Acta Technica 62 No. 2B/2017, 129–140

Design and implementation of meteorological prediction and early warning information system for slope geologic hazard based on the WebGIS of RIA

Guan Xinbang[1]

Abstract. In geological disasters, heavy rainfall is the cause of slope geological collapse, debris flow and other disasters, and will lead to greater property, life and safety crisis. Meteorological prediction and early warning information system for slope geologic hazard based on the WebGIS of RIA was designed and implemented; first of all, the present situation of geological disasters was introduced, and the main technologies of the WebGIS of RIA and the algorithms of weather forecast and early warning for slope geological hazard were analyzed; and then meteorological forecast and warning information system of slope geological hazard based on WebGIS of RIA was designed; finally, the application status of early-warning information system in high incidence area of slope geological hazards in China was analyzed. Therefore, the system is helpful for the rescue personnel to carry out remote consultation and decision-making command of the slope geological disaster area.

Key words. RIA, WebGIS, weather forecast of slope geological hazard, early warning information system.

1. Introduction

With the expansion of the population of the world, the scope of human activities expands, and the natural environment is deteriorating, and the occurrence of geological disasters is more and more frequent, which brings more and more serious losses to human society, the incidence of geological disasters is high in China [1]. Geological disasters are widespread, and characterized by extensive distribution, which will produce serious threat to the safety of people's lives and property, affect social and economic development, and restrict the long-term sustainable development of society. Especially in recent years, China's geological disasters occur frequently, the

[1]China University of Mining and Technology (Beijing), Beijing, 100083, China

flood season is affected by meteorological factors, slope geological disasters occur frequently, and any disaster prevention must be based on early warning [2]. The occurrence of geological disasters is a dynamic process of change, and also a very big project for the study and early warning of geological disasters. Therefore, it is necessary to use modern science and technology, information technology and multi-disciplinary collaboration to assist in the study.

Up to now, all countries in the world have set up special geological disaster prevention and prediction institutions. Combined with the knowledge of computer science and geographic information system, a specific information management system for geological disaster prediction and early warning has been developed. With the rise of Internet technology, some countries have basically realized WebGIS based on the publication and application of the geological disaster prediction information system [3]. The researchers have carried out the deformation monitoring of the landslide and timely captured the relevant information of the landslide indications, so as to effectively prevent and control the geological disasters of the landslide. Deformation monitoring generally includes surface deformation monitoring and depth deformation monitoring, and surface monitoring includes geological inspection, simple monitoring of surface instruments, geodetic leveling network [4].

2. State of the art

Since 1980s, great progress has been made in the research and development of the geographic forecast and early warning information system. The geographic information system (GIS) is a tool based computer, which can be used to map objects on the earth and analyze events in detail according to the research and development of the techniques and methods for the prediction of sudden geological disasters [5]. Based on the analysis of boundary conditions and structural elements of geological disasters, the geological hazard environment and various parameters are determined by the number of parameters (experimental or instrumental determination) or linear change values, then the rigid body equilibrium equilibrium theory or the improved limit equilibrium theory is used to establish mathematical expressions or empirical expressions to predict the distribution of geological hazards and dynamic processes [6]. This method is applicable to the prediction and assessment of a single geological hazard (falling gradient), but not suitable for large area regional forecasting [7]. Although specific (especially early) engineering examples play a part, this simple problem gradually exposes the approximate defects of geological disasters and it is always unsatisfactory when predicting the dynamic disaster of instability with the continuous recovery of geological disasters [8].

3. Methodology

3.1. The main technology of WebGIS based on RIA

RIA technology can be introduced, and its visual effects can be added into WebGIS applications to suit the user-friendly needs of the system. Therefore, it's feasible to construct WebGIS architecture under RIA, and the design and implementation of the system are more in line with the idea of object-oriented software development. The main techniques include the following:

The spatial database management system and relational database management system are quite mature, commercial RDBMS not only supports B/S and C/S mode, but also supports data distribution, through SQL and ODBC, almost all GIS software can work together based on public identification numbers. Object relational database technology and object oriented database technology are mature gradually, and become the main technologies of GIS spatial data management in the future.

Life cycle of the whole information system includes object -oriented, object-oriented (OOA), object-oriented design (OOD) and object-oriented language (OOL), and object-oriented data management (OODBM). The object-oriented control database technology is gradually mature, spatial object query language (SOQL), spatial object relational analysis, object-oriented database management, object-oriented software technology and GIS are closely related, and this is a good way to describe geography from the development of object-oriented technology [9].

Client/server has a wide range of meanings, database technology and distributed processing technology are closely related. Data communications and geography operations of client / server are balanced to take advantage of the server's high-performance benefits, handle complex critical services, and reduce network traffic, and users can make full use of the various resources of the network by planning the client / server model of the GIS system [10].

WebGIS not only has the functionality of most or all of the traditional GIS software, but also has the advantage of using Inetmet's unique features. These unique features include that users don't have to install GIS software on the local computer to access remote GIS data and applications on the Internet, perform GIS analysis, and provide interactive maps and data on the Internet. The main features of WebGIS are object-oriented, distributed and interoperable. Any data and functions of GIS are an object. These are deployed on different servers on the Internet and are assembled and integrated when needed, and any other system on the Internet can exchange and interact with these objects. Architecture of WebGIS is as follows (see Fig. 1):

The client will complete three operations:

(1) The first one is to manage user interfaces and deal with application logic.

(2) The second one is to generate a database request and send a request to the GIS server, and then accept the result from the GIS server.

(3) The third one is the formatted result, which is published to the user, and the corresponding function of the network server is to accept the request of the client user and generate the dynamic web page content to return to the client.

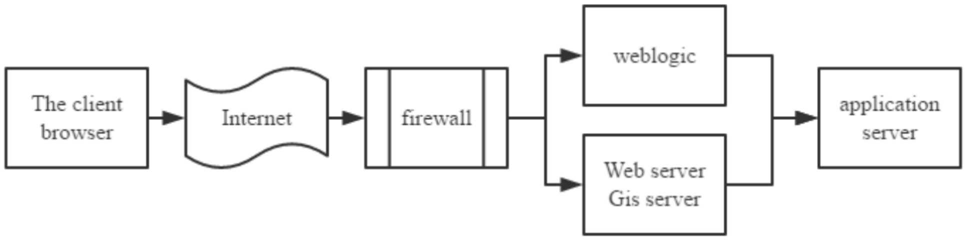

Fig. 1. Architecture of WebGIS

The corresponding functions of the GIS server are as follows:
(1) The first one is to accept database requests from the client.
(2) The second one is the processing of requests of the database.
(3) The third one is the formatted result, which is sent to the client.
(4) The fourth one is to maintain the database.

The implementation of this system architecture is based on the implementation of the server (thin client), that is, clients only need browsers, and no other Java plug-ins need to be downloaded; the server is responsible for dealing with customer's requests, as well as related space calculation, data query and other high load operations, non-map requests are executed on the network server side, while map requests are switched to the ArcIMS application server via the network server, and the result is returned after the server processing of the ArcIMS is established.

3.2. Warning algorithm for meteorological forecast of slope geological hazard

The occurrence of meteorological disasters and geological disasters is a process from chronic change to a variety of natural factors, including human factors. Geological condition is a necessary regulation of MGD, and rainstorm is a sufficient condition for occurrence of MGD. Thus, MGD is a function of geological factors (d), human factors (m), and precipitation (r). That is, MGD $= f(d, m, r)$. For specific regions, MGD is a function of precipitation (R) in the medium and short term forecast of MGD, that is, MGD $= f(r)$, geological conditions and human factors are basically the same. Precipitation monitoring and prediction produce MGD short-term, medium term forecasts and alarms. The prediction of the risk (possibility) of MGD is calculated by the formula

$$\mathrm{MGD}(r) = \sum_{i=1}^{n} Y_i(r) + g\,, \qquad (1)$$

where Y represents the cumulative rainfall of multiple storm periods, $_i$ represents the value in the sample, n is the number of sample data, and g denotes the threshold of the non resistance factor. The principle of the formula is calculated and the relationship between weather conditions and prediction, establish the prediction equation, and assuming that the numerical prediction results exactly, and the numerical results as predictor equation (Hofer et al. 2015 [11]). In addition, the MGD forecast is similar to the strong rainfall forecast, and the general statistical method is used as the model. In daily and fixed-point MGD forecasts, small probability events rarely occur in daily precipitation events (Youssef et al. 2015) [12].

The ETA numerical prediction model is simply referred to as η prediction model, which is a way to forecast by analyzing the intensity prediction of precipitation centers above regional moderate rainfall that is basically consistent with the actual situation. According to the different configuration of weather system, and degree of deviation between rainfall and actual weather is predicted by η model, precipitation predicted by η model is treated as a post process. That is correct for the intensity of center of the rain, position of the rain, and precipitation of each point in the predicted rainfall

$$R_{\mathrm{b}} = \frac{R_{\mathrm{a}}}{R_{\max}} \times R_i + R_i \,. \tag{2}$$

Here, R_i is a forecast of the ETA model rainfall rainfall in value, R_a is the fixed point correction before rainfall, $R_{\max}$ denotes the maximum rainfall data collected before the correction value, R_{b} needs to be corrected after correction for point rainfall. The rain area should be considered in the drift correction effect of average wind speed forecast area and direction on drift. The weather forecast system area forecast rainfall correction and intensive rain drift process of rainfall products using the ETA model (Kadiyala et al. 2015) [13]. Then using the weight method and successive correction method, the prediction of the ETA model lattice into rainfall weighting method is

$$y_0 = \frac{\sum_{i=1}^{n} W_i y_i}{\sum_{i=1}^{n} W_i} \,. \tag{3}$$

Here, y_0 is the ETA model grid point precipitation interpolation to forecast the precipitation forecast value of single station and Y_i is the forecast value of precipitation lattice precipitation at the ith grid point near the single station. Symbol W_i is the weight coefficient of the ith grid point, and n is the total number of samples.

3.3. Design of meteorological forecast and early warning information system for slope geological hazard

The prediction and warning information system for sudden geological disaster makes use of the various functions of GIS which are determined by the characteristics of geological disasters. The uncertainty of geological disasters and the complexity of the interaction among geological factors cause that GIS is used to manage the data of these geological disasters after a large number of basic geological environment data are collected. Effective treatment methods, temporal and spatial distribution of geological disasters are presented in the analysis of the probability of occurrence of geological disasters. Slope geological disaster area and its prevention are shown in Fig. 2.

The system uses GIS technology, network technology and decision support system, and provides decision support system for designing and developing meteorological early warning for geological disasters. The real-time weather information and the

Fig. 2. Meteorological forecast and early warning information system for slope geological disasters

prediction of geological disasters are analyzed through the study of the relationship between geological disasters and their induced factors-meteorological factors [14]. The system automatically receives weather information, once there is the possibility of inducing disaster, the system will reach the threshold of the weather information displayed on the map, a preset warning prediction scheme is automatically entered, a warning device is used to trigger through an alarm device. Through the warning forecast with light sound, alert messages are automatically sent to related personnel of the group defense system and mobile terminals of the population threatened to achieve the purpose of early warning and prediction [15]. The framework of the meteorological forecast and early warning information system for slope geological disasters is depicted in Fig. 3.

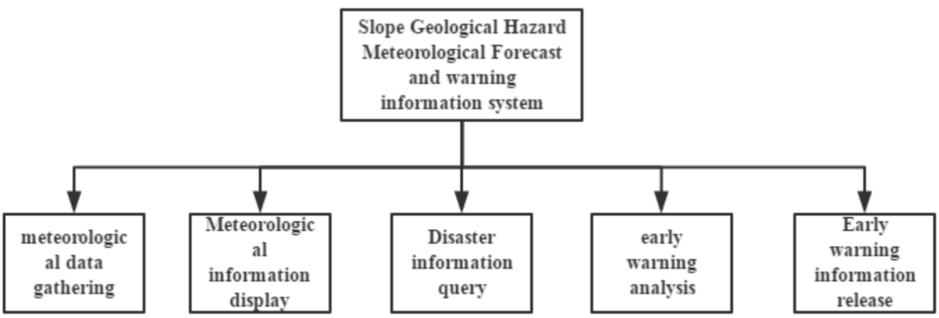

Fig. 3. Meteorological forecast and early warning information system for slope geological disasters

4. Result analysis and discussion

4.1. Configuration and implementation of meteorological forecast and warning information system for slope geological hazard of based on WebGIS of RIA

The meteorological forecast and warning information system for slope geological hazard of based on WebGIS of RIA needs to be equipped with advanced spatial data server software, provides users with greater support for spatial databases, and supports multi-user editing, a large number of spatial databases and any number of users. The system consists of a unified ArcSDE data management for geological disaster, database for prediction and release of sudden geological hazard. The data contained in this database includes: special data of sudden geological disasters, thematic data of rainfall observations reported by flood stations, and the auxiliary basic terrain data. The spatial database is organized according to Table 1.

Table 1. Composition of a spatial database

Data of sudden geological disasters	Forecast map of disaster probability	Ground fissure
		Caving-in
	Disaster spots and disaster prone areas	Mud-rock flow
		Hill-creep
Data of margin observation of news station	Rainfall in the past 1 hour	-
	Rainfall in the past 2 hour	-
Data of basic terrain	Administrative boundaries, water systems, roads	-

The background service program will carry on the real-time update to maintain the updating of the data. Attribute structure of disaster probability forecast chart is set with the field of "Probability", and attribute structure for observing rainfall element class is set with the field of "Rainfall", which are used for thematic symbol rendering respectively.

The configuration of the ArcIMS application server: ArcIMS maps are configured in two main ways: Author and ArcMap. The LAPS system is selected in the map configuration selection ArcMap to publish more complex thematic maps. Two topics need to be published respectively: disaster probability prediction and rainfall monitoring station, they all use basic terrain data to assist in thematic maps and communications. Each observed rainfall elemental class is based on the “rainfall” field, and represented by graduated value and magnitude of rainfall, different sizes and different colors. The prediction of sudden geological disaster is divided into five grades. Among them, the third and fourth levels represent the release of forecast and the fifth level represents the release of alerts with yellow and orange as signs respectively, as shown in the following Table 2.

The probability value of characteristic class stores of the probability field (range 0–1) of prediction of sudden geological disasters is based on the value of field, and presented as unique value. Basic ground features are mainly used to assist display, and display the proportion of different distribution according to management level and visual effect, so that the location of the disaster area is very clear through the realm and place names.

Table 2. Grade of prediction and early warning of geological disaster

Rank	The first level	The second level	The third level	The fourth level	The fifth level
Probability	0.0–0.2	0.2–0.4	0.4–0.5	0.5–0.8	0.8–1.0
Possibility	Little	Less	Large	Larger	Great

4.2. Analysis of application of meteorological forecast and warning information system for slope geological hazard based on WebGIS of RIA

China's slope geological disasters occur mainly in Sichuan and Yunnan Provinces.

Meteorological forecast and early warning information system was applied in the above two areas. The meteorological forecast and warning information system for slope geological hazard based on WebGIS of RIA showed that the relationship between MGD and the current precipitation in Yunnan was: the MGD during period of rainstorm was the pre 0–4 days, the number of storms was between the sixth and the eleventh day. In the precipitation patterns caused by rainstorm and MGD relation models, the key rainfall periods of rainstorm induced in many days were 0–5 days and 6–12 days, the key rainfall period of continuous rainy induction was 0–40 days, as shown in Fig. 4.

Collection and analysis of debris flow and landslide disaster in Sichuan basin were carried out through the application of geographic information early warning and forecasting system based on RIA. In the prediction model η, through the analysis of the precipitation of the same day, the precipitation of the first 3 days and the rainy days of the first 30 days of debris flow landslide, the relevant threshold values for the associated weather forecast and warning information of slope geological hazard were obtained and listed in Table 3.

Table 2. Correlation threshold of meteorological forecast and warning information for slope geological hazard

Fig. 4. Information area map of MGD

Forecast precipitation	Rainfall for the first 3 days	The first 30 days before the rain/precipitation rain fall	The possibility of slope geological hazard
Above 200 mm	≥ 100 mm	≥ 16 days	Great possibility
Below 200 mm	Between 12 and 36 hours 100–200 mm	-	Small possibility
50–10 mm	≥ 40 mm	≥ 16 days	Large possibility
30–50 mm	-	≥ 100 mm	Little possibility

As can be seen from the above data, in the prediction model η, the meteorological information in the time period was all taken into account, the meteorological information such as rainfall during the period of time was compared with the meteorological information of slope and geological disaster, an alarm was issued once the threshold was exceeded to remind local authorities and personnel to take appropriate defensive measures. In addition, according to the forecast data model η, efforts should be made to build appropriate protective structures and equipment on hardest hit areas of slope geological disasters.

5. Conclusion

The prediction information system of slope geological hazard is based on the condition that rainfall is relatively slow in the case of geological disasters caused by geological environment factors, and combines the geological disasters caused by geological and meteorological conditions with slope geology and weather. From the point of view of system analysis engineering, it is necessary to put forward a meteorological forecast and warning information system for slope geological disaster which is cooperative and suitable for the application of prefecture level business by using advanced GIS technology, database technology and computer programming technology. In this paper, the meteorological forecast and warning information system for slope geological hazard based on WebGIS of RIA was studied and designed, first of all, the present situation of slope geological hazard and its loss for people's life were introduced; then, the current situation of the related information technology system of prediction and early warning for slope geological disaster was introduced, and WebGIS of RIA technology, correlation algorithm of prediction and warning, and design framework of the whole system were introduced in detail; finally, the configuration, implementation and application of the weather prediction and early warning information system for Slope Geological Hazard based on the WebGIS of RIA were analyzed. The results show that the system can meet the urgent requirements of disaster prevention and mitigation, and can effectively reduce the slope geological hazards induced by meteorological factors, but there is still a lack of geographical positioning technology.

References

[1] T. Wu, M. Qi, Y. Li, H. Yan: *On the application of RIA technique in WebGIS development.* Bulletin of Surveying and Mapping (2006), No. 6, 208–211.

[2] F. G. Xiong, X. Han, L. Q. Kuang: *Design and implementation of geological hazard forecast system based on WebGIS.* IEEE International Conference on Computational Intelligence and Software Engineering, 11–13 December 2009, Wuhan, China, IEEE Conference Publications (2009), 1–4.

[3] L. Zhong, S. Xiao, Y. Zhou: *Research on the early warning and forecast system of geologic hazards in Hubei province based on WEBGIS.* IEEE International Workshop on Education Technology and Computer Science (ETCS), 7–8 March 2009, Wuhan, Hubei, China, IEEE Conference Publications *1* (2009), 602–606.

[4] W. Li, W. Wang: *Design and implementation of the early warning and forecast system of abrupt geological hazard based on WebGIS.* Journal of Zhejiang University of Technology *37* (2009), No. 6, paper 002.

[5] N. Wang, T. Shi, Y. Li, Z. Lian, P. Ke: *Quantitative assessment on the influence of rainfall on landslides in Jianshi county of Qing river basin, China.* Environmental Earth Sciences *75* (2016), No. 3, paper 241.

[6] W. Chen, B. He, L. Zhang, D. Nover: *Developing an integrated 2D and 3D WebGIS-based platform for effective landslide hazard management.* International Journal of Disaster Risk Reduction *20* (2016), 26–38.

[7] J. N. Munyendo, D. Kuria, K. Mubea: *Development of AWebGIS supported road traffic accident data management system: A case study of Nairobi county.* International Annual Conference on Sustainable Research and Innovation (SRI), 6–8 May 2015, Nairobi, Kenya, Published in the Journal of Sustainable Research in Engineering (2015), 218-227.

[8] M. Ding, F. Wei: *GIS and DWR based short-term and impending landslide forecasting for Liangshan prefecture (China).* Tehnicki Vjesnik - Technical Gazette *22* (2015), No. 3, 695–702.

[9] M. A. Abdelfattah, A. T. Kumar: *A web-based GIS enabled soil information system*

for the United Arab Emirates and its applicability in agricultural land use planning. Arabian Journal of Geosciences *8* (2015), No. 3, 1813–1827.

[10] O. Rahmati, A. N. Samani, M. Mahdavi, H. R. Pourghasemi, H. Zeinivand: *Groundwater potential mapping at Kurdistan region of Iran using analytic hierarchy process and GIS.* Arabian Journal of Geosciences *8* (2015), No. 9, 7059–7071.

[11] B. Hofer: *Uses of online geoprocessing technology in analyses and case studies: A systematic analysis of literature.* International Journal of Digital Earth *8* (2015), No. 11, 901–917.

[12] A. M. Youssef, B. Pradhan, H. R. Pourghasemi, S. Abdullahi: *Landslide susceptibility assessment at Wadi Jawrah basin, Jizan region, Saudi Arabia using two bivariate models in GIS.* Geosciences Journal *19* (2015), No. 3, 449–469.

[13] M. D. Kadiyala, S. Nedumaran, P. Singh, S. Chukka, M. A. Irshad, M. C. S. Bantilan: *An integrated crop model and GIS decision support system for assisting agronomic decision making under climate change.* Science of The Total Environment *521–522* (2015), No. 6, 123–134.

[14] A. Chybicki: *Innovative web-based geographic information system for municipal areas and coastal zone security and threat monitoring using EO satellite data.* Marine Geodesy *38* (2015), No. 3, 203–224.

[15] K. Sowmya, C. M. John, N. K. Shrivasthava: *Urban flood vulnerability zoning of Cochin City, southwest coast of India, using remote sensing and GIS.* Natural Hazards *75* (2015), No. 2, 1271–1286.

Received May 7, 2017