Seismic Spatial Information Grid: Applications of Geo-Informatics in Earthquake Disaster Management

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Abstract. Earthquake is one of the most serious natural disasters, which has caused huge casualties and economic losses to human society every year. It is very necessary and urgent to construct a platform to prevent and mitigate earthquake disaster. Compared with the traditional seismic data management methods that always only use a single isolated information technology, seismic spatial information grid(SSIG), which is a thematic spatial information grid with applications of geo-informatics in earthquake disaster management, has integrated many kinds of spatial information technology. In this paper, SSIG has been introduced into earthquake disaster management. It describes the construction, data acquisition, storage and application of SSIG. The proposed system was exemplified in Yushu earthquake in Qinghai province of China. The case applications show that the SSIG can effectively manage and analyze massive seismic data. As the system has run very stably, it can be recommended to a national level of China.

Keywords: spatial information grid, earthquake, disaster and risk management, geo-informatics, seismic thematic grid.

1 Introduction

Every year, the natural disasters bring great damage and injury to human society[1,2]. As one of the top ten natural disasters, earthquake has great impacts on the environment and society, and often caused vast economic losses and casualties. So how to mitigate and manage the damages is an important issue faced by mankind.

Earthquake disaster is affected by the geology, environment, society and other factors. Moreover, it is uneven distribution in time and space [3]. It is difficult to manage earthquake disaster. The traditional way is to construct a seismic management database to store the massive earthquake data. Later, the Geographic Information System (GIS) and Remote Sensing (RS) technology were introduced to manage the earthquake disaster. However, these management methods are isolated, disconnect technically. It is difficult to meet the needs of earthquake disaster management.

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F. Bian et al. (Eds.): GRMSE 2013, Part II, CCIS 399, pp. 397–406, 2013.

Spatial information grid (SIG) integrates a variety of spatial information technology. It can organize and dispose spatial data in grid unit under the distributed network environment. Based on SIG, this paper tries to use it to manage earthquake disaster. SSIG has been proposed as an application of geo-informatics in earthquake disaster management. The system collect, store and manage different kinds of seismic thematic data and related data in grid unit. It implemented the acquisition, share, access, processing and analysis of massive seismic spatial information resources.

2 Characteristics and Requirements

2.1 Characteristics of Earthquake Data

Earthquake events occur dynamically both in time and space. The characteristics of seismic data are as follows.

(1) Spatial heterogeneity. Studies have shown that the spatial distribution of seismic activity is complex and random[4,5,6]. The distribution and occurrence of earthquake has a spatial heterogeneity. Different tectonic zone has different earthquake thematic data and various attribute data. Moreover, earthquake disaster risk is different from area to area.

(2) Multi-factor. Earthquake is closely related to many factors no matter in the cause or in the assessment after the disaster. Multiply factors could affect the earthquake disaster, such as tectonic, environment, economics and so on. These impact factors are different between areas. Therefore, the seismic data are massive and complex in both structure and storage.

2.2 Requirements of Earthquake Disaster Management

As the earthquake data are discrete, spatial heterogeneous, complex and multi-factor related, it needs to construct a relevant seismic spatial information management platform. The management system should organize and manage different kinds of information which distributed in different area. Firstly, it should build location-based model and divide the large block into lots of small range grids. Therefore, the seismic data in the same grid can be regarded as uniform. Secondly, every grid could collect and store the earthquake thematic data and various attribute data. The system also could manage and analyze the earthquake data in the grid unit.

3 The Principle of Seismic Spatial Information Grid

3.1 Definition of SSIG

Spatial information grid links all kinds of spatial information resources and realizes their sharing and utilization in wide network [7,8]. Seismic spatial information grid is a thematic spatial information grid complied with the characteristics of earthquake disaster. It integrates various kinds of spatial information technology to achieve the earthquake disaster early warning, management and service. SSIG is a typical application of geo-informatics in earthquake disaster management. It manages massive earthquake data and other related data.

3.2 Types of SSIG

SSIG concludes both irregular and regular grid. Regular grids consist of a series of polygons with the same size and specifications. On the other hand, irregular grids are some arbitrary polygons with different size and shape. According to the characteristics of earthquake disaster, it needs to construct both irregular and regular ones. They are in different level, and carry different earthquake data as well as the impact factors information.

3.3 Construction of SSIG

Seismic spatial information grid construction is the foundation and key steps of the system. Building an irregular grid needs to create a new layer and then draw grid layer by GIS-based editing. The irregular grid is mainly used for the storage and management of some irregular seismic factor information. The proposed system has chosen the administrative district boundary as the irregular grid. Different levels of administration of the grid store different earthquake information.

Regular seismic spatial information grid is mainly used to assess earthquake losses under the equal area. Drawing regular grid needs to set parameter first. Parameter setting could be manual input or referring to the template layer or element. Then the first grid is drawn through the presetting size and location. The grids are cloned one by one until the interesting region is full of grids with the same size and shape (See Fig.1). Regular SSIG construction process is shown in Fig.2.

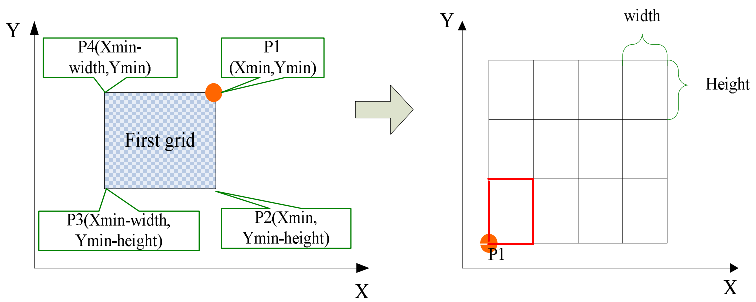

Fig. 1. The construction process of regular grid

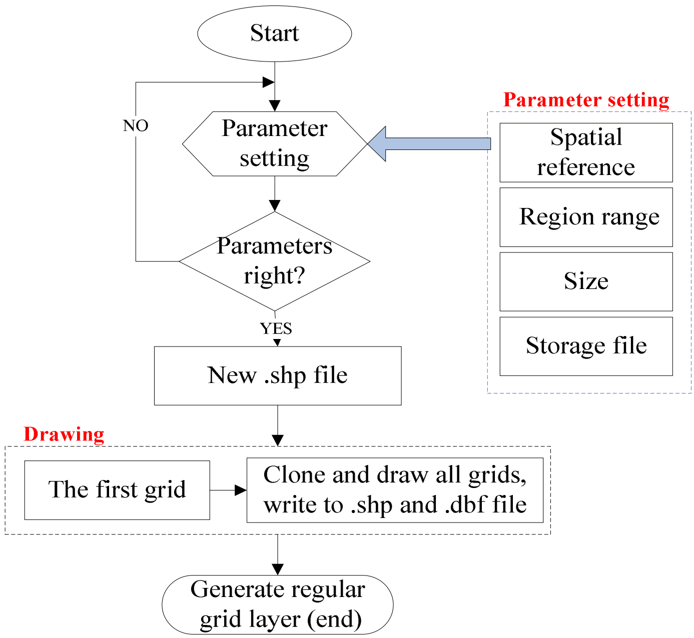

Fig. 2. Flow chart of regular grid drawing

3.4 Data Collection and Acquisition

The grid-based earthquake data collection and acquisition are both by manual input in the layer attribute table and automatic collection. Spatial overlay analysis is adopted in the automatic collection way. Overlaying the blank grid layer and the seismic thematic information layer can generate a gird layer with abundant seismic information. SSIG data acquisition process is shown in Fig.3.

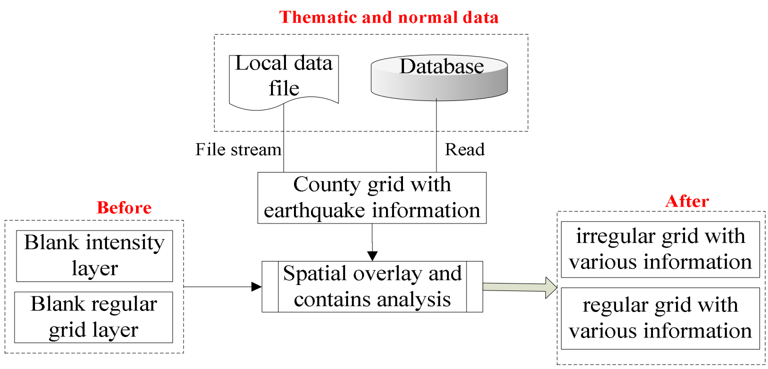

Fig. 3. The flow chart of seismic data acquisition in grid

3.5 Data Organization and Storage

As seismic data are massive, multi-factor related and spatial heterogeneous. It should be stored and managed with appropriate data structure in uniform data standard and spatial reference. This study proposed a mixed data organization model (see Fig. 4). It adopted both ArcSDE and SQL Server to organize and store data in grid unit. Geodatabase model is used to store various data in Relational Database Management System (RDBMS) such as SQL sever, oracle and so on. ArcSDE as a Spatial Data Engine(SDE) is adopted to extend the RDBMS. In this storage schema, all data would distribute into the corresponding grid with different resolution and spatial position.

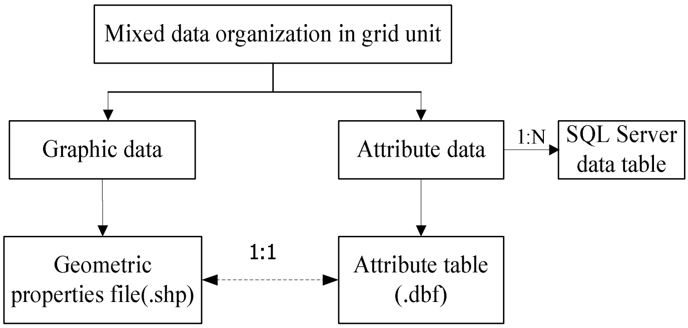

Fig. 4. The model of seismic spatial data organization

3.6 Data Query and Service

The seismic spatial information grid has stored geology, economy, buildings and other related information. It is massive and multi-source heterogeneous. To obtain useful and interesting data from these diverse data, it needs to have a good query function. Data query is an important module of SSIG.

The proposed system has given a bidirectional query way. They are the query from attributes to graph and the query from graph to attributes. The former is some function like identify in ArcGIS. The later refers to the relational database query function and Spatial Data Engine (SDE). From the grid data search, statistics and analysis, it can dig out deeper information from the earthquake data. Some applications such as intensity map drawing and earthquake disaster assessment are provided by SSIG.

4 Application

4.1 Study Area

On April 14, 2010, the Ms7.1 earthquake occurred in Yushu county of Qinghai province in northwest China. The epicenter intensity was nine. The epicenter is mainly located in 96.6 degrees east longitude and 33.1 degrees north latitude.

It belongs to the third region. In this earthquake, 2698 people died, and huge economic losses are caused in the disaster areas. The focal depth of Yushu earthquake is very shallow and the aftershocks are quite frequent.

4.2 Intensity Map Drawing Based on SSIG

Seismic intensity reflects the damage degree of ground and buildings in earthquake disaster [9]. It is related to location, magnitude, epicenter distance and geotechnical properties [10]. In earthquake assessment, isoseismal lines and seismic intensity attenuation map are always used in statistics analysis of the casualties, building damages and other losses in the same seismic intensity.

In this study, ellipse intensity attenuation model is applied in the fast drawing of an intensity map. Before drawing an isoseismal line, some model parameters and variable values need to obtain. Model parameters were stored in province irregular grids, and the angles of rupture were stored in regional irregular grids. Magnitude and intensity values were input at the client. Then through a loop program, it could draw isoseismal until the intensity is equal to six. When the intensity is less than six degree, the earthquake damage is very small and can be ignored. Fig.5 shows the process to draw a seismic intensity attenuation map. Fig.6 shows the seismic intensity attenuation map of Yushu earthquake.

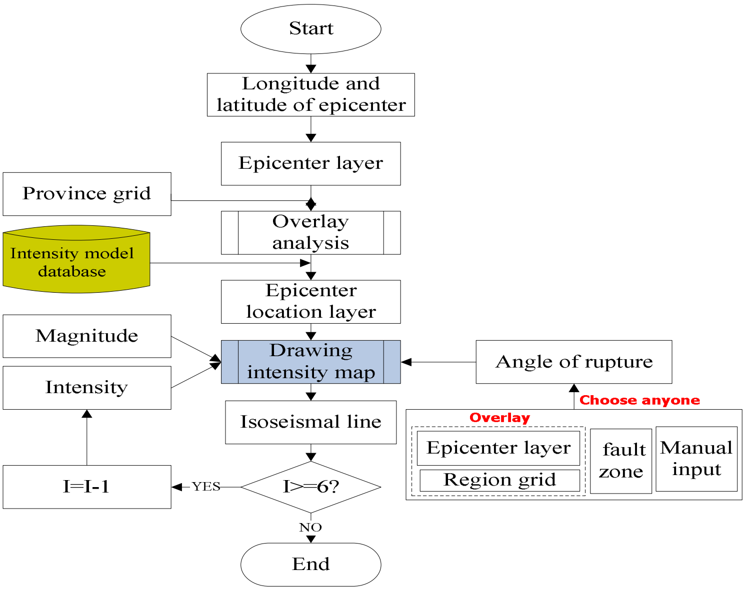

Fig. 5. The flow chart of drawing a seismic intensity attenuation map

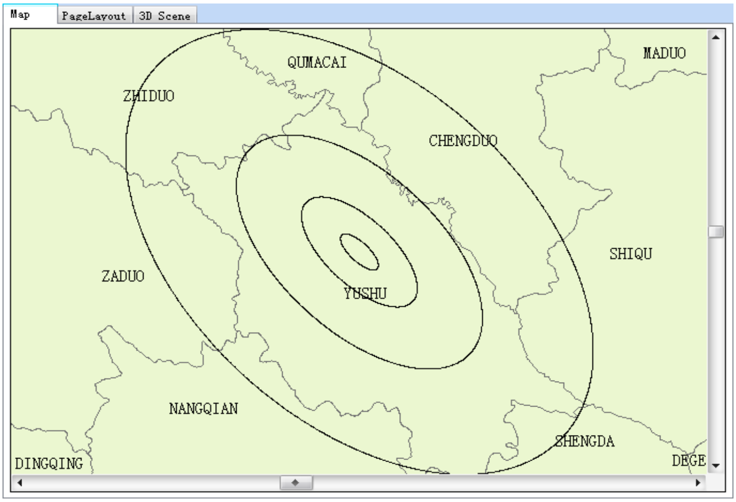

Fig. 6. The seismic intensity attenuation map of Yushu earthquake

4.3 Regular Grid Generation of Yushu Earthquake Disaster

According to Fig.2, drawing regular gird needs to know spatial reference, region range, grid size and storage file first. The spatial reference and region range can refer to layer template. As the Fig.6 has already drawn the seismic intensity attenuation map, the regular grid can use its spatial reference and be divided through the intensity map range. The regular grids of Yushu earthquake with ten rows and ten columns are shown in Fig.7.

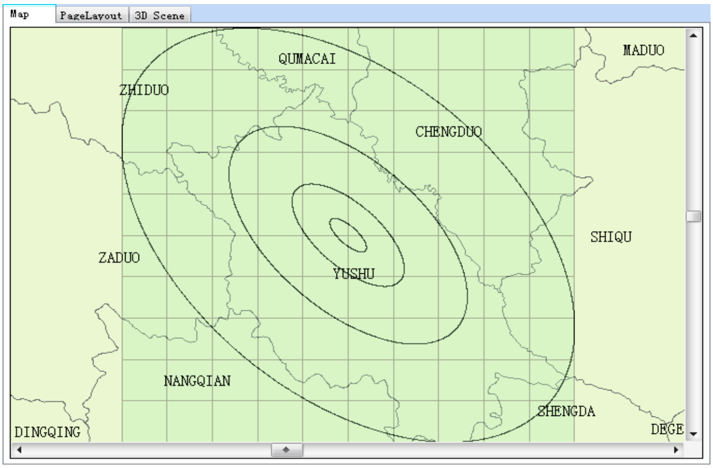

Fig. 7. Regular grids of Yushu earthquake with isoseismal lines overlaying

4.4 Data Acquisition

The above regular grid layer is a blank grid layer without any seismic thematic data. It should collect data to meet the needs of disaster management. Overlaying the blank grid layer and the county irregular grid layer with seismic thematic information can generate a gird layer with abundant seismic information. After the data acquisition, a lot of fields are added into the attributes table of the grid, which can be used to store the earthquake thematic data (see Fig.8).

Attributes of Grid_after

show: All Selected Delete Edit Option

Region	Area_A	Area_B	Area_C	Area_D	Basic_Inte	Population
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	1593	3185	1592	796	6	23447
II	769	1537	768	384	6	21582
II	769	1537	768	384	6	21582
II	769	1537	768	384	6	21582

Fig. 8. Attribute table of grid layer after seismic data acquisition

4.5 Earthquake Data Querying

For the demand of disaster management, it is necessary to query earthquake information in space and time. The querying interface provides a window to input the SQL statements. Interested readers are encouraged to read the relational database management system (RDBMS) documentation[11] in order to undertake more complex SQL queries. For an example, if a user wants to search the six intensity area in casualty, he needs to choose the target layer and then set "Intensity=6". The system would generate a SQL command and a new table of the interest. Then the results of the selected features corresponding to the query command are visually displayed with highlight in the map (see Fig.9).

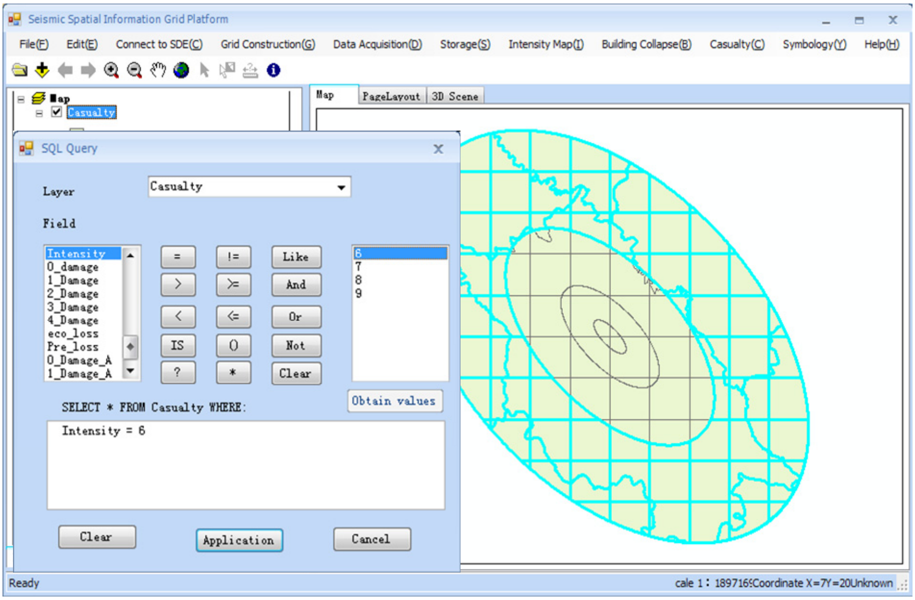

Fig. 9. Visual data querying from attributes to graph

5 Conclusion

This paper provides seismic spatial information grid that integrate various geo-informatics to manage the earthquake disaster. SSIG divides a large area into a plurality of small range to solve spatial heterogeneity of seismic data. By using spatial information technology, SSIG can effectively collect, store, manage and analyze various data in the earthquake disaster.

Although the platform is only exemplified in Yushu earthquake in China, it can be extended to a national or global level so as to manage the seismic data in an effective way and make best use of them. The proposed framework of SSIG in this paper is just an attempt on application of geo-informatics in the earthquake disaster management. As the seismic data is massive and complex, more suitable grid with different sizes and structures will be designed to adapt the special characteristics of the earthquake management in the future study.

Acknowledgments. The authors would like to appreciate the financial supports for this study from the National Natural Science Foundation of China (Grant#41072199, 41101258), the Natural Science Foundation for Outstanding Scholarship of Hubei Province in China (Grant#2008CDB364), the National Key Technology R&D Program of China (Grant#2008BAC36B01) and the Program for New Century Excellent Talent of Ministry of Education of China (Grant#NCET-07-0340).

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