3D Computational Modeling and Stability Analysis of Highway Slope: A Case Study from the X104 Section in Ganxian County

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Abstract: Highway planning requires geological surveys and stability analysis of the surrounding area. In the early stage of the survey, the modeling and stability analysis of the survey area can be carried out by using GIS software to intuitively understand the topography of the study area. The use of DEM to extract terrain factors can be used for simple stability analysis and the source data is easy to obtain, simple to operate, fast to analyze, and reliable analysis results. In this paper, taking the X104 road section in Ganxian County as an example, the ArcGIS platform is used to carry out 3D modeling visualization and stability analysis, and the stability evaluation map of the study area is obtained.

Keywords: 3D modeling; Stability; GIS; Highway planning

1. Introduction

Three-dimensional geological modeling involves constructing geological information within a three-dimensional environment on a computer and creating models for spatial information management, geological interpretation, spatial analysis and prediction, geological statistics, entity content analysis, and graphical visualization. It is a key technology widely used in geological exploration, digital geology, geophysics, mine surveying, mining geology, and GIS [1–3]. It is an emerging discipline formed by the intersection of graphic, image, and scientific computing visualization [4, 5]. Compared with the traditional two-dimensional method, the dynamic display effect of three-dimensional geological modeling can make people understand the complex geological spatial relationship more intuitively. It can provide verification and interpretation for survey and experimental work, and the geological analysis function is powerful [6, 7]. Volume visualization technology uses 3D voxels to describe objects, including all the information inside and outside the object, which provides a strong theoretical basis and visualization approach for 3D geological modeling, but the relevant algorithms are still insufficient and need further research

and improvement[8].

2. ArcGIS spatial analysis method

It consists of server components, mobile and desktop applications, and developer tools that interact with each other through the ArcGIS REST API and common file formats.

Spatial analysis is the analysis and operation of spatial graph data or other data in the spatial database, as well as the mixture between the two. Spatial analysis is the most unique function of GIS, and it is also the most essential difference between GIS and other information systems. The terrain factor analysis algorithm based on DEM is now very mature and the extraction and analysis of terrain factors can be quickly carried out by GIS software[9, 10].

3. 3D visualization of the surface model

The combination of 3D visualization technology and GIS technology has produced 3D GIS, which can query and manage spatial information and display 3D models. Whether 3D visualization can be realized is also an important difference between 3D GIS and 2D GIS[11–13]. ArcScene is the 3D visualization and analysis module of the ArcGIS Desktop product family, which can more intuitively understand the undulating form of regional terrain or interpret the location of slopes and valleys in 3D scenes than floor plans[14, 15]. Based on the DEM data of the study area, a three-dimensional geological model of the study area is established as shown in **Figure 1**.
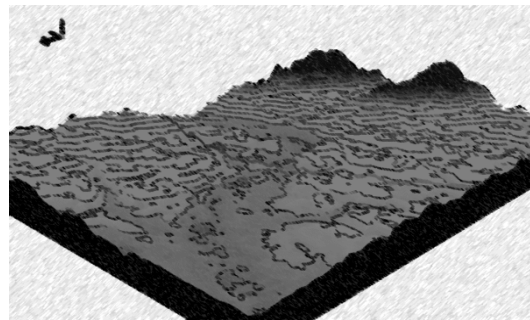

Figure 1. Three-dimensional geological model of the study area.

4. Discussion and Conclusions

Because the units and dimensions of the various terrain factor layers are different, they cannot be calculated directly. Therefore, it is necessary to reclassify and assign values to these layers before applying weights. The scale of each factor should be determined based on the actual situation to ensure consistency and accuracy in the analysis[16]. As can be seen from the **Figure 2**, in the study area, the red area is more stable and the green area is less safe. Most of the areas passed by the study section are stable areas, which are suitable for the route selection of highways, which verifies the conclusion of the stability analysis in this paper.
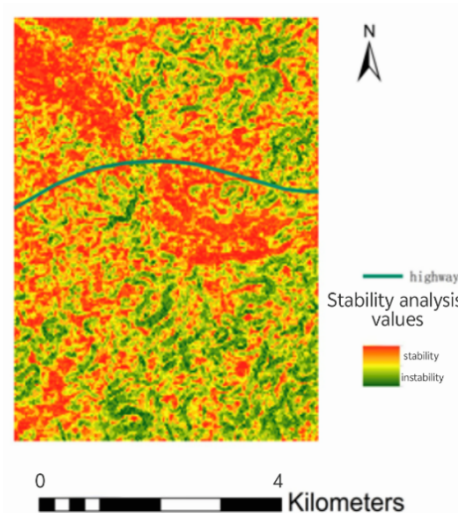
Figure 2. Stability analysis results of the study area.

In this paper, GIS spatial analysis and 3D visualization methods are used, and the main results are as follows:

(1) ArcScene has powerful 3D model modeling and display capabilities, as long as DEM data is provided, it can quickly generate a visual 3D surface model of the area, which can intuitively reflect the topography of the area and facilitate the communication between designers and construction personnel.

(2) Use the method of weighted superposition analysis to evaluate the stability of the regional slope, although the conclusion can be quickly drawn, but directly divide each factor into four grades for evaluation and there are many areas between the two grades in the results obtained, such an analysis is fuzzy, so whether the data can be processed more accurately when reclassifying and assigning each terrain factor will directly affect the reliability of the results.

(3) The use of DEM to extract topographic factors for regional stability analysis, the data source is easy to obtain, fast, and the working cycle is short, but the factors such as regional geological lithology, faults, weak structural planes, groundwater, earthquakes and rainfall are not considered. Regional slope stability evaluation is more to find the possible unstable areas in the study area, to prepare for the subsequent higher degree of investigation and evaluation work.

(4) The actual route selection of this section is basically located in the stable section, which confirms the stability analysis results of this paper.

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Disclosure statement

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