RESEARCH ON HIGH-CUT SLOPE INFORMATION MODEL OF THE THREE GORGES AREA*

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ABSTRACT:

Taking advantages of geo-spatial technology integrated with monitoring methods, and aiming at high-cut slope monitoring and management, this paper proposed a new concept of high-cut slope geo-spatial information model and its corresponding constructing methods. The geo-spatial information is described from individual slope scale to regional scale, which combines multi-level information so as to construct a new convenient way to manage and analyse all the information related with the security of high-cut slope in Three Gorges Area.

1. INTRODUCTION

In the mountain area, various construction projects, newly built ways (especially highways), bridges, large-scale construction of urban infrastructure and housing, will inevitably result in excavations and slopes. The destruction of landslide's original stable state may cause instability or deformation, collapses, stone falling and other geological disasters.

Many researchers have done a lot of works on landslide, and some of them can be adapted to high-cut slope in Three Gorges Area. However, from some aspects, there are some disadvantages in these models, such as:

1. To some extent, some models over-reliance on mathematical method. In fact, multi-level and holographic information is often needed so as to be more objective;

2. The visualized expression of existing model needs further improvement. It is necessary to study the influence factors of high-cut slope from both regional scale and individual slope scale as to get macro and micro information related with the objectivities.

3. It is difficult to improve the accuracy of short-term disaster simulation and forecast because of the shortage of the data before and after the damage of stability. Geo-technology may be helpful to solve the problem.

Since the 1990s, Remote Sensing (RS), geographic information system (GIS), global positioning system (GPS) (3S) play an important role in monitoring, analysis evaluation and prediction of landslide disaster. With the help of 3S technology and comprehensive monitoring system for geological disasters, it is possible to provide multi-level information support, from micro level such as individual high-cut slope to that of macro level, in which regional geological information is concluded. For this purpose, a geo-spatial information model is proposed in this paper.

2. HIGH-CUT SLOPE GEO-SPATIAL INFORMATION MODEL

2.1 Research Levels of the Information Model

In this paper, the concept of spatial information of high-cut slope refers to its general content, and it includes the whole spatial information factors of the slope. These factors include the monitoring point information, the individual slope information and the regional geographic information such as geography, environment, hydrology, geology, meteorology and land cover.

The geospatial information model for early warning of the high-cut slope stability may have the following three features:

1. The holographic expression of the high-cut slope including the ground and underground information;

2. The multi-level expression, which is expressed as point-individual-regional information. Point information refers to the monitoring site, individual information includes all the information related to a specific slope and the regional information is regarded as the regional data corresponding with the stability of the region where the studied high-cut slopes are.

3. The complete digitalization of geo-spatial information.

Geo-technology reveals a better way to fulfil the above three demands. Basically, our research on the high-cut slope disaster early warning information began with three levels: abstraction level, methodology level and application level (Figure 1). The abstraction level only summaries micro and macro elements on the spatial information model, and only concept and semantic aspects are concerned in this level; In methodology level, the research aims at the methods of construct the spatial information model and the expression model, which is based on the models created by abstraction level; The application level research refers to the high-cut slope stability early warning based on all information models being created.

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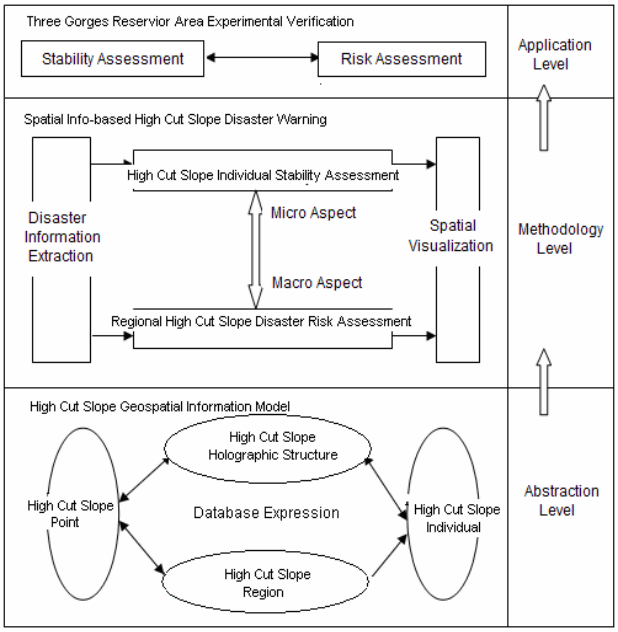

Figure 1. Research levels of geospatial information model

2.2 Construction of High-Cut Slope Geo-spatial Information

2.2.1 Research Status of GIS, GPS and RS Technologies in Landslide Monitoring and Early Warning

The functions of 3S technology in landslide monitoring are (Fu Xiaolin, 2004): Usually, RS(remote sensing) is regarded as an important data source used to construct and update the geological thematic database, which is use in GIS, such as the developing characteristics of geological disasters, the formation lithology, regional structure and other geological environment, ecology resources, etc); GPS provides GIS with spatial coordinates, which can accessed to the surface of target elements of disaster (such as the elevation, borders and deformation monitoring points and three-dimensional coordinates, etc); GIS is used as an efficient tool of the storage, processing, analysis, classification functions of the multi-source data (such as topographic maps, land use, weather, vegetation, basis of geology, hydrogeology and engineering geology, geological environment and geological disaster monitoring, prevention and treatment projects, remote sensing images, GPS and other spatial data). GIS also has the advantage of the spatial analysis of multi-source data and two-dimensional or three-dimensional expression of the former analysis results.

3S technology in landslide hazard assessment and geological research mainly focused on landslide spatial evaluation, forecasting and mapping. GIS can be used as analysis tools for landslide risk assessment (Christian Conoscenti, 2008); Logistic regression model, remote sensing and GIS have been used for landslide risk mapping (S.LEE, 1005); Gao Kechang took Wanzhou of Chongqing as an example, and studied GIS application and information model-based landslide disaster assessment (Gao Kechang, 2006); High resolution remote sensing image has been used for quantitative assessment of landslide risk (N.-W.Park, 2008); ASTER image data has been used for the Three Gorges valley landslide hazard assessment (J.G.Liu, 2004); Hu Deyong discussed the way of using GIS and RS method to obtain and manage the high-cut slope disaster information, and also discussed high-cut slope spatial forecast methods under the hot and humid tropical rain forest region (Hu Deyong, 2007).

It is well accepted that geo-technology is helpful for geological disaster warning. Our research aims at taking good advantage of geo-technology, which as characterized by 3S technology, so as to combine 3S technology and geological disaster warning methods together to make the disaster warning more convenient.

2.2.2 Relevant Research Content of the High-Cut Slope Geo-spatial Information Model

The research is based on the high-cut slope semantic model, which is used to create high slope disaster early warning spatial information models. The main works are as the following:

(1) Regional level spatial information modeling: with the geospatial information modeling theories, the spatial continuous object collections and spatial scattered object collections should be analysed. The regional level model may be accomplished based on the concept of domain and object oriented spatial information modelling ;

(2) RS-based information modeling: This research studies RS-based information modeling method of the high-cut slope regional and individual levels. The perspectives of this research are remote sensing, imaging mechanism and geographic driving force, integrated with image information and geographic theories;

(3) Research on GIS-based information modeling: This research focuses on GIS-based information modeling method of the high-cut slope regional and individual levels. The perspectives of this research are visualized expression and geographic theories of GIS;

(4) Research on integrated monitoring data modeling: This research studies the modeling method of internal characteristics of individual high-cut slope, which based on landslide monitoring data and mechanism of landslide internal stress;

(5) Research on holographic spatial information modeling: Base on the results of (1) to (4), this research explores the holographic spatial information model, and analyzes the integrated expression of landslide disaster from both regional and the individual factor. This research also studies corresponding relationship between factors. The research also studies high-cut slope macro-micro integrated three-dimensional visualized expression model;

(6) Research on dynamic analysis modeling: Base on the results of (1) to (5), this research studies a timing and spatial related comprehensive modeling method in order to create a landslide disaster dynamic information analysis model and spatial information analysis model;

(7) Research on spatial-timing high-cut slope disaster early warning modeling: Base on the results of (1) to (6), through the spatial statistical regression and spatial structural adaptive model, the research provides a spatial-timing high-cut slope disaster early warning model.

2.2.3 High-cut Slope Information Model based on GIS, GPS and Remote Sensing Technologies

For the advantages of geo-spatial technology (including GIS, GPS and RS) in high-cut slope disaster monitoring and early warning, this paper provides a high-cut slope information modeling solution (Figure 2).

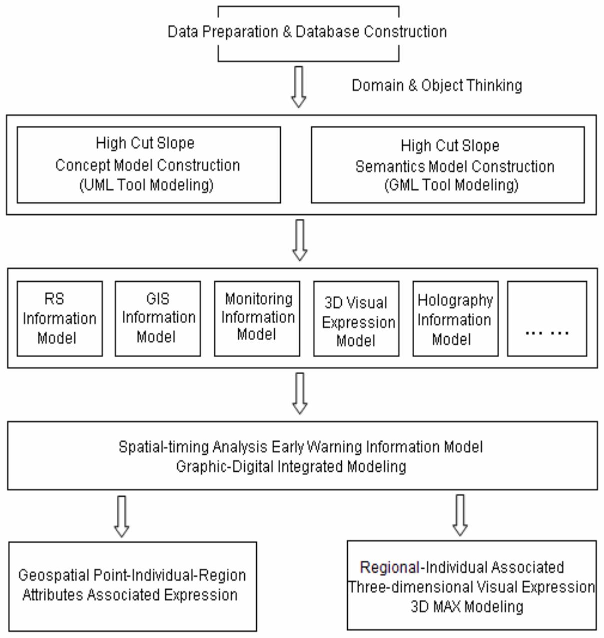

Figure 2. Contents of the high-cut slope information model

First of all, by referring relevant literature, We build a GIS database through spatial data engine (SDE), which includes the necessary multi-source spatial data on point, individual and regional levels of high-cut slope;

Second, based on the analysis of multi-source data and information from the high-cut slope point-individual-regional, the integrated factors which will cause disaster are summarized and extracted. These integrated factors include topography, climate, vegetation, geological structure, and other regional factors. These also include individual shape, composition, structure, stress and other related factors. On this basis, the high-cut slope disaster concept model is created, and express by unified modelling language (UML);

Third, we use geography mark-up language (GML) to express the semantic model of high-cut slope disaster. This expression is based on the concept model created by UML. This expression also lays foundation for building the high-cut slope disaster spatial information model and implementation of relevant algorithms;

Fourth, based on high-cut slope regional and individual features, and through visualized means such as map, graphic, image, analyze the visualized expression on high-cut slope point-individual-regional levels and reveal the digital features of high-cut slope, and establish initial understanding of landslide disaster spatial information expression;

Fifth, by selecting spatial and non-spatial information variables of regional and individual high-cut slope disaster early warning analysis based on graphics, image science, map algebra and geological disaster theories, research the standards and measurement of high-cut slope information expression, and then establish the expression methods on high-cut slope point-individual-regional levels;

Finally, integrated with 3D MAX modeling tool, and through OpenGL and GML, develop the three-dimensional visualized expression of the high-cut slope information.

3. MULTIPLE SCALES OF THE INFORMATION MODEL

Multi-source data is the foundation of high-cut slope information model. Taking the Three Gorges Area as experimental area, we select RS data (SPOT5, IKONOS, QuickBird, aerial photos), basic geographic data (residents, roads, contour lines), thematic data (geology, vegetation, precipitation), high-cut slope monitoring data (displacement, drilling tilt, acoustic emission rate) and basic data (data from slope's planning design stage, survey and design stage, construction management stage and inspection phase of the evaluation stage, etc) and social and human data, and other heterogeneous data as the source of experimental data and, then use ArcSDE and Oracle9i to create The multi-source data database. In this paper, the landslide spatial information model can be abstractly summarized from three scales: point scale, individual scale and regional scale. Each scale has its different factors for disaster expression and description.

3.1 Point-scale Information Model

Point-scale model is the most microscopic foundation in spatial information model and also the minimum monitoring unit which is the basis of high-cut slope disaster monitoring. Point-scale model is multi-feature which includes: spatial position features, timing-sequence spatial feature and other attribute features.

3.1.1 Spatial Feature of the Point

Spatial feature of the point mainly refers to the three-dimensional coordinates. The coordinate can be obtained in variety ways such as GPS monitoring network, total station measurement, etc (Figure 3 is an example of monitoring point records).

监测点编号	区域	高切坡编号	高切坡名称	X	Y	H
GPSJC006	王家坪	FJ复0005	王家坪片区高切	3434800.7	352050.26	0
GPSJC005	王家坪	FJ复0005	王家坪片区高切	3434798.8	351866.23	0
GPSJC001	王家坪	FJ复0001	王家坪片区高切	3434838.3	352034.79	0
GPSJC002	王家坪	FJ复0001	王家坪片区高切	3434872.5	352114.51	0
GPSJC007	王家坪	FJ复0005	王家坪片区高切	3434781.4	352100.84	0
GPSJC004	王家坪	FJ复0005	王家坪片区高切	3434796.5	351822.96	0

Figure 3. Monitoring point records

The expression or storage of the spatial information in database is also multiple. As shown in Figure 4, the upper graph is vector expression example and the lower one is raster-vector overlapped expression example (the raster data is selected from IKONOS image).

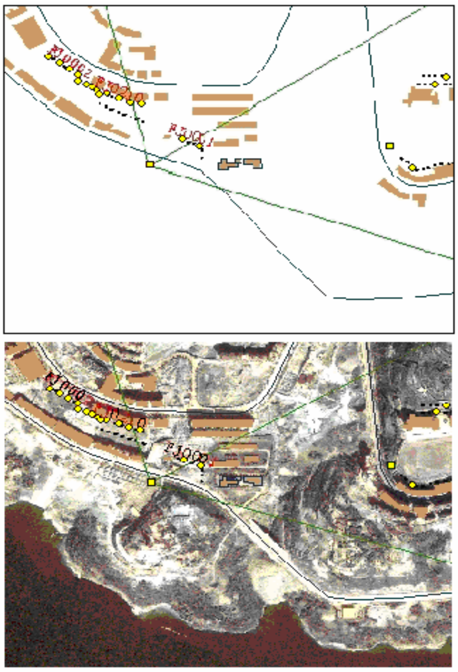

Figure 4. Vector and vector-raster overlapped expression of point's spatial position

3.1.2 Timing-Sequence Spatial Feature of the Point

Timing-sequence spatial feature mainly refers to the deformation data of the monitoring point. This feature is the most important basis of landslide disaster monitoring and prediction, and the deformation characteristic is a direct reflection of the whole landslide's stability. Table 1 is an example of timing-sequence displacement data of a point.

Date	Displacement (cm)
1/8/1984	323.2
1/9/1984	326.3
1/10/1984	342.1
1/11/1984	362.5
1/12/1984	390.6
1/1/1985	434.9
1/2/1985	489.3
1/3/1985	550.3
1/4/1985	622.2
1/5/1985	751.1

Table 1. Displacement data of a monitoring point

3.2 Individual-scale Information Model

As every high-cut slope is of the relatively independence and is the kernel of stability analysis and early warning, information of individual high-cut slope become the mainstay of the whole information model (Figure 5 is an example of typical landslide displacement-time curve).

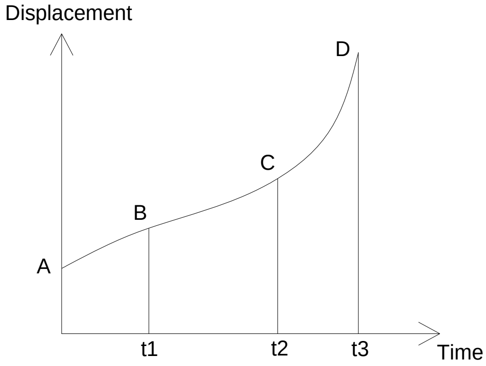

Figure 5. Typical landslide displacement-time curve

In landslide data management, stability analysis and disaster prediction, there mainly involves three types of data: Basic geographic information data (such as location, area, volume and stereo geological profile, etc), feature data (such as material, monitoring methods and monitoring staff, etc) and prediction model parameter data (the methods work on spatial data and feature data), so GIS can be used as the graphics platform, thus achieving a rapid spatial data management, automatic access to model parameters, graphics rendering and the results of visualized expression, and other functions. So from the view of management function, the database should include three parts: spatial data management, feature data management and prediction model data management; while from the view of expression, it contents graphic-digital integration (graphic and non-graphic data. Figure 6 is spatial information of high-cut slopes extracted from remote sensing image and Figure 7 is its' corresponding attributes).

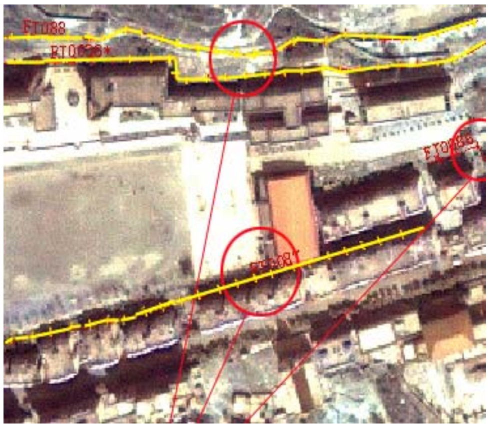

Figure 6. Graphic expression of high-cut slope

高切坡编号	高切坡名称	安全等级	治理情况	坡长	面积	坡高	切坡类型
FJ0221	施家梁高切坡						
FJ0012	施家梁高切坡						
FJ0222	施家梁高切坡						
FJ0063	施家梁高切坡						

Figure 7. Non-graphic data

3.3 Regional-scale Information Model

The high-cut slope point-scale and the individual-scale model are from relatively independent and macro level to describe the spatial information. But if there are only these levels, the model can hardly provide holographic information. It is necessary to study landslide regional factors which will impact the stability of high-cut slope. These factors include regional climate, surface water distribution, geology, geomorphology, social and human, and so on. It should also integrate with GIS, GPS and RS technologies to obtain high-cut slope regional macro-level information factors systemically (Figure 8 is an example of regional vector data of Zigui county of Sichuan province).

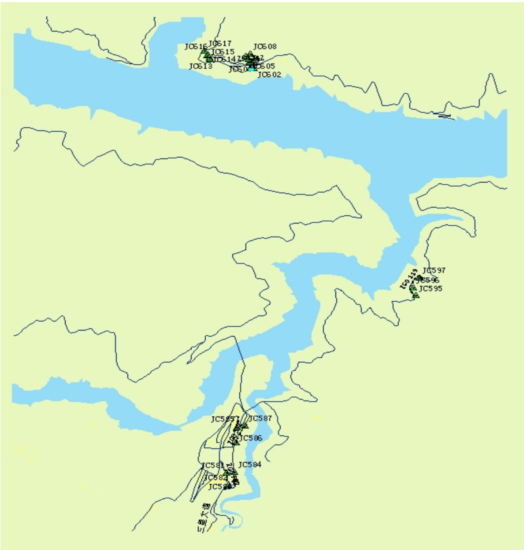

Figure 8. Example of regional vector data (Zigui.Yichang)

Because of its obvious advantages, such as easy access to wide scope data, faster information obtaining, and shorter cycle and so on, remote sensing technology is valuable for construct the regional-scale landslide spatial information model. At the same time, the use of different resolution remote sensing data, the regional-scale model can provide different levels of information on the Three Gorges Reservoir Area coverage (Figure 9 and Figure 10).

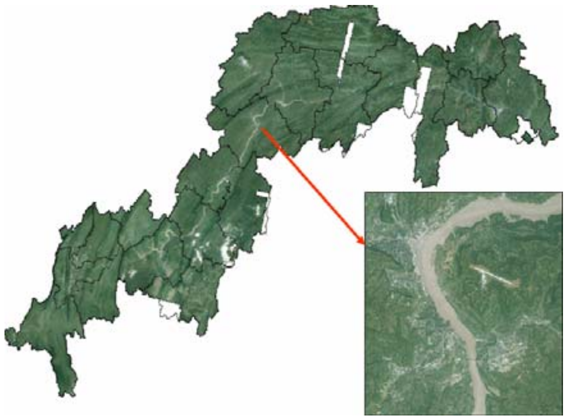

Figure 9. SPOT5(10m) multi-spectral remote sensing data coverage (Three Gorges Reservoir Area)

DEM data with the combination of remote sensing data can also provide a three-dimensional expression and analysis model from regional scale (Figure 11).

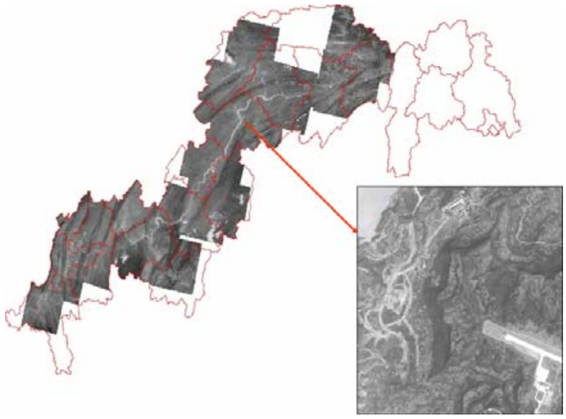

Figure 10. SPOT5(2.5m) panchromatic remote sensing data coverage (Three Gorges Reservoir Area)

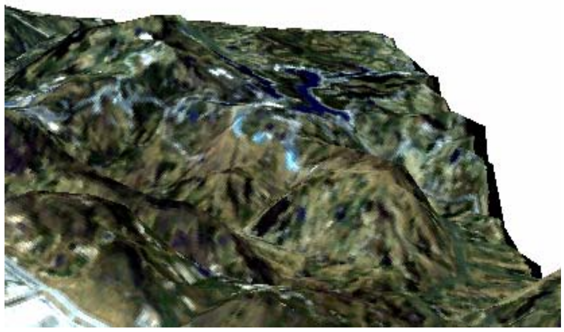

Figure 11. Three-dimensional model expression example

4. CONCLUSION AND DISCUSSIONS

This paper describes the concept of high-cut slope information model, and also discussed the methods of constructing 3S-based holographic geospatial information model. These theories can be used to comprehensively express both high-cut slope disaster regional and individual level information, and also can be used to implement the integrated 3D visualized spatial expression of high-cut slope regional factors, surface status, and internal structure, stress, strain, etc. These theories will enrich the theory and method of high-cut slope disaster early warning analysis, and provide a more theoretical, scientific and practical new way of exploring early warning of high-cut slope disaster.

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