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Spatial data integration of 3D GIS and visualization technology

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Abstract. GIS technology is more and more widely used in production and life, but the study and apply of 3D GIS are urgent because the traditional two-dimensional model is difficult to meet the needs of people. The application facing the geometric field was combined with the discrete fitting idea, the spatial database was converted through AutoCAD graphical data, the automatic modeling was achieved by the hierarchical representation strategy and discrete algorithm, finally, the OpenGL was used to exaggerate the visualization of 3D models. In order to verify the feasibility and reliability of the technology, the drilling data information of geological exploration and production exploration in a mine was selected for analog simulation, therefore, the 3D model that can slit, browse and roam, and can be applied in specific engineering practice was successfully constructed.

Key words. 3D GIS, spatial data, visualization, geology.

1. Introduction

In the information age, the demand for information is increasing, and the requirements for its accuracy and real-time are higher. In this social situation, geographic information system (referred to as GIS) comes into being, and it is applied to production and life [1]. GIS can carry on the storage and processing of the spatial location information of the research object, which makes the GIS more widely used and have more functions. With the extension of the application of GIS technology, it has developed into a new science which integrates information science, surveying and mapping remote sensing, environmental science, computer science, management science and so on [2]. Western developed countries have already started the research and application of GIS technology. According to statistics, they have doubled their investment in the GIS system every two or three years [3]. However, the research in GIS in China started late. Although it has developed rapidly and achieved some results, the related technologies are not still mature enough to be popularized widely [4]. The results of existing GIS research are more focused on the description of

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two-dimensional spatial information, so it is difficult to give people the most original feelings of nature [5]. In this case, three-dimensional GIS technology needs to be used to truly show the three-dimensional spatial information for building the information system which integrates the collection, analysis, management and reproduction of information data. The research aims at the analysis of 3D GIS spatial data integration and visualization technology for geological applications, which has certain research value for the development of 3D GIS technology in our country.

2. State of the art

The earliest research of GIS originated in the 80s of last century, and more and more scholars began to study the three-dimensional GIS with the deepening of research and the promotion of application of GIS [6]. In the initial study, the three-dimensional GIS system is used mainly in the special applications of geology and mining and other similar areas, and the spatial analysis is realized by constructing a gridded data model, in this case, the functions of GIS are relatively single [7]. Thus, the initial three-dimensional GIS system can only perform simple spatial analysis, the three-dimensional GIS system has considerable technological progress in spatial analysis ability with the in-depth study of people, but it is still not put into practical engineering applications [8]. With the development of computer technology, the three-dimensional query and display functions of 3D GIS system are unable to meet the needs of people, many analog systems begin to combine traditional GIS technology with 3D visualization technology, so as to realize the access and visualization of mass data on the basis of database [9]. In recent years, with the development of network technology, GIS research has begun to develop towards the Internet network, formed a Web-GIS on the basis of the Internet, and published spatial data on Web, so as to provide users with relevant analysis, query and browse functions of spatial data [10]. At present, many commercial GIS systems are added with 3D GIS modules, and terrain analysis and real-time three-dimensional flight browsing are implemented by using three-dimensional terrain data related to data sets of remote sensing image [11]. However, the focus of these 3D GIS systems is the analysis of topography with two-dimensional surface, and the two-dimensional data which is displayed in the three-dimensional environment cannot really be called the three-dimensional GIS system. [12]. However, it is necessary to carry out research on modern 3D GIS technology based on visualization technology as the demand for 3D GIS system is getting higher and higher. The combination of GIS and visualization technology can greatly enhance the realism and the operability of GIS graphics

2.1. Methodology

2.2. Construction of three-dimensional hierarchical model

In order to construct a 3D entity that can be applied to the geological field, it is necessary to combine the idea of discrete fitting; the automatic construction of the model is realized by using the hierarchical representation strategy and discrete algorithm of the 3D GIS model. The amount of data that 3D GIS needs to process is enormous, the real-time spatial analysis and operation are required, which make the visualization of 3D GIS model more difficult. Based on the existing research, the idea of combining discrete approximation was put forward in this study, the automatic construction of the model was realized by using the hierarchical representation strategy and discrete algorithm of the GIS model, and the OpenGL technology was used to exaggerate the visualization of the 3D model. The specific principle is shown as shown in Fig. 1.

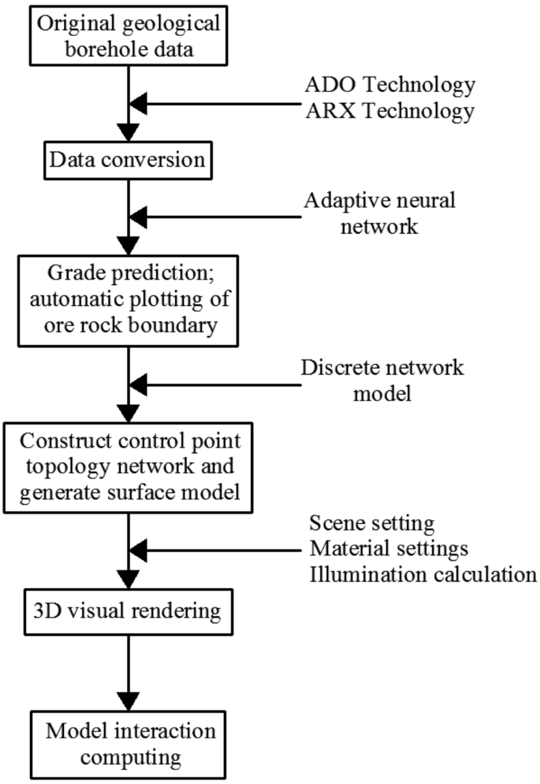

Fig. 1. Construction principle of 3D model

After the data of the original geological borehole was given, ARX and ADO technology was used to conversion of storage format in CAD graphics and GIS spatial database, the information region in the position of transverse section was predicted by an adaptive neural network, and the boundaries of ore and rock according to the grade threshold of the boundary were determined. The 3D surface model could be generated after constructing the topological relation between the control points in the data hierarchy, finally, the OpenGL technology was used to exaggerate the visualization of the model. This method can effectively reduce the influence of human factors on model construction, so the model constructed can reflect the original spatial structure characteristics of geological bodies more truly; the whole modeling process can achieve higher automation and avoid excessive interaction, which greatly improves the efficiency of modeling.

2.3. Conversion between CAD graphics data and GIS spatial database

According to the habit of existing engineering practice, almost all of the data is stored in the CAD graphics format either in the process of geological exploration or in the production design. Building 3D model of geological body requires the storage in the form of spatial database Therefore, in order to facilitate the operation and improve the applicability, the realization of the conversion between CAD graphics data and GIS spatial database was put forward based on ARX, MFC and spatial database technology. Not only can the transformation of specific CAD primitives be made, but also batch conversions can be made, so as to provide a perfect spatial database support for the construction of 3D model. AutoCAD is a computer aided software developed by American companies, and provides three embedded programming languages: ARX, ADS, and AutoLISP. The call relationship between them and AutoCAD is shown in Fig. 2.

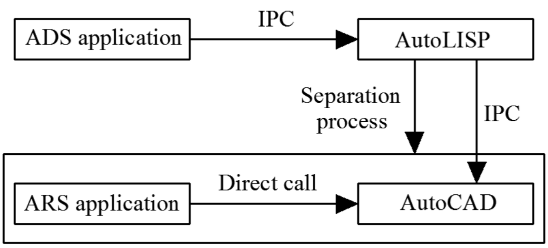

Fig. 2. Call relationships for ARX, ADS, AutoLISP, and AutoCAD

The graphical data file in CAD was defined as an object of AcDbDatabase class and organized in a hierarchical structure, as shown in Fig. 3. Each hierarchy object has two relations synchronously: including and being contained; the root of its collection is the object of graphic database.

The technology combined with ARX, MFC and database was used to realize the conversion of graphic database to spatial database, so that a 3D model was successfully constructed. The first step is that ARX extracts the attribute information of the basic entities in the CAD graphics file, and then the attribute information of the graph area is written into the spatial database by using the object-oriented database programming interface (ADO), so that the data can be converted smoothly. In addition, the attribute data can be obtained from the spatial database, and then drawn and displayed by ARX technology, so the reverse conversion of the spatial database can be realized.

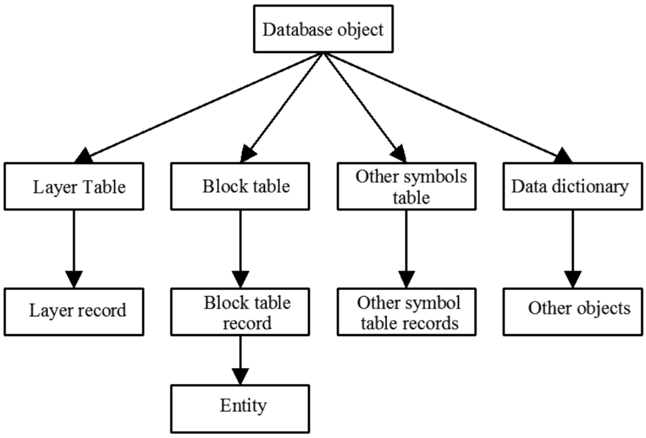

Fig. 3. The graphical data structure of AutoCAD

2.4. Three-dimensional hierarchical model and visualization

The construction of a hierarchical indexing mechanism is to facilitate the localization of spatial objects, so as to achieve various retrieval operations. Different entities are made up of different layers or sections, the layers contained in each entity can be maintained with the corresponding ID current table, and the spatial semantics is used to illustrate the binding attribute of the entity. In the same entity, different layers may also be composed of one or more closed polygons. The vectors of the control points are connected together by turns and form polygons, the linear table of the control point is stored in the three-dimensional data point of the underlying operation, and each control point is treated as an object with 3D data attribute. Based on hierarchical indexing mechanism, localization of spatial target and retrieval operations can be implemented more succinctly, and the operation is more convenient for computer programming. The hierarchical indexing mechanism is shown in Fig. 4

In order to construct a 3D model successfully, the key point is to establish the topological relation between the control points correctly, which determines the adjacency relation between the discretized surface triangles. When the topological relation is properly established correctly, the distortion of surface of the model can be reduced to a great extent, and the geometric features of the surface of the 3D model can be reflected more really. In traditional methods, the method which is made in advance is often adopted; the data structure of this method is relatively complex and has more work, so it is difficult to make dynamic changes after the creation of a three-dimensional model. Therefore, the neural network model was used for reference and a discrete network model was proposed to dynamically construct the control point of the topology network. The geometric and attribute information of the surface of the model are affected by the discrete topological relation of the triangle plane, however, the surface model cannot really reflect the spatial structure

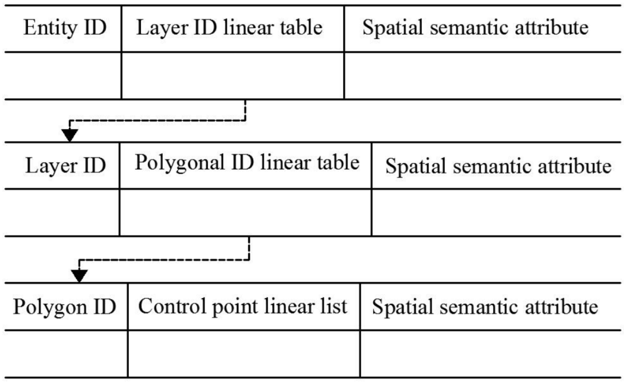

Fig. 4. Hierarchical indexing mechanism

relationship of the model, so it is necessary to exaggerate its visualization, specific steps are included: settings for model scene variables, settings for color and environment variables, and material properties; calculation of light conditions, and the use of chained library OpenGL of open graphics to realize visual operation.

2.5. Dynamic interaction and algorithm of 3D hierarchical model

In the process of specific application of GIS, engineering designers should carry out the dynamic interaction in real time. The model system not only can change from many angles, arbitrarily cut and observe its internal structure at random, but also realize the display of features of spatial structure from all directions.

In computer graphics, the introduction of homogeneous coordinate representation can be more convenient for the description of various algorithms of graphic transformation. After the use of homogeneous coordinates, two-dimensional, three-dimensional, or even three-dimensional high dimensional space graphics can successfully achieve the easy and efficient transformation from one coordinate system to another coordinate system; in addition, the homogeneous coordinate system can be used to represent infinite points, and even make them transformed into finite distant points by using perspective changes.

In the production design in the geological field, the model should be able to cut so that the internal structure of the model can be observed and thus the engineering drawings can be generated, which is of great significance to the whole field of geology. The new cutting algorithm which combined the characteristics of 3D GIS hierarchical data model was proposed, based on the principle of optimized search, the triangles with small plane intersected with the cut section were searched according to the data structure of hierarchical model. The schematic diagram of cutting is shown in Fig. 5

In Fig. 5, the vertical plane perpendicular to the surface of the paper is a straight line AB, the entry edge and the exit edge are defined as l_1, l_2, respectively, the former is formed by intersecting the section and the triangular sides of surface of entity, one

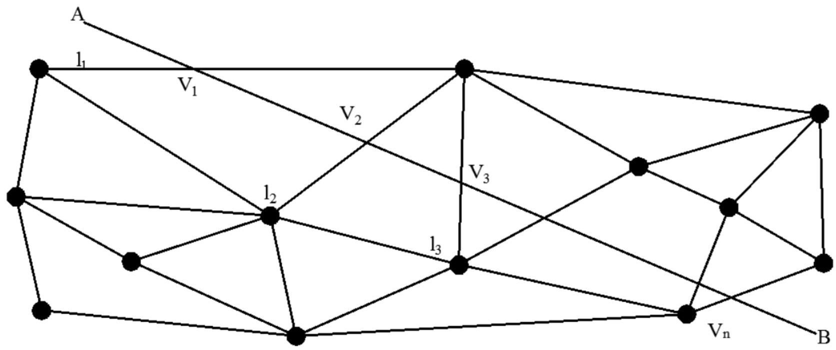

Fig. 5. Sketch map of model cutting algorithm

of the other two sides of a triangle is l_2. Symbol Q denotes a triangle with a single edge, and the exit edge is changed into the exit edge according to the topological relation between discrete triangle planes, the first step of the cut algorithm is to set the state variable, followed by the search the first edge intersecting the tangent plane. On the basis of the two endpoints on the entry edge, the small triangles intersecting the cut plane were searched, of which the edge that intersected the cut plane was the exit edge, and intersection point was preserved after calculation. Three-dimensional dissection can provide a virtual platform for engineering designers to observe the geological structure from a wide range, so that they can propose a more reasonable engineering design.

3. Result analysis and discussion

The related data was simulated based on the related techniques of 3D GIS spatial data sets and visualization, the data used in this paper was the spatial data and related attribute data of primary geological exploration and production exploration drilling of a mine in China. The mine has been running for 8 years since 2008. Therefore, the geological data obtained during the production process is relatively perfect, there are also data provided by geological exploration boreholes in the areas without construction. These figures contain the spatial coordinates and grade attribute information of the corresponding sampling section. The platform used in the experiment was Windows2003, Server, OpenGL1.3 and MapInfo, and its hardware was configured as 512DDR memory, 2.4 GHz CPU, 128 M NVIDIA graphics card.

First of all, the graphic data in CAD was transformed into the storage format of extended SQL Server2003 by using the transition mechanism between CAD graphics data and GIS spatial database. Secondly, the adaptive neural network prediction was used to automatically generate the boundaries of ore and rock in each section so as to form a three-dimensional profile of geology. Figure 6 shows the two-dimensional section of the 3D cut and its sectional correspondence. After the conversion of data, the two-dimensional data was converted into a spatial database that can be used.

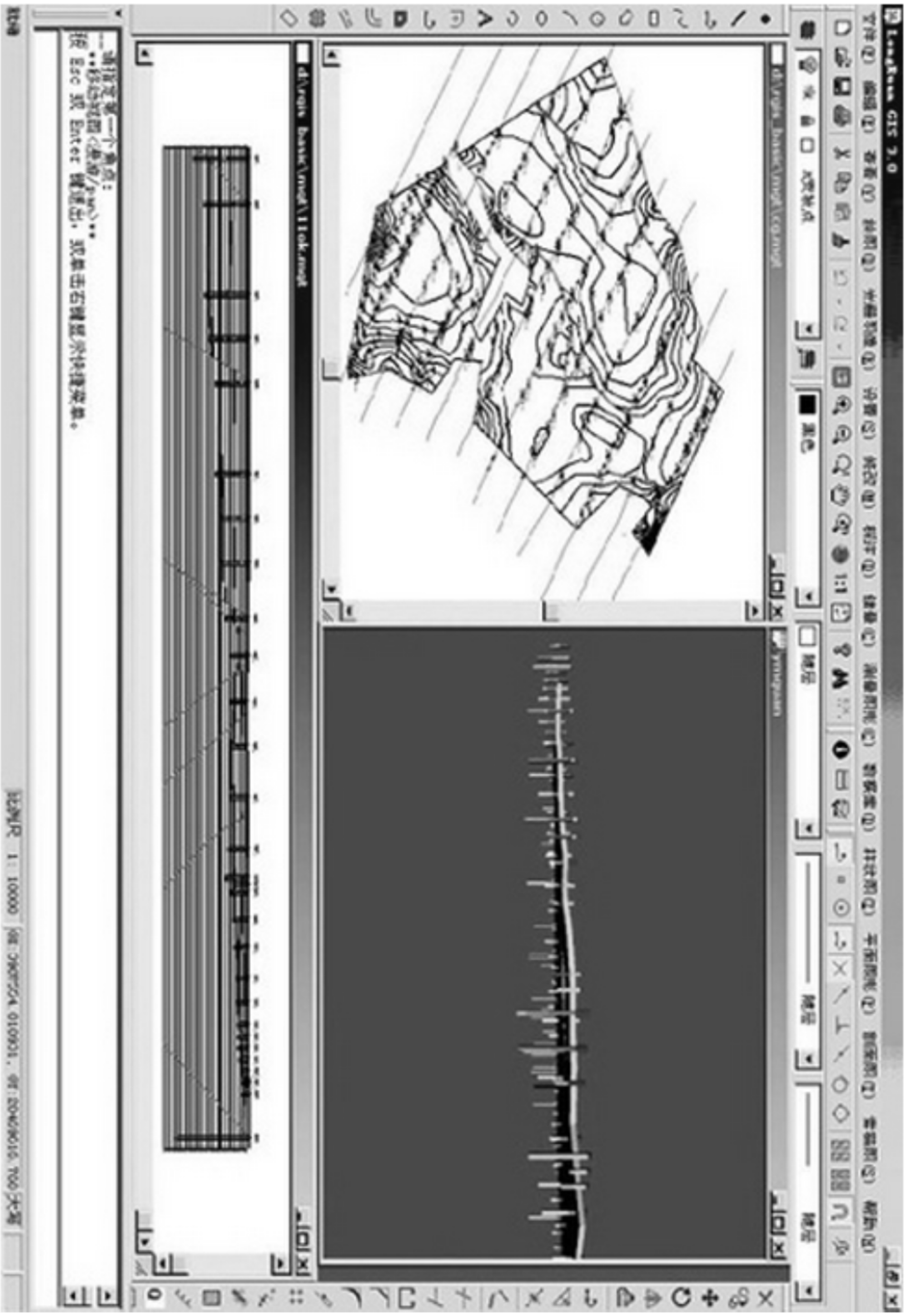

Fig. 6. Three-dimensional dissection forms two dimensional sections and its plane section correspondence

In the formed section, each section is composed of one or more closed polygons which do not intersect each other, and different colors represent different geological bodies. As long as the data is complete, the topological relation between the inner control points of adjacent cross sections can be successfully established. The topological relation was constructed by the discrete network model, and the topological relation of the control points in other adjacent sections was established according to analogy, and then the wireframe model of geological body was constructed. Finally, OpenGL was used for visual rendering, and the wireframe model composed of topological relation was transformed into surface model. After loading all kinds of attribute data, the normal vector of triangle plane was calculated respectively; and under the condition of illumination, different material was represented by different colors, and a 3D solid model of geological body was generated.

The tools provided in the system can scale, rotate, and translate and so on, so that the model can be cut arbitrarily. After the additional clipping planes were set, the rest of the work was done automatically by the system. Figure 7 shows the typical cut of a model, it is very clear to observe the construction of concrete structure through the three-dimensional dissection results. Two dimensional mapping of the model's cutting results was carried out to obtain the geological section of the two-dimensional coordinate plane. In addition, the system can meet the needs of different statistical analysis and production.

After the 3D visualization model of the mine was built, the 3D visualization and roaming of the corresponding area were carried out. Figure 8 shows a three-dimensional view of the mine floor.

From the point of comprehensive analysis, the system can not only realize geological, equipment, plant, terrain and other 3D models building based on GIS spatial data set and visualization technology, but also realize the panorama and browsing of the whole picture from the ground surface to the ground floor. Three-dimensional visual editing platform with relatively perfect function can be used to realize data editing, coating management, automatic modeling, import and export and other functions, and implement and the import and export of 3DMax; in addition, the association between 3D virtual scene and integrated automatic data, the inquiry, modification and input of data of relevant equipment, as well as the real-time monitoring in the process of operation can be realized.

4. Conclusion

Based on the three-dimensional spatial data model of GIS, the presentation of geological structure from all aspects can be realized, and many limitations and shortcomings of the traditional two-dimensional GIS plane can be effectively solved. Based on ARX, MFC and spatial database technology, the conversion of CAD graphics data and GIS spatial database was realized, and the visual rendering operations of the model were carried out by OpenGL. This method can realize the conversion of AutoCAD graphics data better, overcome the influence of human factors in the process of model building, and automatically generate any section map. The actual data of a mine in China was exploited in the analog simulation. It can be seen

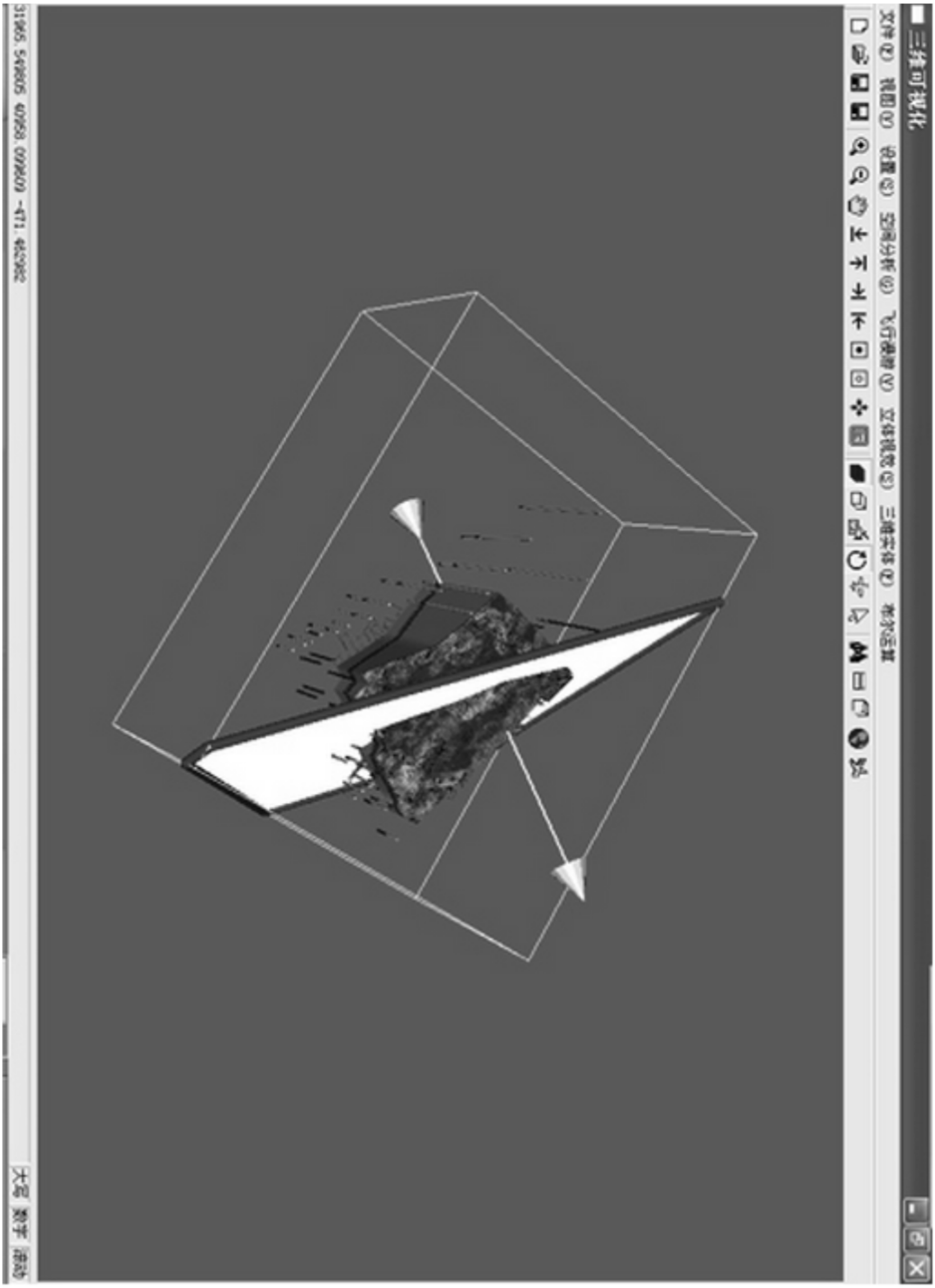

Fig. 7. Model cutting

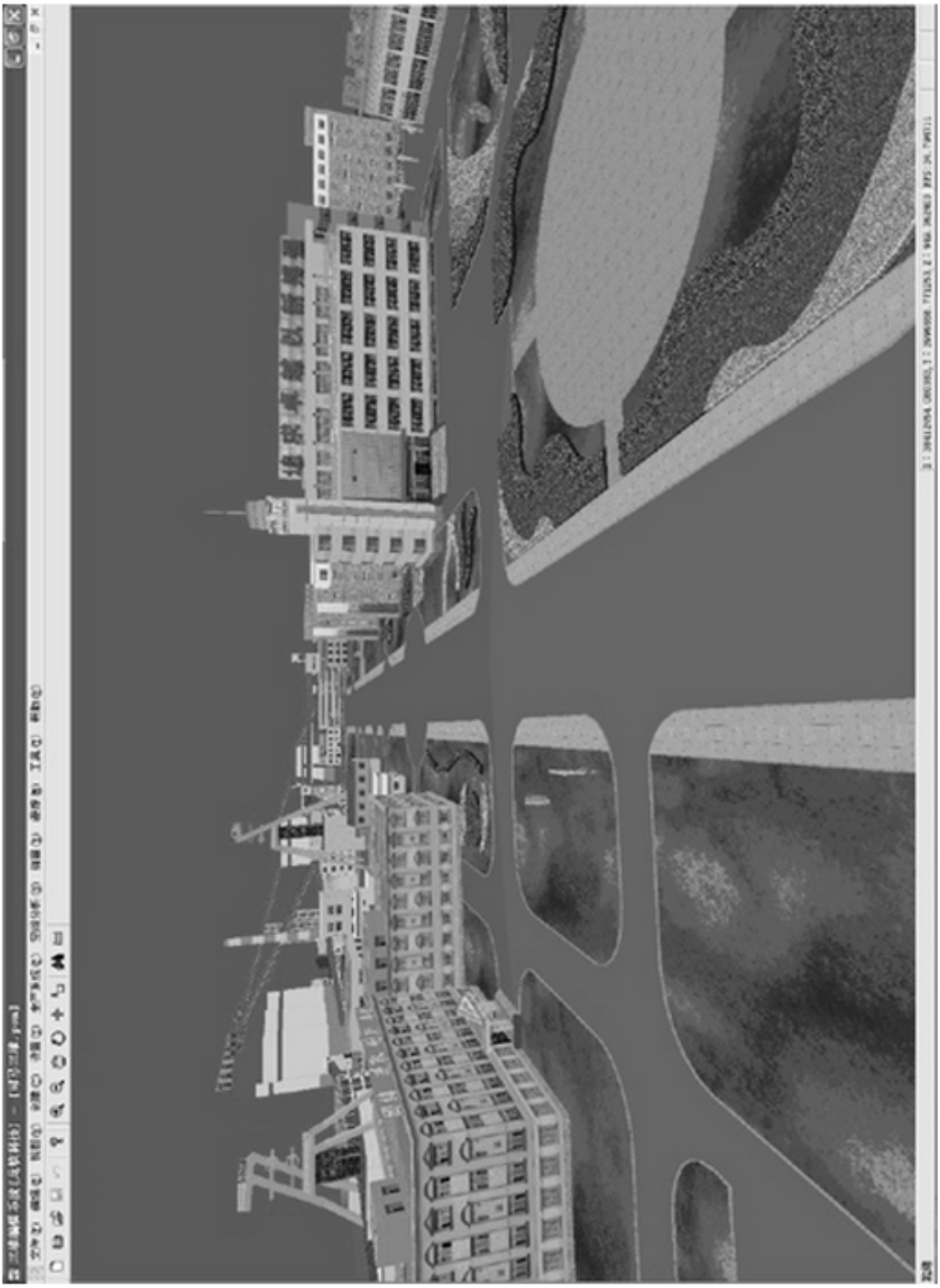

Fig. 8. Three-dimensional visualization and navigation of mine surface

that a 3D model for geological application can be successfully constructed after the conversion of CAD graphics data to the spatial database. The tools provided in the system can realize the scaling, rotation, and translation of graphics, and the model can be cut arbitrarily, and the section of corresponding model can be obtained. In addition, roaming and browsing can also be carried out to facilitate the daily management of mines. However, the experimental system needs to be further improved, and a whole set of platform for 3D GIS modeling, analysis and visualization can be formed.

References

[1] Q. Hamid, M. H. Chauhdry, S. Mahmood, M. S. Farid: *Arc GIS and 3D visualization of land records: A case study of urban areas in Punjab*. National Academy Science Letters *39* (2016), No. 4, 277–281.

[2] M. Alcaraz, E. Vázquez-Suñé, V. Velasco, M. Diviu: *3D GIS-based visualization of geological, hydrogeological, hydrogeochemical and geothermal models*. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften (German J. Geol.) *167* (2016), No. 4, 377–388.

[3] B. Li, J. Wu, M. Pan, J. Huang: *Application of 3D WebGIS and real-time technique in earthquake information publishing and visualization*. Earthquake Science *28* (2015), No. 3, 223–231.

[4] N. Dell'Unto, G. Landeschi, A. M. Leander Touati, M Dellepiane, M. Callieri, D. Ferdani: *Experiencing ancient buildings from a 3D GIS perspective: A case drawn from the Swedish Pompeii Project*. Journal of Archaeological Method and Theory *23* (2016), No. 1, 73–94.

[5] j. Huang, R. Huang, N. Ju, Q. Xu, C. He: *3D WebGIS-based platform for debris flow early warning: A case study*. Engineering Geology *197* (2015), 57–66.

[6] X. Y. Wei, Y. Wang, X. P. Yan, Y. F. Tian, B. Wu: *Design and realization of the 3D electronic chart based on GIS and virtual reality technology*. Applied Mechanics and Materials *744–746* (2015), 1669–1673.

[7] A. S. Harvey, G. Fotopoulos, B. Hall, K. Amolins: *Augmenting comprehension of geological relationships by integrating 3D laser scanned hand samples within a GIS environment*. Computers & Geosciences *103* (2017), 152–163.

[8] H. Huang, J. Ni, Y. Zhang, T. Qian, D. Shen, J. Wang: *Web3DGIS-based system for reservoir landslide monitoring and early warning*. Applied Sciences *6* (2016), No. 2, paper 44.

[9] C. Tao, Q. K. Wang: *GIServices-based 3D internet GIS: GeoEye 3D*. Acta Geodaetica Et Cartographic Sinica *31* (2002), No. 1, 17–21.

[10] Y. Li: *Street level urban design qualities for walkability: Combining 2D and 3D GIS measures*. Computers, Environment and Urban Systems *64* (2017), 288–296.

[11] C. Xiong, X. Lu, M. Hori, H. Guan, Z. Xu: *Building seismic response and visualization using 3D urban polygonal modeling*. Automation in Construction *55* (2015), 25–34.

[12] A. Tiwari, K. Jain: *A detailed 3D GIS architecture for disaster management*. International Journal of Advanced Remote Sensing and GIS *4* (2015), No. 1, 980–989.

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