Research on the Open Source GIS Development Oriented to Marine Oil Spill Application

Ruifu Wang
Geomatics College, ShanDong University of Science and Technology, Qingdao 266510, China
Key Laboratory of Surveying and Mapping Technology on Island and Reef, SBSM, China;
Email: wangruifu@263.net

Nannan Liu, Maojing Xu and Xiangchao Kong
Geomatics College, ShanDong University of Science and Technology, Qingdao, China
Email: {liunannan_89@126.com, xumaojing0417@163.com, kongxiangchao9913@163.com}

***Abstract*—With the frequent occurrence of marine oil spill and the serious environmental pollution as well as enormous economic losses it causes, there is a growing demand for oil spill emergency response. It becomes a trend to research on spatial information analysis and publishing based on GIS. Compared with the expensive and system-huge commercial software, open source platform which is free and small-scale is becoming a new choice. This article develops the marine oil spill monitoring information analysis & publishing system based on DotSpatial, the upgrade version of the open-source .NET development of component library. In this system, the monitoring information of oil spill is visualized, rendered, analyzed and finally published on the web. However open source GIS is functionally limited and instable. DotSpatial can not read the spatial information of RS images well and the mapping module is unstable. This article solves some technical problems. For example, the spatial data is processed such as re-projected via GDAL to match the images layers with the vector layers. Vector oil spots data is generated and rendered, and the major axis and minor axis are drawn. Moreover the map extent to output can be determined by dragging a rectangle using GDI+, and the decorating of the map to putout is also improved. By adopting several developing methods comprehensively, this paper researches on the marine oil spill application oriented system development based on open source GIS. It provides references for other similar system researches and developments of spatial information expression and analysis.**

***Index Terms*—open source, GIS, oil spill, DotSpatial, monitoring information**

I. Introduction

A. Background

Marine oil spill occurs frequently in recent years, and it leads to serious pollution and enormous economic losses. After the outbreak of the disaster, the managers and the public should be informed of the degree and the extent of the disaster, so it's very important to publish the monitoring information and the spatial statistical result regularly and timely[1][2][3][4]. GIS is powerful in spatial analysis, it's often applied to the statistics of disaster distribution, area and some other spatial information.

GIS was being applied widely to various fields since it came into being in the 1960s. The commercial software which meets the demand of every industry is comprehensive in function and high in price. So it's not suitable for those functional single GIS applications.

It's just a little part of GIS to analyze and publish the oil spill monitoring information, and the commercial software cost much additionally. It's a new trend to develop systems based on the platform of open source GIS. Open source GIS means that the developers can release the source codes of the software according to some protocol, and also allow others to download, modify, apply, and release the codes on the premise of following the protocol [5]. It's best characterized as being free, but not so powerful in functions.

We use the platform of MapWinGIS/DotSpatial, the open source development component library, to develop our marine oil spill monitoring system.

This paper explores the oil information analysis and publishing system based on open source GIS, gives the corresponding solutions to some problems of open source GIS software.

B. Previous Related Work

With the development of GIS, more and more scholars and related researchers around the world choose GIS as the platform for marine environmental monitoring and emergency response. GIS does well in spatial visualization, spatial analysis and statistical mapping. It provides real-time information for decision-aid in marine accident response.

Yancheng Liu from Dalian Maritime University in China established the mathematical models of marine spilled-oil's transportation, spreading, evaporating and

Corresponding author: Nannan Liu.
This work was supported by the Public Science and Technology Research Funds Project of Ocean (No. 201205010-4).
An earlier version of this paper was presented at the 21st International Conference on Geoinformatics.

doi:10.4304/jsw.9.1.116-120

emulsification processes aimed at problems of marine oil spill crisis response. It can be the scientific bases of oil spill response decision making [6]. Long Ye from Shanghai Maritime University in China developed the system of contingency resource allocation and transport for dealing with the oil spilling accidents at sea, to research on the integration of the contingency plan and the resource allocation and transport [7].

In addition, a great number of researchers around the world reply RS technology together with GIS to the marine oil spill accidents, for example, to monitor, analyze and map the oil spill extent and its moving trend.

Our maritime workers have begun to utilize RS technology to monitor oil spill. Professor Ying Li monitored the oil spill occurred in Mexico based on a series remote sensing images and GIS technology. It's very helpful in cleaning and controlling the oil slicks [8]. Lei Bing, the engineer from Yantai oil spill response technical center of China maritime safety administration, developed a satellite remote sensing system for maritime application based on the integration of RS and GIS [9]. In Canada, H. Assilzadeh & Y. Gao from Department of Geomatics Engineering Schulich School of Engineering, the University of Calgary presented a method using SAR image and GIS technology applications for oil spill management in coastal area in their paper, mainly including extracting coastal oil-spilling information, predicting the movement and creating map products from various analysis aspects [10]. Mira MOROVIC from Croatia and Andrei IVANOV from Russian said that SAR together with GIS can significantly improve identification and classification of oil spills. Their method is used to product oil spill distribution maps [11].

Being aware of the advantages of open source platform, more and more people began to research on marine GIS based on it. Xiantao Li from Zhejiang University in China put forward a network three-dimensional visualization system of marine information under the open source stack [12]. Ei Fujioka et al. work on advancing global marine biogeography research with open-source GIS software and cloud computing [13]. However, it's hard to find researches on marine oil spill with open source GIS.

II. Application Analysis

This article aims at researching on the visualization, statistics and publishing of the oil spilling monitoring information based on open source GIS. MapWinGIS/DotSpatial is adopted as the development platform, with GDAL as a complement.

A. Development Mode

MapWinGIS is an open source component which is suitable for small and medium GIS applications. The core is an ActiveX control named MapWinGIS, based on which the developers can add GIS features into their own systems [14]. As the upgrade version of MapWinGIS, DotSpatial is more powerful. It can support more development environment.

GDAL (Geospatial Data Abstraction Library) is an open source library for reading, transforming, and editing the raster spatial data [17]. Many open source software and even commercial software are based on it. It has its own data models and APIs, and provides a series of command lines to process data.

B. Research Contents

The function of our system includes map viewing, data displaying, rendering, statistic, mapping, bulletins release and some other modules. The core is data display, rendering and mapping.

DotSpatial supports raster data differently from vector data when they are added into the map. Reprojection and some other data processes should be done in order to display them and match them well with each other. In our system, vector oil spots data is transformed from the raster monitoring data, then it's rendered, numbered, and major axis and minor axis of every spot are drawn. These can help show the disaster and its development trend clearly. For mapping the oil's spilling extent with other related information, users drag a rectangle to define the extent. Then the result bulletin is published as a web page. Figure 1 shows the scheme of the system.

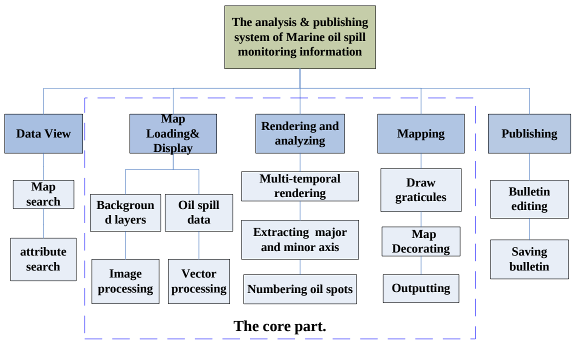

Figure 1. The system scheme.

III. Key Problems and Technologies

While developing the analysis & publishing system of marine oil spill monitoring information, there exist several problems in spatial data matching, data transforming, vector data rendering, mapping and outputting and webpage designing and making etc. This article gives the corresponding solutions to some of them.

A. Data Display and Manipulation

DotSpatial does well in manipulating vector data, but weak in manipulating raster data. For example, the data size should be limited below 40M, as larger images can not be added into the map. DotSpatial can not read the coordinate system information of raster data well, because it can only read the coordinate system of proj4, and it's always different from that of the vector data.

Moreover, DotSpatial can not stretch the image added into the map automatically, thus the image can not reflect the differences between grids if the spatial distribution of the grid values is irregular.

The data used in this paper is an ENVISAT SAR image, and its size is always over 100M. So we use GDAL to resample, reproject, and stretch it before adding it into the system. The file size is reduced to less than 40M by resampling. To match the SAR image with the vector map layers, the projection is implemented by GDALWARP, an API of GDAL for image transformation. Pixel value is stretched to statistic the value distribution. To enhance the visual effect, the pixel value is converted to a grey range of 0~255 in this system.

B. Vector Information Extraction and Rendering

For the oil spill analysis, some responding algorithms are designed to extract the spatial structure of the oil spots, compute the attributes and render the multi-temporal data.

IV EXTRACTION OF OIL SPOTS SPATIAL STRUCTURE

The spreading trend of oil spots can be found in its shape. But the shape of every spot is always irregular. In order to show the movement and the change of every oil spot in long time series, the area, center point coordinate, major axis and minor axis and their breakpoint coordinates .etc should be calculated to represent the spatial structure.

The oil data transformed from RS image is raster data, which is unfit for spatial structure information statistic. So we transform it into vector data that is good at representing the spatial structure of every spot. DotSpatial does not have this function, so we use GDAL to transform the oil-spilling extents in the SAR image into polygon features.

The major axis of an oil spot is the line segment between two nodes which is the most distant from each other in the polygon boundary. The minor axis is the line segment perpendicular to the major axis and clipped by the polygon boundary. The mutually perpendicular major axis and minor axis together build the basic skeleton of an oil spot (Fig 2, Fig 3)

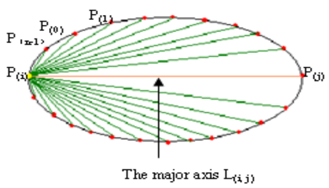

Figure 2. The major axis.

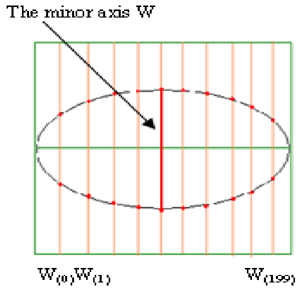

Figure 3. The minor axis.

Suppose the number of the nods of an oil spot is n ($P_{(0)}$, $P_{(1)}, \cdots, P_{(n-1)}$). Link every nod with every other nod, we can get the line segments as follows:

$$
\begin{array}{cccccc}
L_{(0,1)} & L_{(0,2)} & L_{(0,3)} & L_{(0,4)} & \cdots & L_{(0,n-1)} \\
 & L_{(1,2)} & L_{(1,3)} & L_{(1,4)} & \cdots & L_{(1,n-1)} \\
 & & & & \cdots & \\
 & & & & & L_{(n-2,n-1)}
\end{array}
$$

Suppose the longest one is the line between P (i) and P (j), then L (i, j) is the major axis (L) of the spot. Divide the major axis line into 200 equal parts, and draw the line segments perpendicular to the major axis at every dividing point and clipped by the polygon boundary. There may be more than two intersection points of every line segment and the polygon boundary due to the irregular shape of the polygon. In this case we draw the line between the farthest two points. At last, we choose the longest one from the 200 line segments as the minor axis of the oil spot (W).

V MULTI-TEMPORAL RENDERING

Multi-temporal data reflects the characteristic of the data in time series. The oil spots in the sea are always moving and changing influenced by wave, wind and some other factors. It’s important for disaster managers to grasp the moving and changing trend of them. For this reason the oil spots need to be multi-temporal rendered. As the spots interpreted and transformed from RS images have differences in confidence due to several reasons, we should express the differences at the same time.

DotSpatial does not have the function of multi-temporal rendering. A rendering scheme is given in this paper which combines color filling and pattern filling to render the spots. Oil spots at different dates are filled with different colors and different patterns to distinguish each level of confidence. There are four levels of confidence including high, medium, low and non-confidence in this paper. We mark them respectively with vertical, backward-diagonal, horizontal, and point styles(Fig. 4).

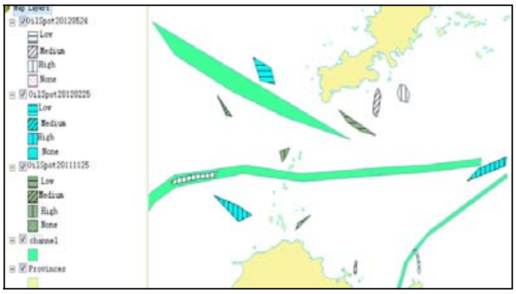

Figure 4. The result of multi-temporal rendering.

VI. Thematic mapping

The mapping module of DotSpatial provides a series of controls and APIs, such as LayoutInsertToolStrip, LayoutDocToolStrip and LayoutMapToolStrip etc. But it's still insufficient due to its instability and the spatial needs in this paper. For example, it can not draw the graticules, the scale bar and the legend controls do not work some times, and it does not allow user to specify a range by dragging the mouse etc.

Following the basic rules of mapping and decorating [18], mapping the monitoring information of oil spill is improved based on DotSpatial and Windows GDI+. Through Windows GDI+, the users can use the mouse to drag a rectangle as the output extent. The system draws the graticules by calculating the coordinate values and then drawing line elements together with text elements as labels. While decorating the map after determining the output extent, the scale bar and the legend controls of DotSpatial do not work due to the instability of open source platform. Therefore we group different elements to fabricate the scale bar and legend for our own needs. This program not only compensates for the controls of DotSpatial, but also makes the map rich and varied.

VII. Conclusion

This article explores the marine oil spill application oriented system development based on open source GIS. The system realizes data matching and displaying, information abstraction, rendering and attributes calculation, the information mapping and result publishing etc. Because of the imperfection of the open source platform, there exist several problems and difficulties during the development. So we make changes and innovations in the development idea, which combine multiple development platforms and technologies such as GDAL and GDI+, to compensate the imperfect open source GIS. This research may be useful to other similar researches and developments based on open source GIS.

With the increasing popularization of the open source technology characterized by being free, it is becoming a favorable way to analyze and distribute the spatial information. However the open source GIS software is still incomplete in function. If it can get more supervision and controls while distributed to the market, it will be a convenient and economical choice in the development of spatial information system.

Acknowledgment

The authors would like to express appreciations to colleagues in our laboratory for their valuable comments and other helps.

References

[1] Y. Li, G. Lan, B. Liu and D. Chen, "Dynamic analysis on oil spill in Mexico Bay based on remote sensing and GIS," *Marine environmental science*, vol. 31(1), 2012, pp. 80-82.

[2] Y. Jin, D. Xiong and S. Yan, "Research on Marine Oil Spill Tracing and Monitoring System Based on GPS/ GSM/ GIS," *Traffic environmental protection*, vol. 24(6), 2003, pp. 6-8.

[3] B. Peng and F. Shao, "Study of a new method about marine spilled oil detection," China Sciencepaper, < http://www.paper.edu.cn/releasepaper/content/200703-247 >.

[4] J. Jiao, "Research on the prediction of oil spill based on GIS In Bohai Bay," *Marine environmental science*, vol. 30(5), 2011, pp.735-738.

[5] C. Yang, "Open GIS(WebGIS)," *Institute of remote sensing applications Chinese academy of sciences*, <http://wenku.baidu.com/view/c2c4245d804d2b160b4ec0ea.html>,

[6] Y. Liu, P. Yin, J. Lin and J. Zhang, "Prediction of Oil spreading and transport over the sea," *Journal of Dalian Maritime University*, Vol. 28(3), 2002, pp. 41-44.

[7] L. Ye, "System of Contingency Resource Allocation and Transport for dealing with the Oil Spilling Accidents at Sea," Unpublished Master dissertation, Shanghai Maritime University, China, 2006.

[8] Y. Li, G. Lan, B. Liu and D. Chen, "Dynamic analysis on oil spill in Mexico Bay based on remote sensing and GIS," *Marine Environmental Science*, Vol. 31(1),2012, pp. 79-82.

[9] L. Bing, F. Sun, C. Shu and G. Dong, "a satellite remote sensing system for maritime application based on the integration of RS and GIS," *Remote Sensing Information*, Vol. 27(5), 2012, pp. 97-101.

[10] H. Assilzadeh and Y. Gao, "Oil Spill emergency response mapping for coastal area using SAR imagery and GIS," OCEANS 2008.

[11] M. MOROVIC and A. IVANOV, "Oil Spill Monitoring in the Croatian Adriatic Waters: needs and possibilities," *ACTAADRIAT.*, Vol. 52(1), 2011, pp. 45-56.

[12] X. Li, "Study of Service-oriented Web 3D Visualization Based on Open source GIS," Unpublished Master dissertation, Zhejiang University, China, 2011.

[13] E. Fujioka, E.V. Berghe, B. Donnelly , J. Castillo; J. Cleary, C. Holmes, S. McKnight and P. Halpin, "Advancing Global Marine Biogeography Research with Open-source GIS Software and Cloud Computing," *Transactions in GIS*, Volume 16, Number 2, 1 April 2012 , pp. 143-160(18).

[14] J. Sun, "Open source exhibits the charm of spatial information," *Software World*, vol. 11(20), 2007, pp: 84-87.

[15] C. Liu and L. Chen, "GDAL Multi-source Spatial data Access Middleware," *geo-spatial information*, vol. 9(5), 2011, pp: 58-62.

[16] A. Dang, “Some topics on the standardization of the thematic maps,” *Developments in surveying and mapping*, 1987, (6): 23-27.
[17] W. Li, X. Liang and J. Lin, “Mathematical Model and Computer Simulation for Oil Spill in Ice Waters Around Island Based on FLUENT,” *Journal of Computers,* vol. 8, NO. 4, 2013, pp: 1027-1034.
[18] L. Qin and J. Zhang, “Development of Dangerous Source’s Monitoring, Management and Emergency Rescue Decision-Making Support Information System,” *Journal of Computers, Journal of Computers,* vol. 6, NO. 4, 2011, pp: 732-739.
[19] A. Muhammad and N. Tripathi, “Evaluation of OpenID-Based Double-Factor Authentication for Preventing Session Hijacking in Web Applications,” *Journal of Computers,* VOL. 7, NO. 11, 2012, pp: 2623-2628.