The Development of Marine Oil Spill Operational System Based on GIS

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***Abstract*—With the rapid development of the oil industry and oil transportation, oil well blowout and marine oil spill accidents ca • used a lot of environmental damage in recent years, so there is a growing demand for oil spill disaster emergency response. It is difficult to monitor oil spill by conventional ways in real time due to the large range of oil spill, so remote sensing technology becomes the most effective means for oil spill monitoring, and as a spatial information processing means, GIS can extract oil spill monitoring information and make the products in a way of assembly line. But remote sensing image processing and GIS spatial analysis involve two separate disciplines. They relate to different softwares or complex operations, and the users should be trained in professional knowledge. This article introduces how to integrate the remote sensing functions and GIS platforms seamlessly. Based on GIS, we establish the operational monitoring system on marine oil spill, which realizes monitoring data processing, information extraction, product outputting, probability statistics and brief publishing etc. This article mainly solves how to package RS algorithm library and organize data. Also, it aggregates mass irregular oil spill spots and smoothens the target in a new way, and analyzes the ocean flow field. We design a simple and automatic processing procedure which is called one-key processing, and oil spill monitoring works more effectively and accurately in this way. The system is on trail in the operations department and reaches the level of operational application.**

***Index Terms*—algorithm package; monitoring of marine oil spill; probability statistics; operation production**

I. INTRODUCTION

A. Background

With the development of industry, marine pollution is becoming more and more serious. Oil spill pollution from ships, petroleum platforms, and wars becomes one main type. Of all the marine pollution, marine oil spill pollution is in the first place on the occurring frequency, distributing area, polluting level, and the influence [1]. At the same time, the oil spill would lead to a wide range of fire easily, which threatens ships and Marine facilities. Therefore, it is important to carry out the monitoring of oil spill quickly and efficiently, and publish disaster monitoring and spatial statistics information timely and regularly for pollution treatment and marine ecological environment restoration.

B. Previous Related Work

To meet the urgent need of Marine oil spill surveillance, domestic and foreign scholars have carried out researches in many aspects. The traditional marine oil spill monitoring tools include closed-circuit television, photographic monitoring system and fixed-point monitoring sensor etc. But they are not suitable for a large range and all-weather marine oil spill monitoring. Remote sensing technology is the best means for a large range of regional observation. It can give full play to its advantages faced with large-range and dynamic information. Maged Marghany (2001) has analyzed on the strait of Malacca 1996 leak of oil spill accidents using SAR image[12][13]. Solberg etc. (1996,2003,2007)[14] who use ERS-1/2, ENVISAT and Radarsat on Beihai and the Baltic Sea monitor and gradually carry out the study of the oil spill automatically in Norway. Ivanov (2002)[18] shows that RADARSAT can successfully detect oil spill distribution information with the research of oil spill pollution about the Yellow Sea . Domestic scholars and foreign experts analyze oil spill monitoring by means of remote sensing and achieve good effects.

GIS has powerful ability on organizing, displaying spatial data, producing all kinds of thematic products, and counting and expressing the results of spatial analysis. It can express the shape and location of the oil spill spot, and it is convenient to analyze the oil spill spot

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information and make thematic products. It's effective to pro-process oil spots data, and do oil spill probability analysis and business products outputting at the same time while combining remote sensing image processing module and the GIS spatial analysis.

Remote sensing image processing and GIS spatial analysis require professional software platforms and operation staff. But they are two different disciplines. At present, there is no special integration platform for oil spill remote sensing and GIS at home and abroad, so the whole process of monitoring and processing is very complex.

This article integrates remote sensing and GIS. It embeds remote sensing image processing algorithm into GIS platform to build the oil spill monitoring system, which analyzes the problems of image processing and GIS spatial expression. It explores monitoring of the marine oil spill and the business results outputting model.

II. Application Analysis

This paper aims to study the integration algorithm of remote sensing image processing on the platform of GIS. It also researches on the one-key business processing technology of oil spill information extraction and products producing with GIS components.

A. Development Mode

In order to simplify the business operations and make it convenient for non-professional personnel to deal with remote sensing image, this paper embeds GIS spatial analysis expression module, encapsulates remote sensing image processing algorithms to DLL(Dynamic Link Library), and finally integrates different functions on .NET platform.

A lot of tools are developed to deal with remote sensing images, and many open source organizations are engaged in this work. So some routine functions can be directly achieved combined with their results. This article uses GDAL to do conventional remote sensing image processing. GDAL is the Open Source library dedicated to process remote sensing images. It can read, display and project images etc. As the components in this article are based on C# environment while C# is not compatible with GDAL, this article encapsulates GDAL remote sensing image processing algorithm to DLL in C++ environment then invokes it in C# environment.

ArcGIS Engine is a major component GIS, so this paper uses ArcGIS Engine as GIS integration environment.

B. Research Contents

The research contents of this paper mainly include three parts. Firstly, the remote sensing image processing algorithm is analyzed, and the algorithm of reading data, projection transformation, filtering and format conversion of remote image is encapsulated using language of C++. Secondly, the remote image algorithm is invoked and integrated in the GIS environment. The remote image is pre-processed and the flow data is analyzed, rendered and homogenization treated. Thirdly, the extraction result of remote sensing image is processed from the perspective of GIS. It improves the accuracy of the extraction of oil spill information. The main approaches are as follows. The artificial interactive selection and corrosion expansion algorithm are added. Oil spill probability statistics algorithm is designed and implemented based on the results of the extraction of oil spill, . Considering the needs of business, one-key production module is designed for special productions.

a) Image data preprocessing

The original RS image has a lot of noises and false information and the default coordinate information does not match with GIS, so image pretreatment is required. This article invokes the encapsulated remote sensing image processing algorithm to do radiation correction, enhanced Lee filter, geometric correction and morphological processing and so on. All the work is to eliminate noises and false information to match the image with GIS spatial data.

b) Comprehensive information extraction and processing in GIS

The remote sensing image after pretreatment has a lot of false information, so the computer cannot identify the suspected oil spill directly. It should be interactively selected as a matter of experience by the users. The extracted oil spill information is raster data, and it cannot be selected directly. In this paper it is transformed into vector data and directly overlaid with the original image. The users click on the overlaid vector data based on professional knowledge to simulate the screening of raster data.

The suspected oil spill spots distributed irregularly and edges are serrated obviously. It can not meet the practical needs. It is the problem of the algorithm itself. It is difficult to correct the remote sensing information extraction algorithm , so this article improves the result of remote sensing image information extraction from the perspective of GIS by the way of aggregating, corroding, expanding and reconstructing the vector oil spill area. It realizes the deep combination of remote sensing and GIS.

c) The analysis and expression of Marine flow field

The ocean flow field is the key factor that affects oil spill drift. It provides an important basis for grasping the development trend of marine oil spill to understand the flow field information around the oil spill. The sea flow field information used in this paper is based on the numerical simulation of ocean. It cannot be directly expressed in GIS, and needs to be parsed. In order to be consistent with the traditional expression of marine flow field, this paper makes a field symbols to render the data. Aimed to solve the problem of low efficiency in displaying the dense flow field data, data sparse algorithm is designed in this paper to enhance the data display effect.

d) The probability and statistics of oil spill based on GIS

In order to remove the false oil spill area, oil spill

probability statistical algorithms is designed in this paper. This algorithm is based on the extracted suspected oil spill. It is designed with multi-parameters, multi-levels, multi-factors and multi-custom weights after considering the spatial relationship especially the distance factor between oil spill area and the surroundings where oil spill may occur. This article counts the oil spill probability and to get oil spill information timely for business department we store the statistic information .

e) Business production

The real-time monitoring information of oil spill should be released timely. In this system, the real-time oil spill information, statistical reports and thematic map, etc. are inserted into the outputting template to generate oil spill monitoring brief. Statistic form and thematic map are generated automatically. This paper designs the method of thematic map outputting and the related decoration including adaptive algorithm of drawing graticule, etc. Figure 1 shows the system function structure.

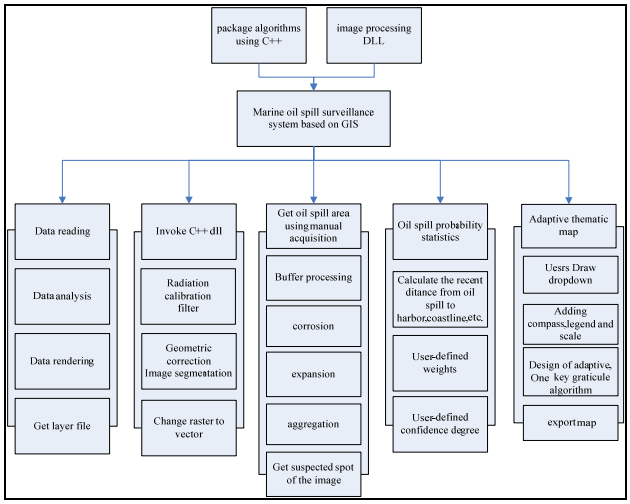


Figure 1. The system scheme.

III. System Design and Implementation

The oil spill monitoring business system is based on GIS mainly designs processing algorithm of the seamless integration of remote sensing images in the environment of C# language. It can combine, make oil spill spots smooth, analyze and express the flow data. This system also gives the functions of the oil spill probability and the key technology of one-key business monitoring displaying and products exporting.

A. Remote Sensing Image Processing Algorithms Package

It is difficult for general users to process remote sensing image. It needs professionals to process it using professional software because of its complicated steps. This article uses the open source GDAL library to process remote sensing image. While its operating platform supports for c ++ better and is more compatible. This article integrates the remote sensing image processing algorithm which has been realized by C++. This method not only combines the advantages of both languages but also shows the complementary advantages of GIS platform and RS technology.

Firstly, to eliminate the factors like radiation distortion which influences image quality, this article applies radiometric calibration to the original image. We use method of open-window median filter to process the image. In order to match the GIS spatial information, a geometric correction is applied. To outstand some certain information, image enhancement and morphology processing are done to the RS images.

These functions require the user to identify parameters. If users set them interactively, the processing is discontinuous. According to the actual business requirements, this article sets the parameters with empirical values to make sure the system runs automatically. The empirical values can be interactively adjusted as needed.

B.Extracting and Processing Oil Spill Information

The oil spill spots with false information should be screened semi-automatically with professional knowledge. In this paper, experts filter the suspected oil spill spots with remote sensing image as the background.

The oil spots information extracted from remote sensing monitoring data is raster data which cannot be directly and interactively filtered. Therefore, the interface called *IConversionOp* of *ArcEngine* API is used to deal with raster data. The interface named *RasterDataToPolygonFeatureData* is called to convert the raster data into vector data. Then the vector data is set to transparent and overlies over the original image. Taking advantage of the functions of GIS vector selection, users can interactively click on the location of the oil spill to select the vector data automatically which can simulate the function of raster patch selection.

The oil spill spots extracted by remote sensing image processing algorithms have a lot of irregular edges and broken features. They are not consistent with the real situation, and it is hard to correct the algorithm itself. Based on the GIS polygon processing algorithm, this article designs functions including polygon corrosion, expansion, and division operation. In order to reduce the saw tooth phenomenon, we also do aggregation processing for scattered patches, and smooth processing for borders. Broken patches change into smooth edges after the above processing as figure 2 shows.

We use the tool of Geoprocessor and methods including *Buffer*, *MultipartToSinglepart*, *AggregatePolygons* and *Union* to deal with edges of polygon provided by ArcEngine API.

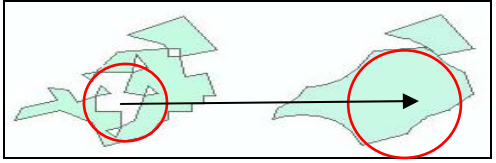


Figure 2. The effect of oil spill extracting

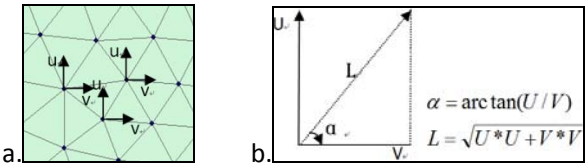
C.Flow Field Data Analysis and Expression

There is no direct correspondence between GIS spatial data and ocean flow field data and therefore it can't be read by GIS before it is analyzed**.** Flow field data is the result of numerical model calculation. It needs to be changed into the format supported by GIS, and its expression way should be established at the same time. This paper changes the flow field data into GIS vector data, and expresses it by the graduated arrow symbol.

a) The flow field data conversion

The ocean flow field data is stored into the format of NETCDF where its structure is not simple but complex and provided by people from professional domain. It is a field of triangulation which its scale becomes smaller and smaller from far to near. The arrow in each triangle vertex is formed by vectors of U and V which says its direction and speed. This article converts the form of triangulation vector U and V into GIS point data and its speed and direction are stored in GIS attribute field. The center of each triangle represents the area position, and the average value of the three vertices represents the flow velocity and direction of this triangle area. So flow information is converted from the aspect of space position, dynamic and shape, etc.

Using java class library named *NetcdfFile* to realize reading and analyzing flow field data. The variable named Variable saves file information and the Index saves variable index number.



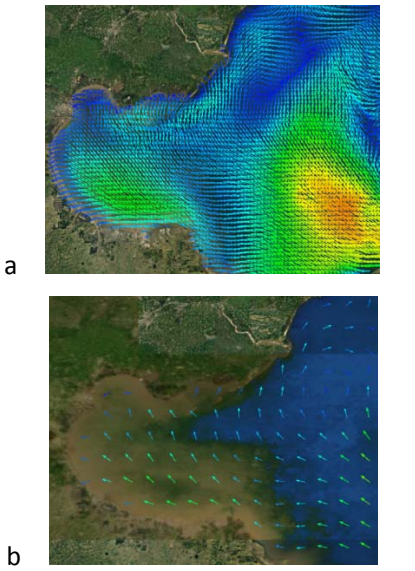
a. scheme of vector and V b. formula of flow expressing

Figure 3. The formula of expressing U and V

b) GIS expression of flow field

This paper designs the display symbols of ocean flow field, expresses flow velocity as a vector length of the arrow. We use the angle to express arrow directions and at the same time it can reflect the change trend of the whole flow field with color rendering.

Flow field data is displayed largely and densely in GIS with poor display effect. This paper designs the algorithm which helps to show the data dynamically and uniformly. The principle of algorithm is to divide flow field into some intervals as different scales and to invoke the corresponding arrow intervals in different scale to display flow field. So we can simulate continuous variation in the form of segmentation. Figure 5 is the result of flow field expressing. It invokes the method of *LayerDefinition* to realize how to make the density thin in the *IGeoFeatureLayer* interface and the method of Renderer is to realize how to render.



a. result of expressing b. result of homogenization

Figure 4. The effect of flow expressing

D.Oil Spill Probability Statistics

For the fact of that oil spill is closely related to ports, waterways, drilling platforms and other factors, so the article studies the relationship between ocean environment elements and oil spill, designs oil spill probability statistics algorithm which has the characteristics of multi-parameters, multi-ranks, multi-factors and custom weight.

a) Oil spill probability statistics

Firstly, this paper regards ports, waterways and drilling platforms as the impact factor. Secondly, we calculate the distance between oil spill areas and the impact factors. At last we count the probability of oil spill areas after setting the weight. We define the distance as H between the central point of oil spill areas and channel, the port distance as G, the drilling platform distance as Z, the influence coefficient as X (A/B), and the effect of weight as M/L/N. Oil spill probability statistics algorithm is as follows (1).

$$W = H * X * M + G * X * L + Z * X * N \quad (1)$$

b) Property information of oil spill areas

This paper stores the data information of oil spill areas in vector data table. In order to calculate the distance between oil spill spot and the influence factors, we need to calculate the position of the center point of oil spill area and determine the nearest point of the target element.

For the channel and the drilling platform, we obtain the center point as computational object. The ports usually have large spatial range and occupy long coastlines. The coastline is linear element and it has a changeable shape, so it's not easy to calculate the distance between center point of oil patch and the coastline. In this paper, we use the shortest distance between points to instead of the distance between points and lines. It is used to convert line elements into point elements in GIS ways, via bubble

method to gradually iterate through the distance between the center point of oil spill area and linear point sets. Above all, we can get the closest point.

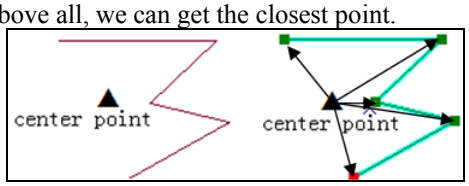


Figure 5. Calculations of closest point

E. Expressing of the Operation Results by One-key Method

Traditional expression of operation results needs a operator to draw the map of monitoring results by hand, which is time consuming, laborious and inaccurate. The paper designs one-key type operation processing module. If the user specifies an output range, the system will generate thematic map and adds to the report automatically. Above all, it realizes the rapid generation of brief.

a) Thematic maps output

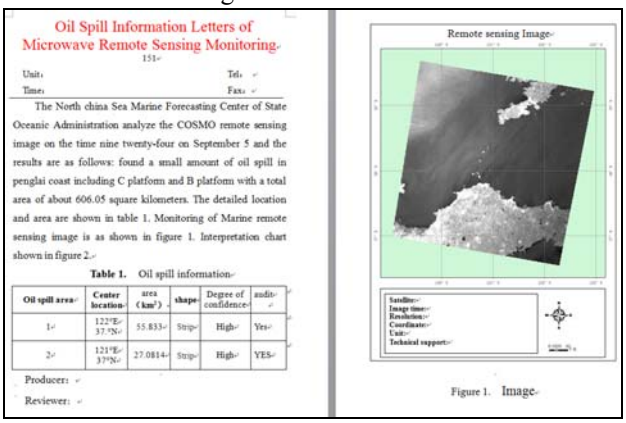
The thematic map functions provided by GIS software have so many limitations that it can't quickly get the extent of maps output, and the mapping elements need to be manually adjusted the position. So it is not accurate. In addition, the latitude and longitude lines are not beautiful which its intervals can be too sparse or too dense. This paper is to solve the above problems, focusing on the design of adaptive graticule drawing function, realizing automatically and intelligently drawing of maps extent, grid lines and annotations.

The key technology of grid map is to confirm interval value of adjacent grid. In this paper, according to the experience of maps output, we control the grid line numbers roughly as about 3-5. According to the exporting map extent, we obtain the average interval of grid. In order to beautify the map, usually we round the interval value. For example, intervals including 1.01, 0.49, and 0.123 should be changed into 1.0, 0.5, and 0.125. So according to the actual situation, we adjust intervals dynamically. This paper sets the piecewise intervals, gets the integer and mods of interval dynamically.

b) generatION of Oil spill brief

It needs to manually insert the oil spill information, header, thematic maps and other relevant information into brief for traditional oil spill report. This method has low efficiency and it is easy to make mistakes. In this paper, we study the output model of oil spill report, and define custom output templates of marine oil spill monitoring. The brief contents are computed automatically before inserting into it without manual interaction.

It needs to insert making time, producer, output time and other basic brief properties. At the same time, it also needs to insert the probability statistics information of suspected oil spill area. Combined with statistics map of oil spill and oil spill thematic map, the oil spill standard template format is completed. The Software generates brief based on this template automatically. The basic word document class named *Application* is used to realize to operate document element in the software. The interfaces named *Range*, *Bookmark* and *InlineShape* respectively, has realized the function about bookmark location and inserting element.


Oil Spill Information Letters of Microwave Remote Sensing Monitoring

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Unit: Tel:
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The North china Sea Marine Forecasting Center of State Oceanic Administration analyze the COSMO remote sensing image on the time nine twenty-four on September 5 and the results are as follows: found a small amount of oil spill in penglai coast including C platform and B platform with a total area of about 606.05 square kilometers. The detailed location and area are shown in table 1. Monitoring of Marine remote sensing image is as shown in figure 1. Interpretation chart shown in figure 2.

Table 1. Oil spill information

Oil spill area	Center location	area (km^2)	shape	Degree of confidence	audit
1	122°E/37°N	55.833	Strip	High	Yes
2	121°E/37°N	27.0814	Strip	High	YES

Producer:
Reviewer:

Remote sensing Image

Satellite:
Image time:
Resolution:
Coordinate:
Unit:
Technical support:

Figure 1. Image

Figure 6. result of business product

IV. CONCLUSION

The GIS-based oil spill monitoring system built in this paper encapsulates the RS processing algorithm, and invokes it on the platform of GIS. In this system the suspected oil spill areas can be screened based on man-machine interaction that improves the screening accuracy. Oil spill probability statistics algorithm is designed to consider the weight of environment around the oil spill areas. A one-key producing module is designed based on templates after studying the products of some relevant departments. The system in this paper is on trial, and it has improved the business level of oil spill monitoring. The method of making thematic map and the idea of one-key producing module can provide some technical help and advices for other similar spatial information expression and analysis system.

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