Research on geo-hazard appraisal and decision in highway based on GIS Technology

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Abstract—**On account of the special landform、geology and rainfall condition, Tianshan Mountain influences the traffic normally. It often comes under bedload、coast、dilapidation at one time. This threatens the stability of the road and the security of denizen along the line. It is especially importment of the Geological disaster decision-making sustain Geography Information System in Tianshan Mountain bring to bear the advanced technology, which sustains in the build and manage of Tianshan Mountain. After analyzing the on the theory of geological hazard about Tianshan road in detail, collected the datum of basic geography and geology along the lines of road in the past, and also contrasted the locale results and remote sensing images, building and consummating both the Geography database and the geological hazard database based the platform of ArcGIS after according synthesizing、coordinating、choosing、concluding and changing by the rules of database. Asked on the ArcEngine platform, developing a set of collections foundations data gathering, the memory, the management, the retrieval, the graphic editor, the space model analysis, the line region stability assessment, the highway alignment route selection as well as the three dimensional route flight achievement graph production and the output is a body "The Tianshan highway geo-hazard stability appraisal and the route selection optimization analysis system".**

Keywords- GIS; geological disaster; system develop; Tianshan highway;database

I. INTRODUCTION

Tianshan Mountain locates at the middle of the second ordinate of the highway outskirt which is called "Two vertical & three horizontal" in Xinjiang. It is not only an important component part in the country's western highway construction planning, but also an important component circuit in the defense highway network. Because of the complex topography condition, geology condition and the bad weather environmental factors, the geological disasters (landslide, collapse, debris flow) along the roads occur frequently that influents the highway unblocked seriously. According to the present situation of Tianshan Mountain, the geological disaster data around Tianshan Mountain, the terrain data and multimedia attribute data are obtained through modern measuring technology and multimedia technology. They are managed according to the integrated data model in GIS. The GIS technology is applied in the construction of Tianshan Mountain that could help to evaluate the geological disasters stability of the region and provide some scientific and reasonable solutions for emergency.

Based on the ArcGIS Engine platform, a set of management software which is suitable for the appraisal and decision of Tianshan Mountain geological hazard is developed. The function of the system includes information browse inquiry, stability appraisal and decision support, 3D visualization analysis, etc. The realization helps the related management departments prevent evaluate and manage Tianshan Mountain geological disasters [1].

II. ESTABLISHMENT OF SYSTEM FRAME BASED ON ARCGIS PLATFORM

Based on that the multi-source data of Tianshan Mountain is integrated into the SQL Server 2000 database by the ways of the GeoDatabase storage, the "Tianshan highway geo-hazard appraisal and decision-support system" is developed with the integrated technology of ArcEngine and Visual C# 2005. The spatial database engine of ArcSDE manages the database of the system. The functions such as the acquisition, storage, management, retrieval of the basic data, graphical editing, spatial model analysis, regional stability appraisal, highway geological routing, 3D visualized analysis and results output are included in the system [2]. The main framework of the system is analyzed from the following 4 aspects:

A. Integration of multi-source data

The following four types material are integrated in the system database. The first type is the fundamental geographic data, includes waterline, administrative division, geographical tagging, terrain, economy, population, rain, snow, temperature, etc. The second type is geological data, the elements contains rocks, geological structure, fault, and geological disaster, etc. The third type is remote sensing data which is the ETM+ images of Tianshan Mountain (Duku section). The four types are the other data which is processed from the basic data, such as the digital elevation model (DEM) and the normalized difference vegetation index (NDVI), etc. [3,4]

B. Appraisal of regional stability & Geological analysis of highway routing

The main destination of the regional stability appraisal based on GIS is stability rank and intuitive special charts. The

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theoretical basis of the appraisal is engineering geological analogy [5]. This method predicts the spatial distribution of the future disasters according to the existing terrain variables which are related with the spatial distribution of the disasters [6]. Combining the information model, the special charts of geological stability are calculated with the powerful data management and spatial analysis in ArcGIS. They are the decision-making basis for highway routing. GIS is utilized in geological stability appraisal along the highway, that each factor which could influent geological stability is regarded as a vector layer and overlaid by relevant mathematical model; the stability of geological pixels is computed from the known ones.

The cost superposition is the research basis for highway routing. First of all, the factors which affect the highway routing design are rasterized and their dimensions are unified so that the cost raster data which comprehends many single factor index is obtained[7]. On this basis, the highway starting point is inputted artificially, and then the minimum cumulative costs from the starting point to each pixel and route direction are computed. Finally, the end point is inputted that calculates the optimum route of the lowest cost.

C. *Prediction and prevention for geological hazard*

The function of the powerful space analysis in GIS and the various kinds of mathematical model are combined. In the regional geological risk assessment, the methods of information quantity, fuzzy comprehensive appraisal and multiple regressions are adopted. In the geological disasters appraisal of single point, the forecasting methods such as Q system classification, RMR system classification, TSMR system classification, fifteen factors, etc are all realized by secondary development based on ArcEngine platform [8]. At the same time, in the process of the calculation and prediction of geological disasters, the prevention projects of geological disasters are closely integrated [9]. The various prevention measures which are suitable for Tianshan Mountain are integrated into the system database.

D. *3D visualized analysis*

Combined with the 3D visualization module in ArcGIS Engine, the 3D graphics visualization and the response to mouse operation could be done on the basis of the top interface SceneViewControl by ArcEngine[10]. The data integration of the system follows the uniform spatial data model, the different details and different levels of data are organized and managed uniformly. Then the GIS spatial database is built. These data contains geological disasters data, terrain data (DEM), images data and multimedia attribute data (Such as images, video and audio). The required data is chosen according to the involved scene size, complexity, goal around Tianshan Mountain [11]. The reasonable details level is divided that could realize the 3D visualization of Tianshan Mountain area. Also, it is able to inquire spatial information and analyze terrain profile.

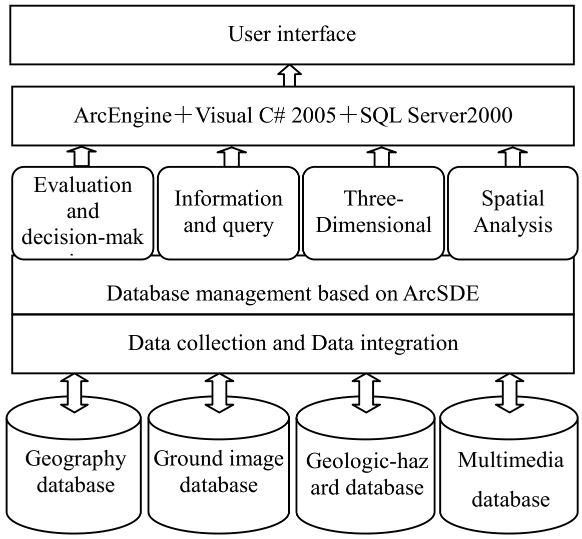

Figure 1. The frame of System structure

III. REALIZING PROCESS OF MAIN FUNCTION

A. *Appraisal of region stability*

The appraisal of region stability is a process of quantitative analysis from qualitative analysis. In the development process, combining the appraisal model of information content with the space analysis function of ArcEngine, which is based on spatial database and raster data in the study area, the special charts of the geological stability in the study area by Visual C# 2005 and ArcEngine is finished(Fig.2) [12].

The main process of the appraisal of region stability includes 3 modules, which include in vector stack module, index system module and geological stability appraisal module. Vector stack module shows that each layer corresponding to every factor is stacked that the final vector layer contains all fields of appraisal factors; Index system module is not only must do, but also the most important step in the process of the geological stability appraisal, which include the three specific functions: new index system (a), maintain and update index system (b), quantify qualitative indexes(c); Geological stability appraisal module takes the information law as analysis model in this module, and makes the special charts of the geological stability appraisal in the region through programming.

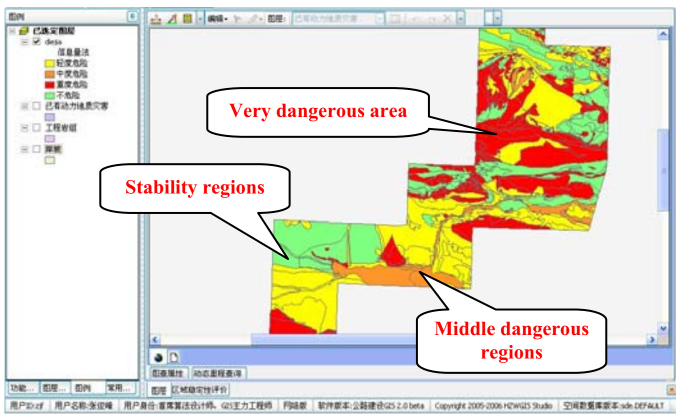

Figure 2. The result of evaluate and analysis in the region stability based on Information Model

B. *Geological location of highway*

On the basis of regional stability analysis, the geological structure stability in the region could be estimated quantitatively. In the process of routing, the man-machine interactive interpretation which is based on this conclusion, It is adopted as the research mentality, so that the highway route could be calculated dynamically. It provides a solution for collecting information rapidly in the mountain region which has a lot of geological disasters. The steps of the system realization are follows: Firstly, the multi-factor and multi-level raster are overlapped with spatial analysis module in GIS. Secondly, the option of the grid units is compared. Then connect automatically. Lastly, the route scheme is formed. It is shown in Fig.3.

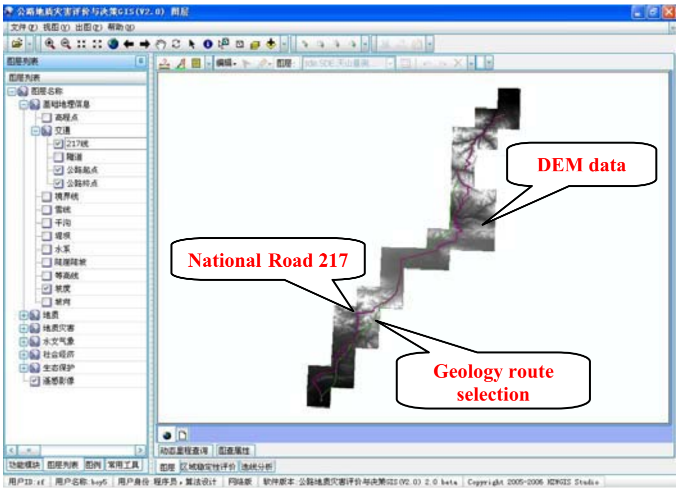

Figure 3. The analysis picture of highway geology routing

The highway geology routing mainly includes three process, they are:

- Grid re-classification. In the analysis of routing, the stability raster data, the slope raster data and the land-use grid data are utilized. In order to eliminate the dimensional effect, the data of slope and land-use need to be reclassified before routing analysis, so that all kinds of data has valued comparability (The stability result is divided into 1-4, so the repeat division doesn't need to do). The classification principle is that the higher level, the lower probability of route through.

- Grid weighted superposition. In the analysis of routing, because of the different contribution of each factor for route, the different weight is attached to each grid according to its importance. The result after stacking is Σ (Weight × Grid pixel value), each pixel value represents the cost when route passes.

- Optimal path generated. In the process of system design, the principle of "people-oriented" is persisted. The operation procedure for user is simplified as possible. Therefore, the distance cost and direction cost are generated in the backstage. In addition, the temporary files are not produced. In this step, using the generated cost data on step, the optimal path, namely vector line through grid pixels with the lowest cost, is got after inputting the beginning and end of the highway.

It follows that the more man-machine interaction, the more practical in the application process. The weight of each factor must be made sure objectively and reasonably, so that the path with the lowest cost and the actual needs must be able to designed after modifying and contrasting repeatedly.

C. *Realization of 3D visualization*

The 3D visualization is a tool which is used to show, describe and understand many geological phenomenons in the surface and underground. In the geology and geophysics, the 3D visualization is widely used. It is a method of describing and understanding model. It is a representation form of data body rather than simulation. It is able to check material continuity and identify material authenticity by use of a great deal of data. It could find and put forward the useful abnormalities, which provides useful tools for analyzing, understanding and repeating data. All of these will be convenient for communicating multidisciplinary.

According to the established scene model and the runtime parameters of each entity object in the scene, the 3D visualization in GIS produces real-time scene. Furthermore, it contrasts the geology optimizing route with the original route in the 3D space, so that it helps manages comprehend the relationship of the spatial data intuitively. In the process of development, the top-level interface which is called SceneViewControl by ArcEngine, It is used to display 3D graphics and respond to mouse operation, etc. With the interface of Imap, Idisplay, IrubberBand and Ienvelope in ArcEngine object repository, the information is transferred to 3D view from 2D view. In the process of realization, the control which is called axSceneControl is responsible for the 3D display of passing-over layer and response to the mouse operation. The concrete realization interface is shown in Fig.4.

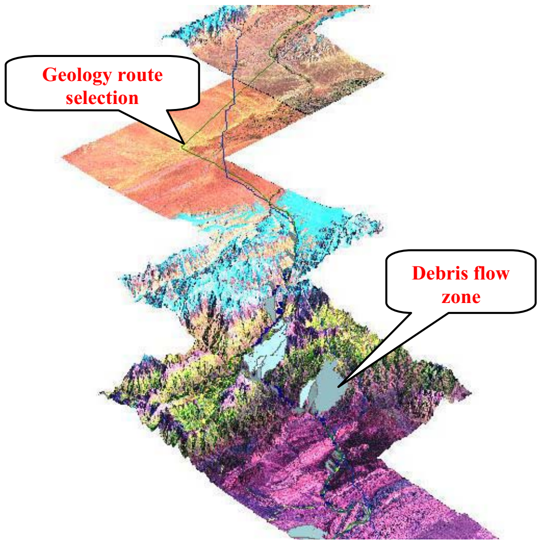

Figure 4. The picture of 3D Visualization analysis

IV. CONCLUSION

The powerful development tool of ArcEngine component use GIS in the appraisal and management of highway geological disasters, which could inquiry, analyze and manage the spatial database, and also integrate the expert database of prediction and prevention for geological hazard. That provides operating platform for prediction and prevention for Tianshan Mountain. The system architecture which is combined with application model and mathematical formula of engineering geology, fully manifests "GIS+professional" design ideas. By adopting the index system and stability appraisal method model, the regional stability appraisal around Tianshan Mountain is done that the risk appraisal map is finished. Meanwhile, the map is one of the geological factors of highway routing. It's both organic union. The shortest path algorithm based on the grid plays an aided decision-making function in geological routing of Tianshan Mountain. The 3D visualization module integrates the different types of data and multimedia information so that the space information query and analytical functions based on 3D is realized. The whole system will provides a kind of reliable decision-making management platform for land resources management department and traffic construction administration department.

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