Online Generation and Dissemination of Disaster Information Based on Satellite Remote Sensing Data

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Abstract. This paper aims to introduce a system framework for online generation and dissemination of disaster information based on satellite remote sensing data, that is, the design and application of the WEB-based Disaster Monitoring and Warning Information System – WEB-DMWIS. By integrating the satellite remote sensing data, scientific workflow technique, and the Application Service Provider (ASP) service model, WEB-DMWIS makes it possible for different levels of users to access customized disaster information via WEB. In this way, it provides an information platform which supports widely-used near real-time monitoring and early warning of natural disasters. The system is composed of two parts: (a) a user-side browser; (b) a server-side disaster information center. After introducing the system framework and functions of main engines, this paper described in detail the principle and realization of the online generation and distribution of disaster information. In addition, the disaster monitoring and early warning information system for fishery industry in Pearl River Delta region is developed on the basis of the WEB-DMWIS to verify and demonstrate the effectiveness of the framework.

Keywords: Disaster Monitoring, Online Generation, Online Dissemination, Satellite Remote Sensing.

1 Introduction

During the last 10 years in last century, a large number of satellites carrying multiple sensors (visible, infrared and microwave) have been launched and applied, which makes it possible to monitor the land, the ocean, the atmosphere, and the ionosphere day and night, and rain or shine[4]. The data from these satellites on natural environment, economic development and human activity have played a great potential in the monitoring and mapping of loss due to various natural disasters (earthquakes, landslides, floods, volcanoes, cyclone / hurricanes, harmful algal blooms, water quality, oil spills, dust storms, droughts, etc.)[5, 8]. Satellite remote sensing data have also

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been used to analyze and understand the reasons and impacts of the disasters. In a word, satellite remote sensing data have become the main data base for the monitoring and early warning system of natural disasters thanks to their large spatial coverage, relatively quick data access and update, long-term time series and relatively high spatial resolution. It can be said that at present remote sensing data have been hardly unused in the process of monitoring and assessment of any serious natural disasters [13]. Natural disasters usually happen suddenly and have extensive impacts. Therefore, the speed and interactivity of the system must be taken into consideration when a natural disaster monitoring, early warning and decision-supporting system is developed, in order to generate the disaster information in a prompt and timely manner as well as to disseminate the information to users at different levels for their convenience. It is clear that the WEB is the supporting platform which meets these requirements and has been generally accepted and widely used [9, 15 and 19]. It has exercised immense influence in our work and life. In fact, with the development of IT and demonstration system, plus the double promotion of technology and demand, the WEB technology is now becoming more and more mature and widely accepted in the management and application of satellite remote sensing data [7, 16, 17 and 20].

However, there are few systems which can realize the online generation and distribution of disaster information based on satellite remote sensing data. The WEB has been playing a significant role in query and access to satellite remote sensing data. The major centers of satellite data processing and distribution in the world have set up their own data distribution websites [10, 11 and 14]. Through these websites, users can select data by interactive parameter setting and data preview images. In addition to providing Level 1 products, these websites also focus on the processing of some Level 2 and Level 3 products which contain some thematic information for users to download. Furthermore, they will also release some detailed pictures of some most serious disasters (such as oil spills and fires) [12, 13] with some analysis and interpretation. However, to generate and dissemination these disaster information, researchers usually use remote sensing data processing and mapping system in an environment without WEB system and then post images about the historical disasters on web with some specific interpretation.

In respect of disaster information visualization, the users' interaction is increasingly supported. Not only the users can preview the image when querying the data, but they can interactively customize the required expression forms. However, the current commercial WEBGIS is unable to provide support because of the complexity of the disaster information retrieval processes and many interactive controls they take. So in the three modules of data management, analysis and visualization, the interactive support of data analysis is hardly realized on the basis of the present network. However, different users care about different space, time and content levels. The visualization forms they require are also different. In this sense, the pre-produced disaster information products might fail to meet specific requirements. Therefore, for the establishment of natural disaster monitoring and early warning information system, it is very important to design and develop a WEBGIS framework which supports users to interactively order the customized disaster information on the WEB-based platform.

In this paper, the design and application of a WEB-based Disaster Monitoring and Warning Information System (WEB-DMWIS)—a system framework-- will be introduced for online generation and distribution of disaster information based on satellite remote sensing data. By integrating the satellite remote sensing data, scientific workflow technique, and the Application Service Provider (ASP) service model, WEB-DMWIS makes it possible for different levels of users to access customized disaster information via WEB. In this way the near real-time monitoring and early warning of natural disasters can be realized. This paper is organized as follows: an overview is presented in Section 2 on WEB-DMWIS including user demands analysis, process of online generation, and distribution of disaster information; the design and implementation of the framework is given in Section 3. Section 4 is a case study of its application. Conclusions and the direction of future development are discussed in Section 5.

2 Overview of WEB-DMWIS

2.1 User Demand's Analysis

With the design and development of near-real-time disaster monitoring and early warning information system which is based on WEB technology and satellite remote sensing data, we aim to start the corresponding disaster information extraction process and generate online customized disaster information according to the customized requests of different levels of users. The system will also map and render images in accordance with the users' requirements, and then dissemination them in near real time to users through the web service. Different users usually care about different disaster information such as disaster information in terms of time, or position, or details? or temporal and spatial scales, or presentation format. Thus, how to describe and organize the requirements of these users and realize the efficient management is one of the most important issues in the process of design and development of the system. In addition, the traditional methodology which completes the information extraction beforehand and then provides pre-processed images for users to download can not meet the customized requirements of users. Therefore, the corresponding disaster information extraction processes in accordance with the users' requirements need to be triggered for online generation and distribution of disaster information. These processes consist of satellite remote sensing data which contain disaster information and a series of necessary data processing, analysis and expression methods to extract and mine information from these data. Managing and scheduling the data and methods so that the disaster information extraction processes can be carried out correctly and fluently are the other two key issues. To conclude, the operation of the whole system is arranged and organized by user requirement management engine, data management engine and method management engine.

In the aspect of remote sensing principle, satellite data used in natural disaster information extraction include not only visible light and infrared data but also microwave data. In the aspect of data level, level 1, level 2 and level 3 data products can all be considered [6]. In addition, different data analysis and visualization methods will have different requirements on data content and data format in the process of information extraction. Therefore, the data management engine should perform the following functions:

- Import and manage various satellite remote sensing data with different spatial resolutions and sources. It is also responsible for data pre-processing, quality control, registration and metadata management. A data model which generalizes all capabilities of various data will be applied to realize the integrated management of data.
- Enquire and gather data required to extract disaster information according to requirements submitted by users. It will then process and combine the data into suitable contents and formats so that they can be provided to information extraction processes.
- Organize and manage the intermediate data generated during disaster information processing. It guarantees the generation of disaster information and automated image rendering.
- Dissemination and manage the final disaster information and images and return them to the users. At the same time, it will update the disaster information database and archive the generated knowledge to history records so that the other users can call them quickly.

Extracting disaster information from satellite remote sensing data is a complex and professional process. Disaster information extraction methodology and modeling have been studied for many years and fruitful results have been obtained. However, most of these methods and models were released in scientific papers and technical reports. Thus, these research results are in a discrete, isolated and static status which can not be efficiently organized into the processes that can be automatically operated [22]. In our system the technology of scientific workflow is introduced. With the establishment of the scientific workflow engine, automatic extraction of disaster information can be realized [1, 2 and 21]. This engine performs the following functions:

- Implement basic functions, such as data preprocessing, analysis and visualization, and modulization of specific information extraction models. It packs the discrete methods and models into functional units which can be used to assemble the disaster information extraction processes.
- Create the workflows of disaster information extraction. It also provides functions such as modifying, editing, saving and loading functions for the workflows.
- Start, monitor and complete the operation of disaster information extraction workflows.
- Query and preview the workflow of disaster information extraction.

The user requirement management engine is the interface between the client-end users and the disaster information service centre. With the management of data flows and control flows, it is responsible to collect users' requirements, staring disaster information extraction process and returning the information at the same time. The user requirement engine established by means of ASP in our system has the following functions:

- Accept the requirements submitted by users, and record their status and submitted services. In this way, the manual for specific tasks can be constructed. It then creates the disaster information extraction task and passes it to the scientific workflow engine for further operation.
- Manage all kinds of status signs during the operation of disaster information extraction so that the interaction and coordination between users and disaster information service centre will be put under control.
- Coordinate and manage various information extraction tasks submitted by different users in the disaster information service centre. Reallocate the resources rationally in order to improve the efficiency.
- Archive and manage the user information and users' queries for statistical analysis of users' usage information so that the services of information center can be adjusted.

2.2 Online Generation and Dissemination of Customized Disaster Information

Supported by the three engines mentioned above, the process of online generation and distribution of customized disaster information in the web-based system contain five steps:

1. Users define the needed services for data, analysis and expression format in an HTML form, and then submit the form through the Internet.
2. The user requirement management engine will search the file history and check whether there are disaster information and image file which meet the user's requirements. If such file is found, it will be used as the result and returned to the user. Otherwise, the data management engine will be arranged to search if there are satellite data matching the temporal and spatial requirements. If such data exist, the user task will be constructed and disaster information extraction process will be triggered.
3. The scientific workflow engine will select the satellite remote sensing data which satisfy the temporal requirement in a specific area according to the disaster information requirements. The selected data will be preprocessed and under quality control. Then relative modules will be called to complete the disaster information analysis and extraction. According to the user requirements in disaster information visualization, the disaster information images will be rendered. Later, the user requirement management engine will be notified for the organization and distribution of the disaster information images.
4. The user requirement management engine will return the disaster information and relative data to the client-end browser. These data will be integrated with the base image and then the custom-built information images can be generated. At the same time, the newly generated disaster information will be saved in form of history data files. User activities will also be recorded in order to analyze the user requirement pattern and thus improve the service quality.
5. Users will browse the disaster information and evaluate the degree of satisfaction with that information. If the result information is satisfying, the users can apply for the acquisition of custom-built disaster information report which contains more detailed information. If the users want to change the interested temporal and spatial

information or visualization format, they can change or tune the settings interactively in the browser. Then the user requirement management engine in the server will reorganize the online generation and distribution of disaster information.

3 Design and Implementation of the WEB-DMWIS

3.1 Architecture of the WEB-DMWIS

In order to realize disaster information online generation and dissemination, we have designed and developed the WEB-DMWIS system as shown in Figure 1. The system is designed into a four-tier architecture:

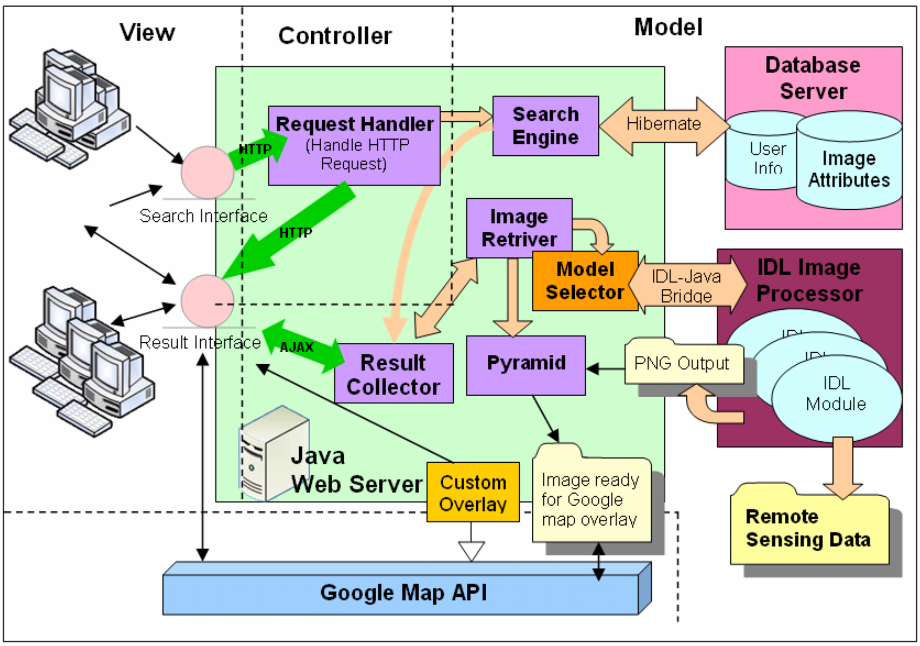

Fig. 1. System Architecture of the WEB-DMWIS

- **View** – the client side which interacts with users directly. It provides interface for parameter inputs and result distribution.
- **Model** – a set of operations that manage the access of the back-end database structure, data collections and other black-box functions with respect to the system. It also handles the object states of the application. Views will send query to models. Models will also notify them when there are object states changes so that corresponding action can be taken in views.
- **Controller** – central collection of all possible queries from the views and choose correct handlers for them. After processing, the controller will dispatch the result to the correct views so that it completes the data flows logically.

- **Google Map API** – a third-party service providing the map service and custom overlay functions. These services enrich the interface in both visualization and manipulation.

3.2 Role of Functional Modules

In this session, the functions in view, model and controller will be discussed.

1) View

Search Interface – collects searching parameters (such as collection date of the data) from users.

Result Interface – shows the searching results by interacting with result collector and Google Map API. It also collects additional image processing parameters.

2) Controller

Request Handler – collects parameters from views. It maintains a predefined list of application behaviors. Such behavior is a specification of which model should be taken to handle a query and which view should be fetched to users after the model finishes processing. Request handler will gather all parameters from the view and pass them to the appropriate model. The model will return its finishing status (if any) to the request handler and the appropriate view will be selected to show the query result to users.

3) Model

- **Search Engine** – all data searching logics are implemented in this model. It will access the database server to retrieve image attributes so that searching can be performed according to the parameters. Searching result will be saved into the "result collector" model. Search engine will notify the request handler whether the search is successful or not.
- **Result Collector** – a special request handling model which handles image processing queries from the result interface. It passes parameters to image processing models and returns the processing result to the view. It maintains a list of searching results.
- **Image Getter** – responsible for monitoring the processing of data in result collector's list according to additional processing parameters gathered from the result interface. Module selector is an auxiliary function which helps image getter to pick up the correct IDL module according to the image processing parameter. Image pyramid will also be arranged in this model. It returns the image attributes, which include the coordinates of north-east corner and south-west corner, number of layers of the pyramid and image path, to the result interface.
- **IDL Image Processor** – a collection of black box functions with respect to the web application which can improve the efficiency in image processing. The IDL module will save the processed images into the location specified by the image getter.
- **Pyramid** – processed image sets in different resolutions. The image generated by the IDL module is too large in size and impractical to be shown in the result interface. Thus, images will be broken down into small pieces when a higher-resolution image is displayed. Pyramid tiles will be saved under the folder which can be accessed by the Internet as well as the Google Map API. This folder location will be returned to the image getter.

3.3 Communication Technologies

In order to realize disaster information online generation and dissemination, four communication technologies have been used in this system to smooth operation of data flow and control flow between the various functional modules. These technologies include:

- **HTTP** – a common communication protocol used between client and web server. It includes client request and server response. Simple query will send HTTP requests or responses through the interfaces.
- **AJAX** – allows web browsers to establish "2-way communication" with the server side and use the server response immediately without fetching to another page. Thus, for example, when the "result collector" returns the image attributes to the result interface, they can be put into the result interface directly instead of opening another interface to show the data.
- **Hibernate** – a Java framework which allows high performance to access the database server by simplifying the model design of database objects.
- **Java-IDL Bridge Connectivity** – a special communication channel established between Java and IDL applications. It is supported by the IDL Connectivity Bridge Library which can export a Java program. This program can call the IDL modules with the functions provided by the Bridge Library's API.

In the next section, we will give a real example of data flow and control flow in the system in application. Because of content limits, the detail of principle and implementation of data model and scientific work flow will be presented in other articles.

4 DMWIS-FIPRD: Disaster Monitoring and Warning Information System for the Fishery Industry in the Peal River Region

Since the early 1980s, the environmental issues have become increasingly prominent with the rapid development of industrialization and urbanization of the Pearl River Delta region. The rivers including the Pearl River are serious polluted. Rivers are seriously polluted, and their water eventually flows into the ocean, which leads to marine pollution. Pearl River is one of them. In its watershed, oil spills caused by well-developed maritime activities such as maritime transport and oil exploitation at sea usually bring large areas of oil pollution, which causes massive death of marine life and leads to enormous economic losses [3]. In order to prevent and reduce the hazards of the harmful algal bloom, water pollution and oil spills on the sea to fisheries and reduce the losses caused by the disasters, we must further enhance marine fisheries and environment monitoring capabilities, as well as major marine environmental disaster monitoring and early warning capabilities [7]. Therefore, a near real-time marine disaster monitoring information system has been developed to monitor the harmful algal bloom, marine environmental pollution and marine oil spills in Pearl River Delta region. The system is designed and developed on the basis of the WEB-DMWIS framework described in Section 2, which consists of two parts, one is browser and the other is server-side marine disaster information center. In our system, the data for operational performance include Moderate Resolution Imaging Spectroradiometer (MODIS) data which contain information of water quality and harmful algal bloom and Advanced Synthetic Aperture Radar (ASAR) data which can be used to detect the oil spills.

MODIS data from the Terra and Aqua satellites of NOAA are received and pre-processed by the Hong Kong Observatory. We are given access to them via FTP within two hours after the satellites pass the region. ASAR data from ESA ENVISAT satellite are received and processed by the satellite ground receiving station at the Chinese University of Hong Kong. In general, the data can be accessed within one hour after the satellite passes the region. The short time delay provides a guarantee for the system's near-real-time disaster monitoring and early warning. To develop the satellite remote sensing data based disaster information monitoring and early warning model, we collected the data of harmful algal bloom and oil spills in the last five years. Besides, 2 in situ measurements were also carried out in the area. Based on these direct and accurate in situ data, the algorithm for water quality parameter extraction, as well as the model for monitoring and early warning of harmful algal bloom and oil spills was developed. The water quality parameters include CDOM (Colored Dissolved Organic Matter), chl-a, TSM (Total Suspended Matter) and CPI (Construction Pollution Index). Similar to the process of generating spatial distribution image of TSM which is shown in Fig. 4, each disaster information extraction process is composed of a series of different functions including data pre-processing, quality control, geometric correction, atmospheric correction, sea and land mask, band algorithm, edge detection, object classification, etc. These processes in the system are organized and operated in form of scientific work flow. The management of scientific work flow is realized by Kepler system in the form of XML file. Kepler is an open-source management system which specifically aims at establishing, operating and verifying the scientific process. For TSM generation process, the establishment and operation of scientific work flow mainly includes the following four main steps:

1. Summarize and parameterize the input and output data for each basic function unit which does data processing, analysis and visualization and for specialized disaster information extraction model. Build the basic function modules of Kepler based on the code realization of the function and model;
2. Build the platform to construct and describe TSM generation process using the visualization flow of Kepler. First of all, establish the information extraction and image mapping and rending, respectively. Then mix these two parts so as to get the disaster information extraction process, which is described and saved in the form of XML file (each XML file includes mission description, component description, flow description and topological relations description.);
3. When a user puts forward the requirement for TSM information generation, as described earlier, while the system runs to interact with IDL (Fig. 2), it actually calls the XML file to implement the corresponding operation, and thus completes information extraction and mapping;
4. When the user gets the information map, he can interactively set up the data stretching parameters and palette if he is not satisfied with the results. According to the user's demand, the management engine will recall the image mapping and rendering module. After that, new maps will be generated online based on the disaster data.

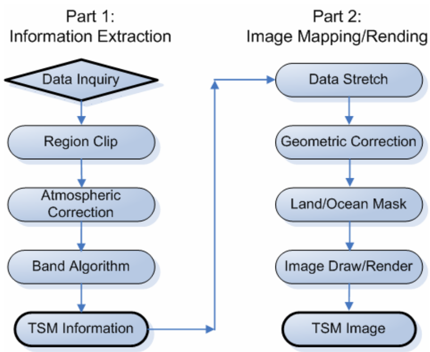

Fig. 2. Process of Generating Spatial Distribution Image of TSM

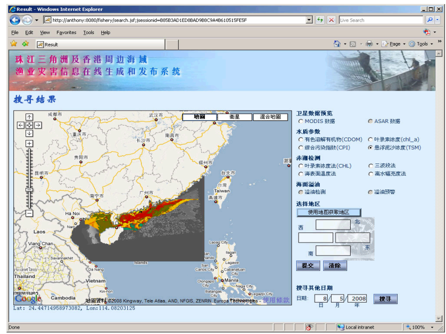

Fig. 3. Browser-end display of TSM spatial distribution generated according to user's requirement

Figure 3 shows the performance displayed in the user-side browser after synthesizing the generated TSM image and Google Map. The TSM image returned from the server in the system uses 'png' format, in which non-marine parts are fully transparent so as not to block the land part on the image. If satisfied with the disaster information displayed in the browser, the registered user can request the generation of a disaster information report such as that shown in Figure 4 which contains auxiliary information, including satellite name, satellite location, imaging time, imaging mode, disaster level (if any), disaster area (if any), disaster trend (if any), and other information.

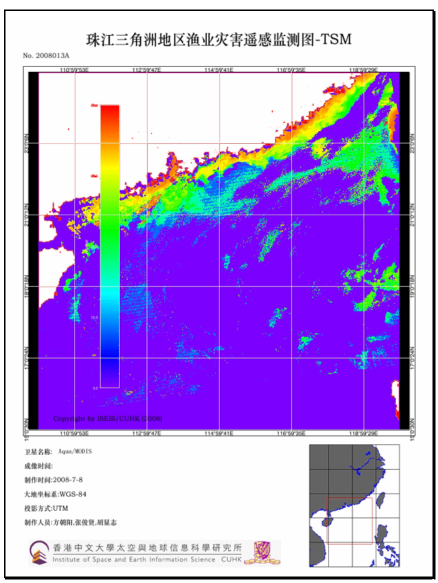

Fig. 4. Detailed disaster report with auxiliary information

5 Conclusion

In this paper, a system framework – design and application of DMWIS is introduced for online generation and distribution of disaster information based on satellite remote sensing data. In this way, the objective of near-real-time monitoring and early warning of natural disasters is achieved. The fisheries disaster monitoring and early warning information system for Pearl River Delta region was developed. The successful development of the system indicates the effectiveness of framework supported near-real-time online generation and distribution of disaster information.

The design and realization of satellite remote sensing data based online generation and distribution system can promote and accelerate the operation of the researches of satellite remote sensing. The system makes ordinary users able to customize the needed disaster information via WEB network. It has the following four characteristics: First, users can achieve personalized customization of near-real-time online disaster information. Second, the image with a size of dozens of KB can describe in detail the needed thematic disaster information. Compared with the satellite remote sensing data of hundreds of MB, the small size of image can be transmitted more rapidly in the WEB environment. Third, users only get the required thematic disaster information in custom-side browser while the raw data are isolated in the server side by the firewall which guarantees the security of data. Lastly, users get the disaster information remotely via the Internet so no substantial investments will be needed for hardware, software or personnel.

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