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Design and Implementation of Earthquake Emergency Response System Based on Grid Data

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Abstract. Generally speaking, the estimate of casualty, economic loss and damage of building or structures after earthquakes is modelled through the evaluating seismic influence field and the data which is administrative units for census and statistics. Thus, the evaluating results have good application in large scale, but are not accurate enough in the case of post-earthquake disaster assessments. The data based on kilometre grid can better embody the spatial heterogeneity of elements. And then it would improve the accuracy of the assessments. The paper introduces the design and implementation of earthquake emergency response system based on the kilometre grid data in Shanxi province of population, economy, and housing from several facets, such as system architecture, technology implementation, database design, functional modules and algorithms, system workflows and product details. Taking the 2010 M4.8 Hejin earthquake as an example, the evaluation is fast, precise, and spatial heterogeneity of the disaster pre-assessment is obvious..

1. Introduction

The earthquake is one of the natural disasters with the greatest impact on human activities. Within a short period of time after the earthquake, details of the disaster will be not too clear. In addition to relying on limited disaster information, the government also needed to rely on the earthquake emergency auxiliary decision results issued by earthquake emergency command centre to launch the emergency response level and formulate the emergency rescue strategy. During the period of the Tenth Five-Year Plan, China seismological bureau has established a nationwide earthquake relief headquarters technology system, which played an important role in the past earthquake emergency events. But the system used the areal weighting to assess the building's collapse and casualties in disaster areas, i.e., the statistics of the population, economy and housing in the administrative unit was treated uniformly according to the area of the unit. Due to the obvious spatial aggregation and directionality of population, economy, housing and earthquake influence, by this method sometimes there would be low accuracy and large errors in the results of disaster assessment. Taking the administrative region as the unit, the statistics in the unit was distributed into the grid according to certain mathematical model [1], the law and the spatial distribution of the population, economy and the building will be easily expressed through the statistics of grid gradiometer data. Using the grid statistical data for earthquake emergency and rapid assessment can improve the estimation precision.

This paper designs a set of earthquake emergency response system based on kilometre grid data, the system uses C/S architecture, integrates the earthquake emergency basic database, professional evaluation model library and Office software into geographic information system (GIS) to assessment the earthquake casualties and distribution of the disaster area, economic losses, building's collapse and so on rapidly, meanwhile outputs standardized reports and thematic maps. This paper expounds the design and implementation of the system from overall system design, database design and function module design.

2. Overall design of system

2.1 System architecture

The system adopts object-oriented software design, integrates GIS seamlessly with office software and the professional model. The application scenarios of this system have high security confidentiality, rapid deployment, high portability and other requirements [2]. The system uses the mature C/S three-tier architecture which is shown in figure 1. According to the general working process and characteristics of the rapid assessment of earthquake emergency, the system design is divided into data layer, functional service layer and application layer. Data layer mainly includes regional earthquake relief headquarters earthquake emergency database [3], which contains 42 small class and 9 big categories data, kilometer grid population, economic and housing data, e.g., basic geographic information, social and economic statistics data, engineering seismic data in earthquake, the background of disaster influence, factors related to disaster, disaster relief, emergency contact and earthquake emergency plans and so on. Functional service layer mainly includes the disaster area and impact assessment model, seismic intensity evaluation model, population casualties estimates model, rescue strength evaluation model, the economic loss assessment model, earthquake emergency auxiliary decision document generation services and so on. The application layer mainly includes personnel casualties and distribution assessment, housing damage assessment, rescue force assessment, economic loss assessment, earthquake emergency thematic map and other auxiliary functions.

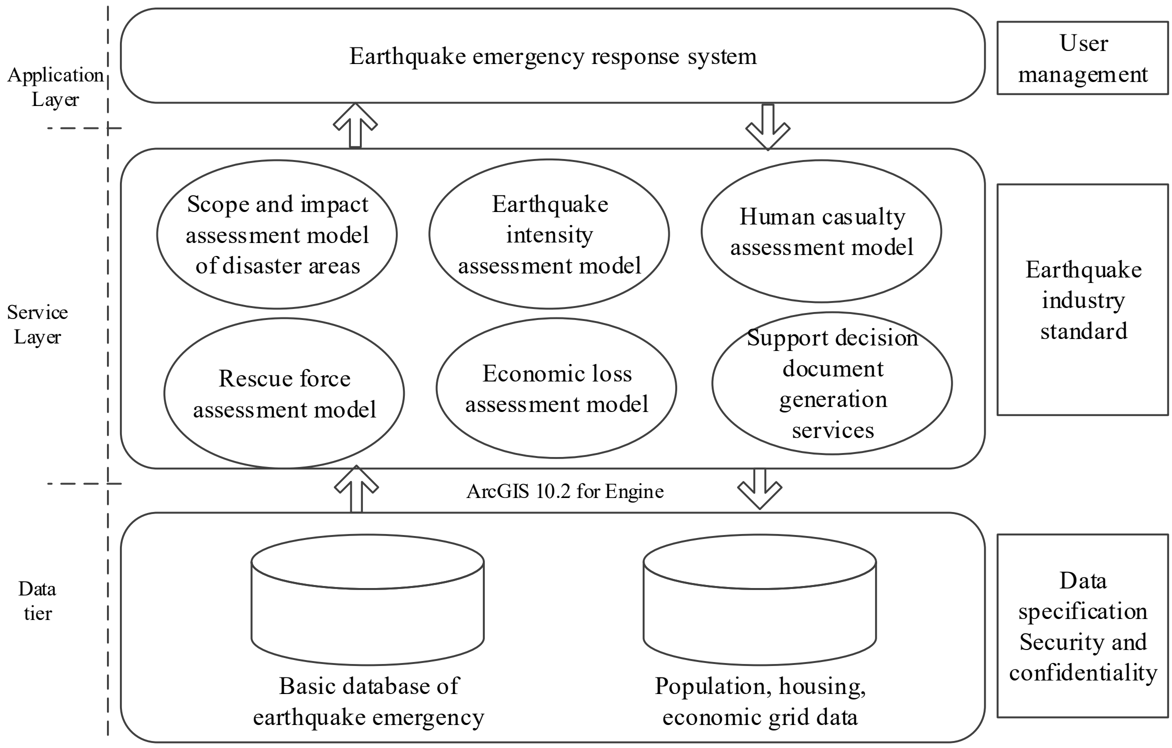

Figure 1. System architecture

2.2 Technology implementation

Earthquake emergency response system with high complexity integrates a variety of professional evaluation models and partial functionality of GIS and office. In practical application scenario, it is required to response quickly, have high availability, high compatibility and good portability. It adopts mature, general and stable technical route in system development. The underlying support technology of the system is GIS, and the ArcGIS Engine Developer Kit 10.2 is used as the base platform for the second development of GIS. ArcGIS Engine is a desktop GIS library product for developers and uses Microsoft's COM specification. It provides some map controls and Command button for many common functions that can be used to implement a map-centric application system [4]. ArcGIS Engine is a very mature GIS secondary development product, has been widely applied in the field of mapping, meteorology, emergency, and other industries construction in the domestic and overseas . During the period of the tenth five-year, the secondary development platform used in national earthquake emergency command system was ArcGIS Engine. The daily work environment is Windows.

In order to install and deploy expediently, the.net platform was used as the base development environment, and DevExpress was used as the UI control to make the system application interface beautiful and concise. The technological implementation methods are shown in table 1.

Table 1. Technical methods of system implementation

technique formal	technical method	description
development model	C/S	system overall architecture
development platform	.NET，C#	development framework an d programming language
development tools	Visual Studio 2013	software for coding and testing
GIS platform	ArcGIS 10.2 for Engine，ArcMap 10.2	GIS secondary development platform
operational environmen t	Windows XP and above， Microsoft Office 2003 and above，ArcGIS Engine Runtime 10.2	client operational environm ent

3. Database Design

There are many data types involved in earthquake emergency response system. According to its data format and usage scenarios, the database of this system mainly includes:

3.1 Earthquake emergency basic database

The data contains the administrative division data of provincial, city and county, township and village five levels, the traffic data of high speed, state roads, provincial roads, county roads and other, historical earthquake data, as well as population, economy, geologic disaster danger point, hazards, scenic spots and historical sites, the rescue force data and so on. These data are stored in the Geodatabase based on vector format. Geodatabase is the primary data structure of ArcGIS, which is the main data format for editing and data management, including file geographic database, personal geographic database, and ArcSDE geographical database. File geographic database is suitable for the processing of GIS projection data, and used for personal and small groups with very high performance. It can be extended to store large amounts of data without having to use DBMS, also can be ported across multiple operating systems. The earthquake emergency basic database is stored in the file geographic database format.

3.2 Kilometer grid database

It includes the population of kilometers grid, GDP, housing data, DEM data of 30m resolution, high-resolution historical remote sensing image data, etc. Considering the usage scenario of raster data,

data volume size, and the portability of the system, raster data is stored as the file in the file system [5].

4 System function module

The function of earthquake emergency response system is to evaluate the damage loss rapidly after a destroyed earthquake. In the unclear case, it just needs users input earthquake three elements (time, location, magnitude) to trigger rapid assessment function [6] ,then the system will obtain information about earthquake coverage and disaster area, casualties and injured population, damage degree and distribution of buildings in a short term with the support of mathematical model, expert knowledge base and basic geographic information, and generate the basic situation of the earthquake zone, disaster briefing and earthquake relief work three main reports. In addition, the system will automatically produce the provincial emergency command center earthquake emergency thematic map, which will be used by the unit and the field task force. The functional modules of the system are shown in figure 2.

4.1 Earthquake triggering

In the "setting up earthquake" interface, the user can input the earthquake's longitude and latitude, the earthquake time, focal depth, and the magnitude of the earthquake to start the rapid assessment process, at the same time, it can be used to modify the earthquake fault diagnosis parameters and obtain rupture length. After setting up parameter, the system can produce the disaster report, the basic situation of the earthquake zone and the auxiliary decision-making document in minutes, and the emergency special plan for the earthquake is started in the background. In addition, the system supports the dynamic modification of the size and direction of the affected fields based on the sequence information of the aftershock and the disaster, and supports to import external impact field for assessing the disaster loss, then exports vector format of impact field documents for use by other working groups.

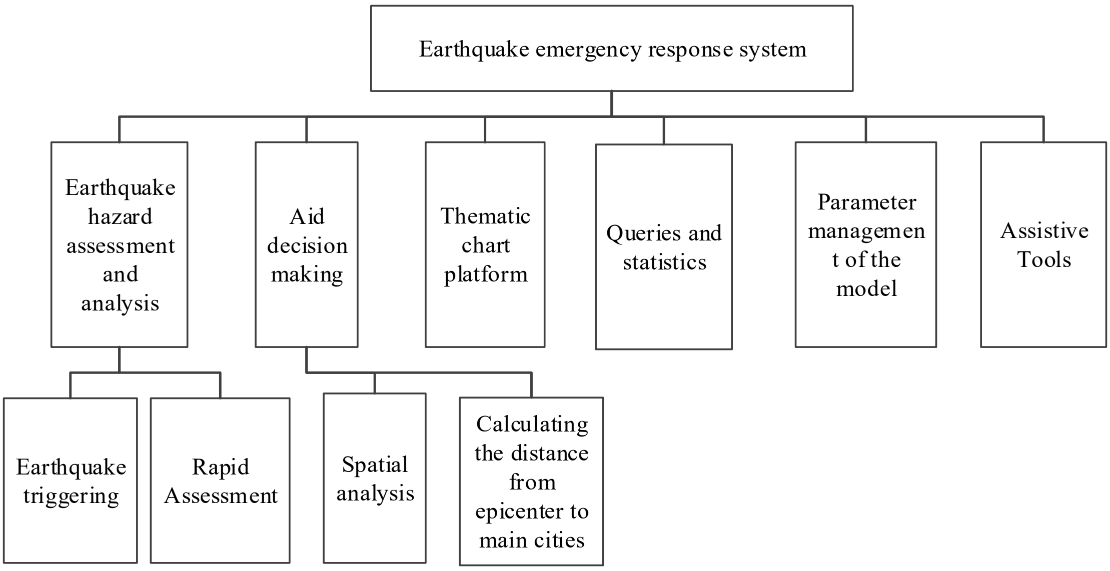

Figure 2. System function modules

The assessment of building earthquake damage is the basis of rapid assessment of earthquake damage. The damage of all kinds of houses in the grid cells can be obtained by combining the data of the grid and the vulnerability matrix of the houses in the area. The types of houses are divided into four categories, including the houses built of wood, soil, stone, brick and brick houses, single-story or multi-story masonry houses, reinforced concrete houses, and other classes. The damage grade of the house is basically intact, slight damage, moderate damage, severe damage and destruction of five grades. The death toll is estimated based on the housing damage situation [7]. The empirical formula adopted is as follows：

$$N_D = RP \quad (1)$$

ND is the death toll; P is the total population of grid units; R is the mortality. The relationship between mortality and house collapse rate is shown by the following formula:

$$lgR = 12.479C^{0.1} - 13.3 \quad (2)$$

Among them, C is house collapse rate.

The number of injured were estimated based historical damage experience to be between three and five times the number of people killed.

4.2 Aid decision making

Path analysis includes Shortest path analysis, optimal path analysis, proximity facility point analysis, etc., which can provide auxiliary decision-making suggestions for personnel evacuation path development and distribution of relief supplies. The toxic gas spreading simulation function can provide help for the gas leak disposal of hazardous sources such as chemical factories after the earthquake. In addition, the system integrates the buffer analysis and distance calculation from the epicenter to the cities, counties and towns.

4.3 Thematic map production

The user can modify thematic diagram category and order through thematic drawing management function, and design the layout and layer elements of thematic diagram according to the actual demand of earthquake emergency.

Through thematic map output Settings, the user can decide the category of the output thematic map category whether to add the earthquake magnitude, and whether the thematic map is scaled to the influence scope of the earthquake or the resolution of outputting thematic map, etc. After outputting thematic diagram automatically, users can output other thematic drawings on their own through the feature graph output function.

4.4 Queries and statistics

Users can query the attribute information of the target layer by drawing points, rectangles, polygons, and round, or get some elements of a layer by fuzzy query.

4.5 Parameter management of the model

With the increase of earthquake cases, the continuous improvement of the database, the improvement of research and analysis methods, and the development of localization research, the model and parameters of earthquake emergency assessment need to be adjusted dynamically. With model parameter adjusted, the model coefficients of the intensity attenuation coefficient, building earthquake damage matrix, building reconstruction parameters, building loss ratio, economic loss ratio and human casualty assessment model are adjusted by users.

4.6 Assistive tools

This function module provides the functions of map operation functions such as zooming and bookmark management in GIS, and also provides some measure functions such as positioning, length measurement, area measurement and interface adjustment, etc.

5 Application case

There was a 4.8-magnitude earthquake in the Hejin City of Shanxi Province at 10:36 a.m. on January 24, 2010. The epicenter was located in urban district of Hejin City with a depth of 12km. According to the emergency plan, the Earthquake Administration of Shanxi Province immediately initiated the emergency response of the magnitude 4 earthquake, the relevant departments immediately activated the system to carry out emergency assessment of earthquake disasters,

Authorities immediately launched this system for earthquake disaster emergency assessment. The results were produced within two minutes. It concluded with three documents: earthquake disaster briefing, earthquake relief work recommendations and basic situation of earthquake zone.

According to the earthquake disaster briefing, the earthquake intensity of the magistoseismic region was Ⅵ degrees, involving one county with a population of about 77,711 people. This GDP of zone was about 85 million yuan. It was estimated that 0 people were killed and 3 people were injured because of damage to collapsed houses. The earthquake may have caused the destruction of 30 buildings, and varying degrees of damage of 4,400 buildings.

According to the earthquake relief work recommendations, the commander provided the following work suggestions: according to Shanxi earthquake emergency plan, this earthquake relief work was led by Yuncheng city. Suggestions were as follows. Firstly, the provincial seismological bureau assisted the earthquake relief headquarters in the disaster area to carry out earthquake emergency response and was responsible for earthquake site emergency work. Secondly, Shanxi earthquake emergency rescue team should always be prepared. Thirdly, other departments assist disaster area to do a good job in earthquake relief.

The basic situation of the earthquake zone mainly contained the following items: the population quantity, total economy and area of the districts involved, the distance from the main administrative residence to the epicenter, earthquake zone's history earthquake catalogue, traffic conditions, geological disaster risk points, nearby rescue forces list, schools, major hazard installations, and the summary table of material requirements including emergency resettlement supplies, rescue team demands, medical personnel and facilities requirements, clothing and food needs, relief and housing costs, etc.

In addition to the above detailed assessment results, thematic maps were outputted synchronously. They were the epicenter location map, seismic intensity effect field initial evaluation distribution map, the population of the earthquake zone map, activity faults and historical earthquakes distribution map, the distribution maps of schools hospitals, major hazard sources, rescue forces and reservoirs, etc.

6. Conclusion

The rapid assessment of post-earthquake disaster is the focus of earthquake emergency and rescue. The application of kilometer grid data in disaster assessment is the research direction after the establishment of the national earthquake emergency command system during the tenth five year plan. There are generally three major types of date utilized by earthquake emergency, consisting of population, GDP and buildings. Grid transformation is to divide administrative units data into certain spatial scaling grid basing on mathematical model. GRID-structured data can show the spatial distribution and differentiation law of geographical elements. Accurate data are the basis for post-earthquake rapid assessment. This paper expounds the design and implementation of earthquake emergency response system based on the kilometer grid data from the aspects of system architecture, technical route, and database design and system function module. The software system uses C/S architecture, which meets the requirements of rapid deployment, portability and safety of the system. It integrates the work flow of post-earthquake emergency command center into the system and can quickly produce the evaluation results and thematic drawings to provide helpful suggestions for the government's earthquake relief work. Taking Hejin M4.8 earthquake in 2010 as an example, the software system evaluated the earthquake rapidly, the users obtained a high accuracy simulation results with expert advice and preliminary disaster and had a fundamental grasp of personnel casualties, building damage situation and spatial distribution pattern in the early period of the earthquake, which provided support for earthquake emergency rescue operation. Compared with the conventional method, the method described by this paper is capable to get better results that is accurate and reflects the spatial distribution of casualties, financial loss, population buried below the pressure and broken houses. This is also more conducive to the deployment of rescue operations.

However, the accuracy of current grid transformation models is limited. The grid data is always static. Improving the accuracy and dynamicity of the models need further research. Social media registration data can reflect dynamic changes in the activities of the crowd. The map POI (points of interest) data can embody the Urban Function Partition. To build a grid transformation model considering these above two parameter will improve data quality. The spatial scale of grid data is another influence on the post-earthquake disaster assessment. To choose the appropriate space scale is a valuable research issue.

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