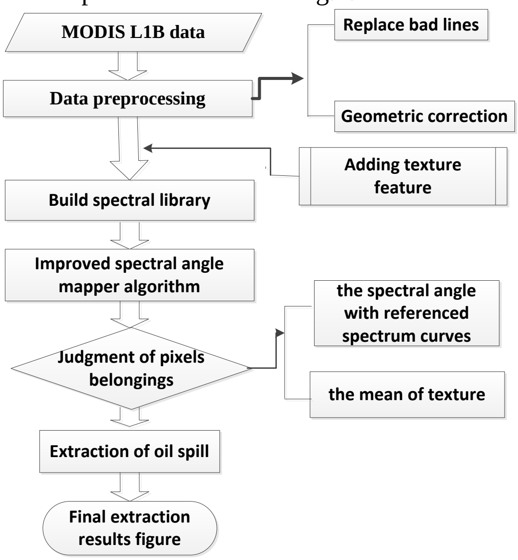

Fig. 9.Spectral matching method to extract oil spill

V. RESULTS AND ACCURACY ANALYSIS

A. Results analysis

This paper compared extraction results respectively using improved spectral angle mapper algorithm, minimum distance algorithm and support vector machine. Fig.10—Fig.15 show the results.

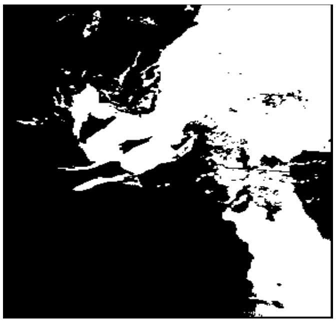

Fig.10.Result using improved SAM algorithm on May 17, 2010

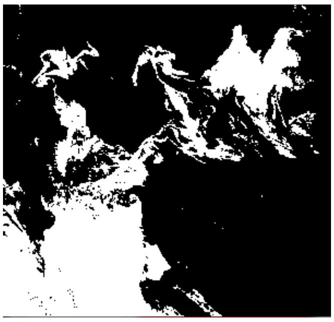

Fig.11. Result using improved SAM algorithm on May 24, 2010

Fig.12. Result using minimum distance on May 17, 2010

Fig.13. Result using minimum distance on May 24, 2010

Fig.14. Result using SVM on May 17, 2010

Fig.15. Result using SVM on May 24, 2010

The extraction results obtained through three algorithms showed that the improved spectral angle mapper algorithm could better extract the objective in comparison with Fig.1. and Fig.2., and then the minimum distance algorithm, finally support vector machine (SVM) method.

B.Accuracy analysis

The accuracy evaluation of classification results is a measure of whether classification result is available. Confusion matrix is one of the methods researchers often use. The commonly used evaluation indexes included overall accuracy, kappa coefficient, commission, omission, cartographic accuracy and user accuracy [9]. The accuracy results were shown in table I, table II, table III, and table IV.

TABLE I THE RESULT ACCURACY BASED ON CONFUSION MATRIX ON MAY 17,2010

Class	Oil-thick	Oil-thin	Water	Total
Other	0	0	0	0
Oil-thick	1054	38	56	1148
Oil-thin	22	1085	0	1107
Water	0	12	947	959
Total	1076	1135	1003	3214

Overall Accuracy=(3086/3214)= 96.0174%;
Kappa Coefficient =0.9402.

TABLE II THE PRECISION RESULTS BASED ON COMMONLY USED EVALUATION INDEXES OF CONFUSION MATRIX ON MAY 17,2010

Class / Accuracy	Oil-thick	Oil-thin	Water
commission	8.2%	1.99%	1.25%
omission	2.04%	4.41%	5.58%
cartographic accuracy	97.96%	95.59%	94.42%
user accuracy	91.80%	98.01%	98.75%

TABLE III THE PRECISION ANALYSIS BASED ON CONFUSION MATRIX ON MAY 24,2010

Class	oil-thick	oil-thin	water	Total
Other	0	0	0	0
Oil-thick	388	110	0	498
Oil-thin	189	558	14	761
Water	10	33	2870	2913
Total	587	701	2884	4172

Overall Accuracy= (3816/4172)=91.4669%;
Kappa Coefficient = 0.8184.

TABLE IV THE PRECISION RESULTS BASED ON COMMONLY USED EVALUATION INDEXES OF CONFUSION MATRIX ON MAY 24,2010

Class / Accuracy	Oil-thick	Oil-thin	Water
commission	22.09%	26.68%	1.48%
omission	33.90%	20.40%	0.49%
cartographic accuracy	66.10%	79.60%	99.51%
user accuracy	77.91%	73.32%	98.52%

It could be seen from table I, table II, table III and table IV, thick oil slick pixels mixed with thin oil slick pixels and sea water pixels, sea water pixels mixed with thin oil slick pixels. Thick oil slick pixels and thin oil slick pixels all belonged to target pixels, so the phenomenon of mixed points between them had no effect on the overall accuracy. Nevertheless, the spectrum curves of thin oil slicks and sea water were similar, it was easy to have a phenomenon of fault classification, which affected the extraction accuracy.

The extraction accuracy used improved spectral angle mapper algorithm was up to 90%, kappa coefficient was above 0.90. The results prove that the approach is effective and feasible at some level, which could provide technical support for oil spill governance and environment dynamic monitoring of marine disasters.

VI. CONCLUSION

This paper carried on oil spill detection in the Gulf of Mexico based on MODIS data. It chose two images with a resolution of 500m according to predecessors' research experience, and added texture feature-mean to origin bands. This improved approach could better extract the oil spill objective. Meanwhile, it also compared the extraction results with minimum distance algorithm and SVM algorithm, the accuracy of extraction results using improved spectral angle machine could be up to 90%, which met accuracy requirement, and could provide technical support for oil spill spread trend and governance. Simultaneously, it could realize the oil spill disaster dynamic monitoring to some extent in view of the MODIS data update fast.

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