FAST FLOODING INFORMATION EXTRACTION IN EMERGENCY RESPONSE OF FLOOD DISASTER

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ABSTRACT:

Flood disaster is one of the natural disasters those have the highest occurrence frequency. Remote sensing plays an active and important role in the flood disaster management such as monitoring, evaluation, emergency response and so on. Affected by the characteristics of flood disaster, emergency response for flood disaster must be guaranteed by a high quality and speedy remote sensing data resources. It has a special requirement to the speed of flood disaster information extraction and updating. In operational works, not same as other ordinary scientific research, "data-information" flow is always a process need to be accomplished automatically. Considering that the ability of extracting flood information will definitively affect the following operational work such as disaster situation analysis, loss evaluation, decision-making support for salvations and so on, it is need to make a father research on the technology of fast automatic flooding information extraction. According to the water characteristics that reflect on the remote sensing images (including optical sensor and microwave radar), the method of extracting flooded area from remote sensing images that can be used currently was analyzed. It includes threshold method, NWDI method, NDVI method, and so on. In the aspect of implementation and application, the automatic abilities of these methods were discussed and they are all thought having some automation ability. Based on this discussion, two automatic/semi-automatic methods of extracting flooded area information fast from remote sensing images were designed: decision tree model method and programming method. Being affected by spectrums of objects, these two methods are all disturbed badly by mountain shadow. By researching on the model encapsulate technology and combining the terrain analysis function of GIS spatial analysis, affection of mountain shadow can be mitigated and the result data can be updated automatically. All the methods reported in this article integrated in a case-study system. They were thought having some good effect. Under the situation not having human-intervention, the flooded area can be extracted from remote sensing images directly.

1. INTRODUCTION

Flood disaster is one of the natural disasters those have the biggest harm to the living of human being and China is one of the countries having the highest occurrence frequency of flood disaster. In the face of severe disaster situation, Chinese government pays great attention to the mitigation and relief work of flood disaster. The practical idea of applying advanced spatial technology to reply to the sudden natural disaster was brought forward by the government. Spatial technology is now thought can be used to enhance the integrated ability of monitoring, precaution and emergency response decision-making support for natural disasters.

China has planned to launch a small satellite constellation for environment and disaster monitoring and forecast (HJ-1). This constellation system will promote the comprehensive application of spatial information technology in China's natural disaster administration and emergency response. At the same time, by using HJ-1, we are beginning to design and construct an integrated ground application system which will have the full functions such as monitoring, analysis, evaluation, and salvation command (Xu, 2002).

The principal requirement to the integrated ground application system is to make operational departments of flood disaster emergency response can construct and run the operation flow in their daily working process. The department's operational working regulation has strict temporal limitation to every phase of flood disaster emergency response. On the other hand, because the acquisition of data and information is the precondition of other operational works, the data processing and information extraction are the first two steps of operational work flow. As a result, we must primarily solve the problems of fast data processing and flood information extraction in the process of constructing ground application system for the HJ-1 small satellite constellation (NDRCC, 2005).

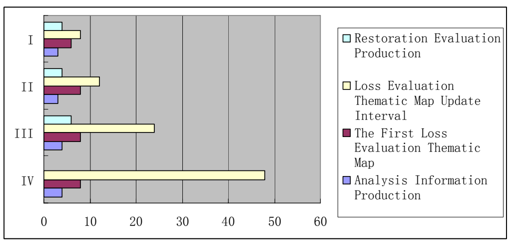

Figure 1. Temporal requirement of operational process

In the phase of meeting an emergency, the first thing we should do is to recognize the cover extent of water as accurately and fast as possible. And then, with the aid of background data, the flood water extent will be acquired. This work, namely the extraction of flood disaster information, is the foundation and precondition of other work (such as disaster loss evaluation, analysis of the evacuation route for affected people by flooding, decision-making support for disaster area restoration, and so on). As a result, it has an important position in the process of key technologies research for flood disaster emergency response decision-making support ground operational system.

2. RADICAL THEORIES

Recognizing and extracting water extent from remotely sensed imageries mainly utilizes the high absorption characteristic of water on some bands (medium infrared and near infrared, especially) of electromagnetic wave (figure 2, 3). Many scholars have made comprehensive and in-depth researches on it. A series effective method has been brought forward. These methods can be divided to two categories totally. The first one is threshold method on single band. And the second one is relationship method between multi-bands. For example, using TM data, we can extract water body by the condition of "B2 + B3 > B4 + B5" (Wang, 2004). Some other methods, such as NDWI (Normalized Difference Water Index) and MNDWI (Modified Normalized Difference Water Index), can be used to extract water body from remotely sensed imageries also (Xu, 2005).

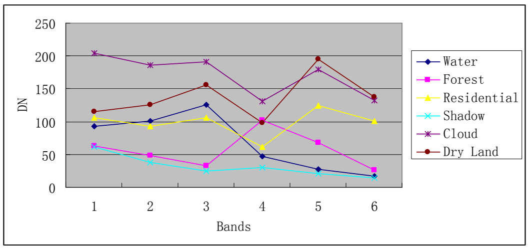

Figure 2. Spectrums of some targets on TM imagery

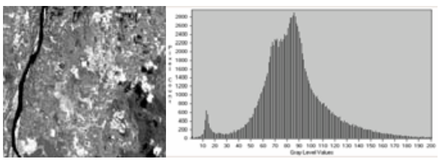

Figure 3. Low reflection characteristic of water body on the 5th band of TM

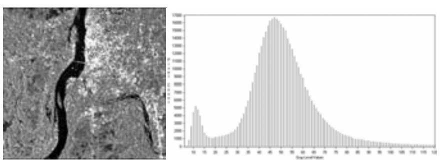

Figure 4. Reflected wave characteristic viewed on SAR image

Above methods were designed aiming at the application of optical sensor data. However, for the flood disaster emergency response work, the special meteorological condition during the disaster taking place brings insuperable difficulty to the utilization of optical sensor data. So, SAR (Synthetic Aperture Radar) imaging data is needed to be acquired at real time to ensure the dynamic monitoring on flood disaster. It is essential to research on the method of extracting water body extent from SAR imaging data.

It has similar radical theory to the extraction of water body extent from optical sensor data. Because the microwave beam will generate faint reflected signature when it meets water surface, the extent of water distributing represents low DN area on the SAR imaging data. So, the threshold method can be used to extract water body from it (figure 4). But the signature emitted by SAR sensor is prone to be disturbed and be affected by mountain body severely, the reduction of speckle noises and elimination of mountain shadows should be considered carefully when we design and realize the extraction method of water body extent from SAR imaging data.

3. COMPARISONS OF OPERATIONABILITY AMONG PRINCIPAL METHODS

Although many water body extraction methods had good experimental effect during the process of research, the application of any one single method cannot fulfil the specific requirements of one of the flood disaster emergency response decision-making support works. Practical situation is usually more complex than experimental condition. To fulfil the requirement of operational system, these methods and their different adaptation abilities to various special conditions should be combined together. The objective was to design operational analysis models with more flexibility, adaptability and customization ability.

With the help of correlative literature, the adaptabilities of some common methods were analyzed and compared (table1, including their design ideas). On the basis of table1, strategies of flood water extent extraction from remotely sensed data for different conditions were designed (table 2).Raster (such as remote sensing image and digital elevation model) is important data format in geoscience research. It has been widely applied in resources survey, ground objects classification, topographical analysis, objects detection and survey and so on.

ID	Method Description	Adaptive Data	Adaptability
①	Threshold method on single band, optical sensor data	Optical images having near infrared and medium infrared bands (such as TM6 Band4, Band5)	Affected by mountain shadow badly Having better effect on images with big-area-water Having Specific requirement on threshold value auto-calculation

②	Relationship method among multi-bands, TM (B2+B3 > B4 + B5)	TM imagery, or other optical RS imagery with equivalent bands to TM B2, B3, B4, B5	Running automatically Having better effect on images with big-area-water Some resistant ability to shadow Affected by residential area and cloud shadow
③	OIF & HIS Transformation (Li, 2006)	Multi-spectral RS Imagery	Adapt to the extraction of scattered water Complex procedure, low automation ability
④	Relationship method among multi-bands, SPOT (B3>B4 & B2 > B1)	SPOT imagery or other imagery with equivalent bands	Affected by residential area badly
⑤	Normalize Difference Water Index (NDWI)(Green –NIR/Green + NIR)	TM imagery (B2&B4) or other imagery with equivalent bands	Affected by residential area badly
⑥	Modified Normalize Difference Water Index (MNDWI)(Green-MIR/Green +MIR)	TM imagery (b2&B5) or other imagery with equivalent bands	Some resistant ability to residential area
⑦	NDVI method(Red + NIR/Red – NIR)	TM imagery (b3&b4) or other imagery with equivalent bands	Having obvious difference between water (or other low plant covering area) and vegetation Histogram has obvious double wave crest which can be utilized to assist other method Some ability of mitigating mountain shadow influence

Table 1. Principal methods and their adaptability of water extent extraction from RS image

<table>
<tr><th>Condition</th><th colspan="3">Adaptive Strategy</th></tr>
<tr><td>Plain Area</td><td rowspan="3">Threshold method on single band ① MNDWI ⑥</td><td rowspan="2">Mitigation of residential area influence ⑥</td><td></td></tr>
<tr><td>Mountain Area</td><td rowspan="2">Mountain area mask & elimination of mountain shadow Extraction of scattered water ②③⑦</td></tr>
<tr><td>Mix Area</td><td></td></tr>
</table>

Table 2. Strategies of flood water extent extraction from remotely sensed data for different conditions

To more mitigate the influence of mountain shadows, digital elevation model data and slop calculation function of geographical information system's spatial analysis can be applied to get mountain area mask. This mask can be used as input parameter of analysis model when we extract water extent from remotely sensed images. And then, the excessively extracted water area which is generated by mountain shadow can be eliminated automatically. Aiming at the processing of SAR image data, the satellite can be looked as light-source and the generation of mountain shadow can be interpreted according to the theory of beam-cast. As a result, on the basis of satellite flying parameter (including azimuth, altitude angle), the mountain shadow can be simulated and calculated. Then, it can be eliminated when we extract water cover extent.

4. FAST FLOOD INFORMATION EXTRACTION METHOD

According to the different characteristic of various water extent extraction method and applying extraction strategies for different conditions, our objective was designing fast flood information extraction method having operational running ability. To fulfil the requirement for operational running, it should have following characteristics: (1) parameterized input data; (2) automatically running; (3) updating of result data.

4.1 Procedure Implementation

Some procedure is so complex that can not be implemented easily by building a model. So, programming method which is more flexible and powerful was considered.

Most of GIS and RS software provide data processing and analysis programming objects, such as ArcObjects of ESRI ArcGIS, Supermap Objects of Supermap, and so on. By utilizing programming tools like visual studio and eclipse, an integrative module can be made out and used for the extraction of water extent from remote sensing images. Complex strategies can be executed and functionalities of mountain shadow, residential area mitigation can be integrated now. Figure 5 and Figure 6 are flow chart and idea of mountain shadow calculation, respectively.

For the flexible and powerful characteristics of programming method, these modules can run automatically and all the functions will be executed step by step as we want.

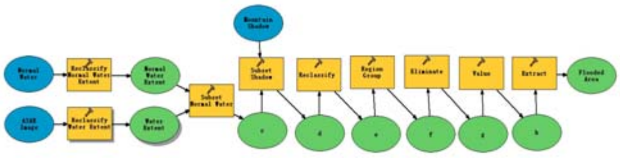

Figure 5. Flowchart of water extraction procedure

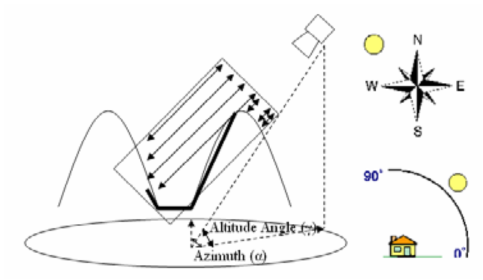

Figure 6. Idea of mountain shadow calculation

Something should be pointed out is that model building method and programming method can be combined together to design the most flexible water extent extraction method. For example, we can use model builder to build NDVI or NDWI model which have input and output data parameters. And then, by using model accessing programming interface, these models can be combined with mountain shadow mitigation procedure to build a full-functional program of water extent extraction.

4.2 Model Encapsulation

All the models and procedure module should be integrated into operational system to make them can be applied in the process of emergency response flexibly and fast. To models made in the building environment, this can be implemented easily because they all have uniform interface (including basic attribute information and parameter list). However, modules may be developed in different programming environments. So, a standard model interface should be designed. Then, all the modules can be encapsulated in a consistent form of integratable model by inheriting this standard interface.

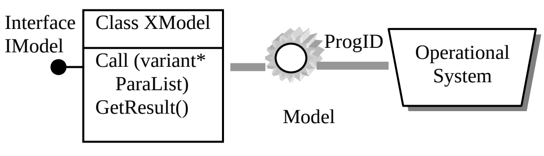

Figure 7. Interface and model definition

A prototype interface and model object definition is like figure 7. Parameter list (such as source RS images, threshold, azimuth, and so on) can be transferred by Call function, and the result data of water extent extraction can be get by GetResult function. It is regulated in a standard form and should be complied with by all the models wish to integrated in the operational system and run automatically.

4.3 Result Data Update and Management

Although water extent extraction is the first and one of the most important step in flood disaster emergency response works, it is not the terminal or the only goal of it. The result generated in the process of water extent extraction will be utilized to implement more works like loss evaluation and decision-making support for restoration. As a result, a good method must be thought out to update and manage the multi-temporal result data.

By utilizing spatial database, basic storage and management of flooding water extraction's result data can be realized. Based on it, a series of data and its management programming objects should be designed and implemented. These objects can be integrated into the water extent extraction model or some other operational functions. At the same time as result data being calculated out, the multi-temporal data series will be updated and the result data will be brought into the uniform management structure. Meanwhile, these objects provide easy-to-use interface to the application of result data in the other operational functions.

5. DEVELOPMENT AND APPLICATION

The fast flood information extraction method was applied in the development of flood disaster emergency response decision-making support operational system. MS SQLServer 2000 and ESRI ArcSDE 9.0 are selected to build a geodatabase. Operational system software was deployed on the platform of ESRI ArcGIS 9.0 GIS. Making use of Visual C++ 6.0, ATL 3.0, data programming objects were designed and developed. To simplify the development of water extent extraction model, RAD (Rapid Application Development) tools like visual basic and VBA were selected. Because the operational system provided a flexible running environment (such as operation management, operation control panel, and so on), the water extent extraction model can be embedded into or unembedded from the system and run automatically anytime and anywhere users want. More important, the model is an indispensable part of flood emergency response operational work flow. The characteristics of the model ensured the temporal requirement of operational work flow can be fulfilled. Meanwhile, the multi-temporal result data updated automatically can be applied in the process of loss evaluation, decision-making support of restoration, report and thematic map production, and so on.

The Dongting Lake was selected as the demonstration area of our research. According to the good application effect, the fast water extent extraction model was proved to have good values of application and popularization (figure 8).

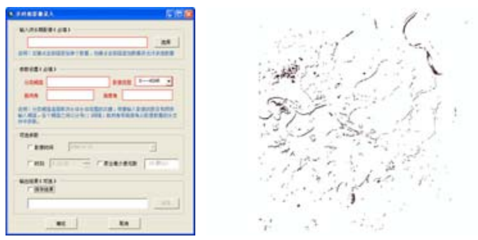

Figure 8. Running effect

CONCLUSIONS

According to the radical theory of water extent extraction from RS images and referencing some good extraction methods, a good technical framework (including algorithms, strategies, application in the Dongting Lake demonstration area, this framework was proved to be effective. However, because the real situation is far more complex than we can imagine, we should reinforce the research on the core specific technologies such as acquisition of accurate threshold value, object-oriented classification of remote sensing images, and so on. Thinking of the flexibility of the framework, these new technologies can be implemented and integrated into the framework. The framework will get a long life by a sustaining scientific research and practical application.

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