Research and Application of Beijing Earthquake Disaster Prevention System Based on GIS

Qingquan Tan and Qun Liu*
Earthquake Disaster Prevention Center
Earthquake Administration of Beijing Municipality
Beijing, China
e-mail: {tanqq & liuqun}@bjseis.cn

Zhonggao Sun
School of Physics and Electronic Technology
Liaoning Normal University
Dalian, Liaoning Province, China
e-mail: sunzg98@sina.com

Abstract—**With the development of spatial information technology and computer technology, GIS technology is widely used in the field of earthquake research. In this paper, the research and application of the GIS-based earthquake disaster prevention system of Beijing is discussed. A four-level system architecture design is presented. The key technology and research results are introduced, including multi-source data integration management, data query and spatial analysis, and user authorization management. A lot of operating interfaces and results are illustrated. Based on the GIS platform and web portal, the system realizes data integration management and efficient service. The system has been deployed and applied in practical work. The actual application results show that the research results have important application significance.**

Keywords-earthquake; earthquake disaster prevention; geographic information system; web portal; integration management

I. INTRODUCTION

Earthquake is one of the most disastrous events, and inflicts severe casualties and property losses [1]. The occurrence of earthquakes cannot be predicted by current technology. The Earthquake damage prevention policy to reduce earthquake disaster has been proven to be effective [2]. In order to minimize the earthquake damage and develop effective earthquake emergency measures, it is necessary to do statistical analysis about the seismic risk sources and vulnerabilities of cities and villages. Over the past few decades, a wealth of basic data, results data, and practical experience related to earthquake damage prevention have been accumulated in the Beijing area [3-4]. In particular, a large number of earthquake safety evaluation studies have been carried out for major urban construction projects. How to achieve effective management and application of results and data, improve data service capabilities, and avoid waste of resources and redundant construction become key issues that need to be resolved. Therefore, by making full use of the powerful spatial data storage management and display analysis functions of the Geographic Information System (GIS) [5], the Beijing earthquake damage prevention work platform is built to achieve unified storage management, analysis and application, and social services for a series of earthquake damage prevention research results and data. It is of great significance to comprehensively upgrade the defense capabilities of earthquake disasters.

Many scholars focus on the application research of GIS technology in the field of earthquakes, and have obtained a lot of valuable research results. Li & Tao (2009) presented a method to integrate remote sensing (RS) data processing, generation of isoseismal lines and human-computer interaction modules into an improved GIS-based disaster reduction system [6]. C Lee (2017) discussed the methods for GIS based optimal impervious surface map generation using various spatial data for urban nonpoint source management [7]. HS Kim & CK Chung (2016) implemented an integrated earthquake hazard assessment system with geotechnical spatial grid information based on GIS [8]. Huang (2013) created a WebGIS-based information management system for landslides triggered by Wenchuan earthquake, providing a tool for landslide risk assessment, emergency management, land-use planning, development of early warning system and enhancement of public awareness of natural hazards [9]. A Kienzle (2006) presented a GIS-based study of earthquake hazard as a tool for the microzonation of Bucharest [10]. Zhao (2010) implemented an integrated software system for the dynamic simulation of fires following an earthquake based on GIS [11]. M Moradi (2017) presented a GIS-based multi-criteria analysis model for earthquake vulnerability assessment using Choquet integral and game theory [12].

This paper presents the design and implementation of Beijing earthquake disaster prevention system based on GIS, which is organized into several sections. In section 1, the research background is introduced. In section 2, the system design is presented. In section 3, the research and application results are introduced. Finally, in section 4, we draw some conclusions and put forward future research items.

II. SYSTEM DESIGN

A. System Architecture Design

The overall architecture of the earthquake disaster prevention system is shown in Fig. 1. The system can be divided into four levels, which include base layer, data layer, application layer, and interactive layer.

- Base layer

The base layer provides the basic software and hardware environment required for the system, including network, server, storage, firewall, UPS, operating system, and so on.

- Data layer

978-1-5386-7437-6/18/$31.00 ©2018 IEEE

The data layer stores all the data resources which are needed in the system, including geographic data, property data, research results data, earthquake data, user data, log data, and so on.

- Application layer

The application layer provides the communication bridge between user operations and background database. The key function modules include GIS map service, load balancing, spatial analysis, data management, data backup, portal integration, other web services, and so on.

- Interactive layer

The interactive layer provides the interface and interactive operations for users and managers. The interactive operations include user management, data management, data query, data export, GIS map operations, system management, spatial analysis, and so on.

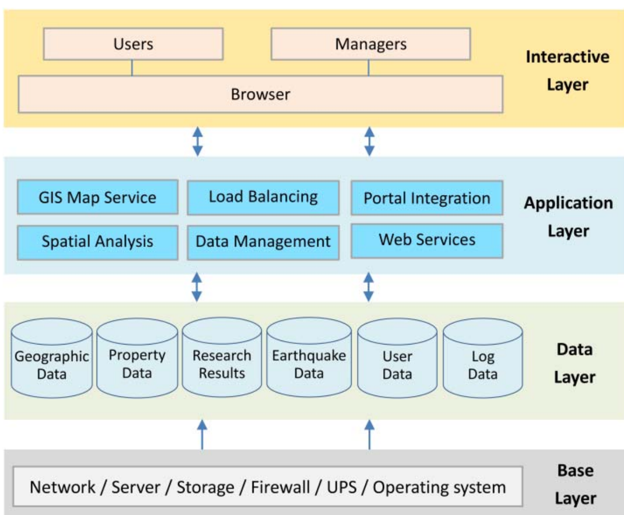

Figure 1. System architecture diagram.

B. Workflow Design

The overall workflow of the system is shown in Fig. 2. The core functions are interactive operations and service functions based on GIS. All the functions are integrated through web portal.

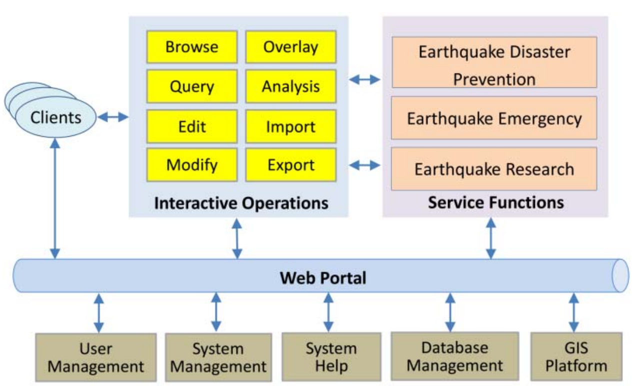

Figure 2. System workflow schematic.

- Service functions

The system provides various functions according to different business applications, such as earthquake disaster prevention, earthquake emergency, and other earthquake research work. For earthquake disaster prevention, the main service functions include: querying seismic fault distribution, seismic fault zone buffer analysis, ground motion parameter zoning management, etc. For earthquake emergency, the main service functions include: historical earthquake enquiries, distribution of earthquake emergency evacuation sites, rescue route planning, disaster loss distribution, etc.

- Web portal

A web portal is a specially designed website that brings information from diverse sources together in a uniform way [13-14]. In this system, the interactive functions, service functions, GIS platform and other management functions are integrated based on portal technology.

- GIS platform

GIS is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data [15]. The system implemented in this paper is a typical GIS application. Based on GIS platform, data from different sources are integrated and managed, and layer overlays are implemented.

In order to improve the efficiency of the map service, the map data is processed into multi-level cache data. And a pyramid model is constructed by generating different abstraction levels of the original spatial data with different scale. When a client requests data at a given scale, the server will search the required data from the pre-cached data instead of searching the original spatial data directly. As a result, the performance and speed of the system will be improved tremendously.

The map tiles stored as pyramid model are static image files and without of spatial referencing information, instead of the original spatial data. In order to realize the final web publication, applications need to tell the real geographic extent of each map tile by its name, which contains the parameters of level, column, and row. If we use n, i, j to represent level, row, and column, lon, lat to represent longitude and latitude, for a global geographic data, where $lon \in [-180^{\circ}, 180^{\circ}]$, $lat \in [-90^{\circ}, 90^{\circ}]$, on the first level (n=1), there are two map tiles which can be expressed as $(n, i, j) = (1,0,0)$ and $(n, i, j) = (1,0,1)$, while zooming in, the value of level is added one and the values of row and column are doubled. For a random point (lon, lat), the corresponding map tile on level n can be calculated by following formulas:

$$\Delta lat = \frac{90-(-90)}{2^{n-1}} \tag{1}$$

$$i = \left\lfloor \frac{90-lat}{\Delta lat} \right\rfloor \left(i \geq 2^{n-1} \mid i = 2^{n-1} - 1 \right) \tag{2}$$

$$\Delta lon = \frac{180-(-180)}{2^{n}} \tag{3}$$

$$j=\left\lfloor \frac{lon-(-180)}{\Delta lon} \right\rfloor \left(j \geq 2^{n} \mid j=2^{n}-1\right) \quad (4)$$

Furthermore, if the map tiles size is $P \times P$ in pixel, the corresponding point in map tile (n,i,j) of (lon,lat) is:

$$P_x=\left(lon-\Delta lon \cdot j\right)/\left(\Delta lon / P\right) \quad (5)$$

$$P_y=\left((90-\Delta lat \cdot i)-lat\right)/\left(\Delta lat / P\right) \quad (6)$$

Accordingly, for every point (P_x, P_y) in tile (n,i,j), the real geographic coordinate (lon,lat) could be easily calculated in reverse.

- Management functions

The system provides different management functions, such as user management, system management, database management, and so on. User management functions include: user registration, user login, user information modification, user rights management, etc. System management functions include: log management, log query, form management, permission assignment, etc. Database management functions include: data query, data modification, data reporting, data backup, and so on.

III. Key Technology and Research Results

A. Multi-source Data Integration Management

The data used in this system involves a large amount of spatial data and non-spatial data. How to realize the integrated management of multi-source data is the primary problem to be solved. In the past decades, a wealth of seismic damage defense research results have been achieved, such as urban active fault detection [16], seismic safety evaluation [17], emergency shelter construction [18], seismic micro-zoning [19], and so on. However, these results data are scattered or simply stored in the form of electronic documents. Therefore, How to realize the management and application of these data, based on a unified web platform, is of great significance for future earthquake damage prevention work.

Figure 3. Earthquake data are overlaid on GIS map.

In this research, based on the GIS map service platform, various types of seismic damage prevention data are spatially processed and presented, which provides real-time overlay and web publishing service based on the international map service specification of WMS/WFS. In particular, hundreds of earthquake safety evaluation projects are electronically and spatially processed, and the seismic fortification parameters given by each project are visualized in a spatial manner. Users can easily get these results on the browser.

Thehistorical earthquakes, active faults, monitoring stations, and evacuation sites in the Beijing area are overlaid on GIS map, as is shown in Fig. 3. All the earthquake safety evaluation projects are overlaid on GIS map, as is shown in Fig. 4.

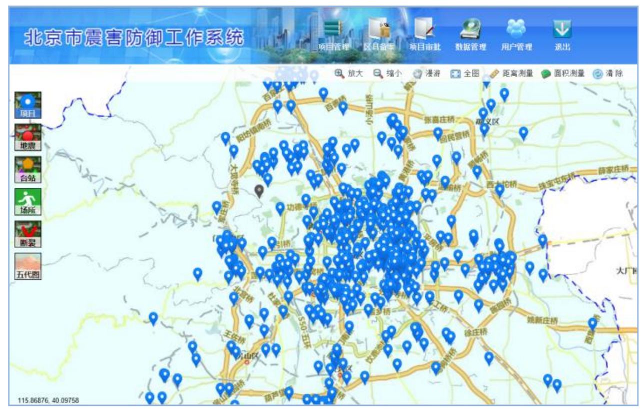

Figure 4. Earthquake safety evaluation projects are overlaid on GIS map.

B. Data Query and Spatial Analysis

For various types of seismic professional data, the system provides attribute query and spatial query methods. Based on attribute query, data with certain specific attributes can be quickly obtained. Taking the earthquake safety evaluation projects as an example, Fig. 5 shows all the projects between the year of 2014 and 2017. Based on attribute query, data with certain spatial characteristics can be quickly acquired. Taking the earthquake safety evaluation projects as an example, Fig. 6 shows all the projects within 5km along a certain fault. The query results can be displayed individually or in different styles. At the same time, they can be exported as Excel files.

Figure 5. Property query results.

Figure 6. Spatial buffer query results.

C. User Authorization Management

Each user is granted different operating rights. Ordinary users can add and query data but cannot modify or delete data. Administrators have all operational rights to the data. At the same time, according to the user's administrative area attributes, only the data of the corresponding administrative area can be operated. Taking the user in Haidian District of Beijing as an example, Fig. 7 shows the user login interface, and Fig. 8 presents the display interface of all the earthquake safety evaluation projects in Haidian District.

Figure 7. User login page.

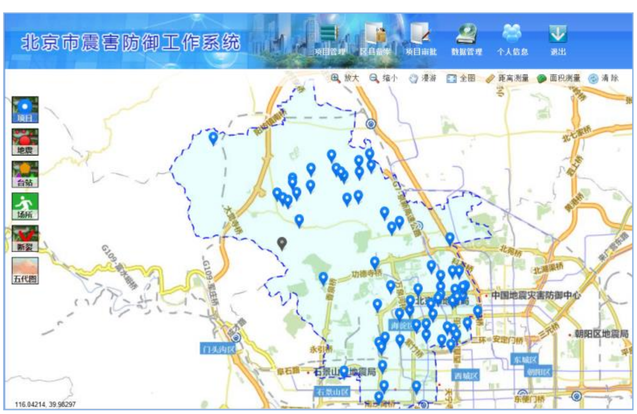

Figure 8. Earthquake safety evaluation projects in Haidian District.

IV. CONCLUSIONS

In this paper, we discussed Beijing earthquake disaster prevention system based on GIS. A four-level system architecture design is presented, including base layer, data layer, application layer, and interactive layer. The key technology and research results are introduced, including multi-source data integration management, data query and spatial analysis, and user authorization management. Meanwhile, some operating interfaces and results are illustrated.

Based on the GIS platform and web portal, the system realizes data integration management and efficient service, with friendly user interfaces. The system has been deployed and applied in practical work. The actual application results show that the research results have important application significance.

With the development of spatial information technology and computer technology, GIS and Internet technology are widely used in various research fields. How to strengthen the application of 3S (RS, GIS, and GPS) integration technology in the field of earthquake, how to improve the acquisition capability of earthquake disasters, and how to enhance the social service capability of seismic information need further research. These issues have been placed on our future research agenda.

ACKNOWLEDGMENT

This research is supported by Scientific Research Fund of Institute of Engineering Mechanics, China Earthquake Administration (2016QJGJ17, 2017QJGJ09), China Earthquake Administration Project of Science for Earthquake Resilience (XH16001, XH17002), Beijing Natural Science Foundation (8164068), and Foundation of Department of Education of Liaoning Province (L201783643). The anonymous reviewers and financial sponsors are gratefully acknowledged.

REFERENCES

[1] Qingquan Tan, “An Earthquake Emergency Command System based on GIS and RS,” International Conference on Information Systems for Crisis Response and Management IEEE, 2011,pp.496-500.

[2] Stoppa, Francesco, and C. Berti. “Reducing seismic risk by understanding its cultural roots: Inference from an Italian case history,” Natural Science, 2013,5(8),pp.78-91.

[3] Zheng-Xin Li, and Hui Li, “Earthquake-related gravity field changes at Beijing-Tangshan gravimetric network during 1987–1998,” Studia Geophysica Et Geodaetica, 2009, 53(2),pp.185-197.

[4] Hanshu Peng, “Developing a Prototype Earthquake Early Warning System in the Beijing Capital Region,” Seismological Research Letters, 2011,82(3),pp.394-403.

[5] Clarke, K. C., S. L. Mclafferty, and B. J. Tempalski, “On epidemiology and geographic information systems: a review and discussion of future directions,” Emerging Infectious Diseases, 1996,2(2),pp.85-92.

[6] Li, Ping, Tao. “Integrating RS technology into a GIS-based earthquake prevention and disaster reduction system for earthquake damage evaluation,” Earthquake Engineering and Engineering Vibration, 2009, 8(1),pp.95-101.

[7] Lee, C., K. Kim, and H. Lee, “GIS based optimal impervious surface map generation using various spatial data for urban nonpoint source

management," Journal of Environmental Management, 2017, 206,pp.587-601.

[8] Kim H S, Chung C K. "Integrated system for site-specific earthquake hazard assessment with geotechnical spatial grid information based on GIS[J]. Natural Hazards," 2016, 82(2),pp.981-1007.

[9] Huang, Runqiu, Huang, et al. "WebGIS-based information management system for landslides triggered by;Wenchuan earthquake," Journal of Mountain Science, 2013, 65(3),pp.1507-1517.

[10] Kienzle A, Hannich D, Wirth W, et al. "A GIS-based study of earthquake hazard as a tool for the microzonation of Bucharest," Engineering Geology, 2006, 87(1),pp.13-32.

[11] Zhao S. "GisFFE—an integrated software system for the dynamic simulation of fires following an earthquake based on GIS," Fire Safety Journal, 2010, 45(2),pp.83-97.

[12] Moradi M, Delavar M R, Moshiri B. "A GIS-based multi-criteria analysis model for earthquake vulnerability assessment using Choquet integral and game theory," Natural Hazards, 2017, 87(1),pp.1-22.

[13] Wong, Michelle, King."Developing an Environmental Health Tracking Web Portal to Meet the Information and Communication Needs of Diverse Users," Epidemiology, 2009,20(6),pp.81-89.

[14] Snoek, L. B., "WormQTL—public archive and analysis web portal for natural variation data in Caenorhabditis spp," Nucleic Acids Research, 2013, 41,pp.738-743.

[15] Tatjana Baros, and T. Stojanovic. "Geographic Information System (GIS) In Mapping of Mine Suspected Area in the Republic of Serpska," Hydrobiologia, 2015,457(1),pp.235-244.

[16] Wang Z, Cai X, Yan J. "Using the integrated geophysical methods detecting active faults: A case study in Beijing, China," Journal of Applied Geophysics, 2018,156,pp.82-91.

[17] Yongkang, Chen, Lichun. Active Tectonic Research for Seismic Safety Evaluation of Long-Line Engineering Sites in China[J]. Earthquake Research in China, 2005, 19(3),pp.317-326.

[18] Liu Q, Ruan X, Shi P. "Selection of emergency shelter sites for seismic disasters in mountainous regions: Lessons from the 2008 Wenchuan Ms 8.0 Earthquake, China," Journal of Asian Earth Sciences, 2011, 40(4),pp.926-934.

[19] Becerra A, Podestá L, Monetta R. "Seismic microzoning of Arica and Iquique, Chile," Natural Hazards, 2015, 79(1),pp.567-586.