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Research and application on dynamic update method of 3D geological model in hydropower engineering

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ABSTRACT

3D geological modeling refers to integrating the kinds of geological data in 3D underground space to form 3D quantitative model. The dynamic update method of 3D geological model is always the hot topic of researchers. Pointing at 3D modeling and visualization, the author team has developed a 3D visualization platform based on IDL and formed the basic modeling tools including data processing from 2D to 3D, 3D objects editing, surface fitting, surface cutting etc. which have been applied in water resources and hydropower projects practically. On the basis of the existing 3D modeling tools above-mentioned, this paper classified the 3D modeling methods according to the specific objects of 3D spatial models expressed (such as terrain surface, water surface, bedrock surface and so on) and designed 3D modeling process as relatively fixed processes. Besides, the paper achieved dynamic update method of 3D model modification process based on database and script-driven approach. This method fits for 3D visualized simulation in which the engineering data needs updating constantly with the progress of works, and has been applied in 3D modeling of water resources and hydropower projects. The anticipated results have been achieved.

KEYWORDS

3D geological modeling; Database; Script-driven; Dynamic update; Parameter control.

INTRODUCTION

3D geological model is the data expression way of geological information in the computer, including data storage structure and the related operations. The use of 3D geological model can not only describe the complicated geological structure under the ground intuitively and express the morphological characteristics of the geological structure and the spatial relationship among the structural elements vividly, but also make geological analysis more flexible, intuitive and accurate by combining it with powerful interactive spatial analysis functions, thus developing an effective way to reproduce the 3D information in engineering geology and for geological meta-analysis quickly and timely.

At present, the common methods about 3D modeling at home and abroad are summarized as following: 3D modeling method of basin stratigraphic framework[1, 2]; " Stratigraphy-entity model" algorithm based on the borehole data[3, 4]; 3D vector data generation algorithm based on the geological section data[5, 6]; 3D formation grain modeling method based on the multi-layer DEM concept[7], modeling method based on the triangular prism or tetrahedron element and 3D stratum simulation technology based on the spatial interpolation technology[8, 9]; Potential field interpolation method used by P. Calcagno etc[10, 11]. Modeling method of structural similarity function proposed by Li Shaohu etc[12].

In conclusion, the most and main modeling data in this area of research is from the exploration section, and when exploration section data has been updated, even if there is a little data updated, the modeling process needs reprocessing manually, so the modeling efficiency is relatively low. The article records modeling process in a way by combining database with script, which can realize the automatic update of the model when data update satisfies certain conditions. The efficiency of 3D model update is improved greatly by using this process.

PROCESS AND METHOD DESIGN OF 3D MODELING

In this paper the design of 3D modeling process is summarized based on application practice and software design for years, the design of 3D modeling process is shown in Figure 1 below.

The data processing is the most complicated in it and at present most engineering data is stored in the form of 2D or provided by paper material. Therefore, firstly it needs to deal with the data before 3D modeling, probably including the following steps: Vectorization of paper material; Vector data format conversion; Fault-tolerant and checking. On that basis it needs to take 3D procession based on the geometric relationship of 2D data and 3D data, namely 3D conversion of 2D profile. Basic modeling software all need the above two steps. The third step is attribute setting, which is data management method put forward for model dynamic updating in this system: to classify and code data according to its property, and to store the basic exploration data and the model which can be expressed by parameters with database, such as the experimental data-water resources and hydropower projects data code is shown in TABLE 1.

Cavern section type refers to a bending variation trend of one cavern section, which is classified into three main types: linear cavern section, helix cavern section and fillet cavern section. The corresponding mathematical model of parameters is shown in Figure 2. Complicated underground cavern group is composed of caverns with different function, such as diversion tunnel, water diversion tunnel, underground powerhouse, construction adit, tailrace tunnel, tailrace surge tank, traffic hole, etc. A cavern is composed of several cavern sections, such as the diversion tunnel, which is made up of the entrance cavern section, diversion tunnel section, arc cavern section and tailrace tunnel section, and each cavern section cross section is of different shape, size and so on. Common underground cavern construction shapes (as shown in Figure 2) are mainly: rectangle (as shown in Figure 2 (a)), circle (as shown in Figure 2 (b)), arch (as shown in Figure 2 (c)) and complex shape (as shown in Figure 2 (d)).

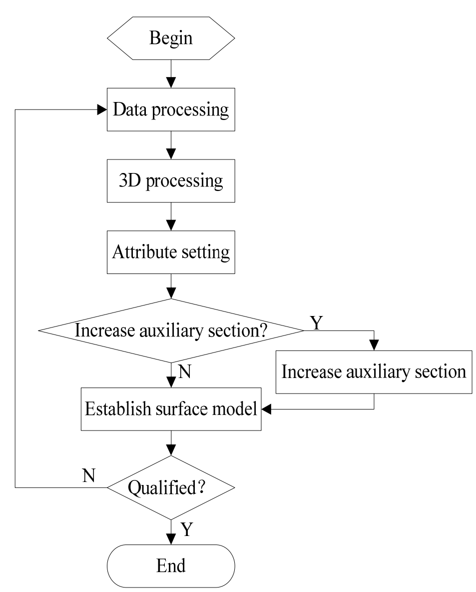


Figure 1 : Design of 3D modeling process

In addition, the cavern construction can be described with control parameters of the center point and six length scalars according to the abstraction of these kinds of common cavern constructions for that the construction of common cavern model section is bilateral symmetry. From Figure 2, it can be seen that given any cavern center coordinate and other six parameters, the construction of arbitrary can be described. Then four constructions can be parameterized into the center point coordinate O and six length scalars a (parameter “a” must be greater than zero), b, c, d, e, f, in which the arc radius needs to be calculated automatically according to the six length parameters and described in sections according to the accuracy requirement. Referring to Figure 2(d), when b=c and d=e=f=0, it is the rectangular section; When a=b=c and d=e=f, it is the circular section; When a, b, c and e are all not equal to zero and d=f=0, it is the arch section. Thus, it can be seen that the section shape of common underground cavern can be represented with a central point coordinate and six length scalars, and then complete the mathematical modeling of cavern section.

According to the above-mentioned mathematical model, given the arbitrary parameter a, b, c, d, e and f, the section shape can be obtained by both judgment and calculation. Using one expression to finish four section models can reduce the data of storage and improve the modeling efficiency.

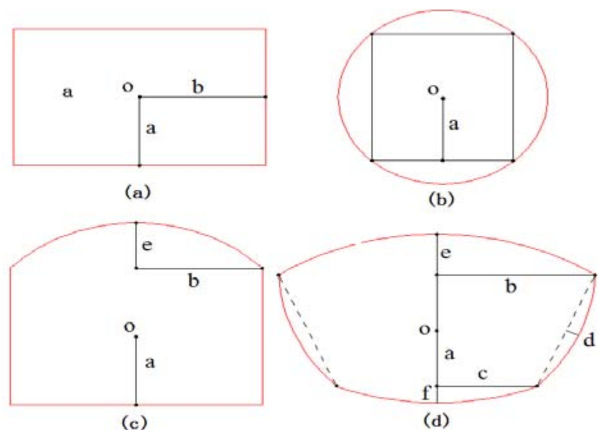


Figure 2 : Common underground cavern construction

TABLE 1: Database model

No.	Attribute identification	Attribute data interpretation	Object type
1	MDWTL	Weak-weathered data	Line, triangle network
2	MDWTP	Weak-weathered surface model	Triangle network
3	STWTL	Strong-weathered data	Line, triangle network
4	STWTP	Strong -weathered surface model	Triangle network
5	CNTL	Contour data	Line
6	DEM	Terrain model	Ruled surface
7	SWTRL	Surface water level data	Line, triangle network
8	…	…	…

In TABLE 1, “attribute identification” is the only representation 3D geological spatial attribute data corresponding to 3D object. “Attribute data interpretation” refers to the Chinese description of the data. “Object type” refers to in what kind of object the data will be presented to users in 3D space, it can mainly manifests as line, triangle network, ruled grid, etc. The data in TABLE 1 exists in engineering database, and the attribute can be added or deleted according to the specific project. In 3D modeling process, data search and reference is based on the description in TABLE 1. The fourth step is to add artificially auxiliary section according to the need, which is used in some project prophase or case with less engineering data, and it controls the precision of the model according to the expert understanding. This step is an optional step. These four above steps indicate the preparation of the 3D modeling, and the process is basically similar to the process of common 3D modeling.

The most important step is 3D surface modeling which is also important to realize dynamic update of the paper. In this paper the data structure of 3D model is adopted as B-Rep boundary representation [13]. Surface modeling here refers to converting the 3D line data or surface data to the surface model data which can represent geological body. 3D surface modeling uses mathematical method, also namely 3D surface generation algorithm, which mainly includes the following kinds of common algorithms: triangulation algorithm, linear interpolation algorithm, bilinear polynomial interpolation algorithm, weighted average method, similar deformation interpolation method and Kriging method [14], etc. The software systems based on the above algorithms have been applied into the practical projects with good effects [15].

In the steps above, the most complicated one is to establish surface model which may be often a repetitive task. 3D model dynamic update in this research is to add script record to realize the model dynamic update at the step of surface model establishment after the process improvement based on the above modeling process. The design about script and the realization of the dynamic update will be given a statement into detail later.

SCRIPT DESIGN

This text draws on the principle of video playback, which records the process of building a surface model by the way of script. The whole process is similar to using the VCR for recording: after getting basic modeling data ready (including three-dimension, set-up of attribute), click start modeling, the system automatically records the surface modeling process, including data selection (selections based on the property), the used modeling methods, the data storage layer after modeling, as well as the corresponding shear treatment and the order of the treatment. For this reason, the author designed a script file which records the process of establishing a surface model. The file is named with a specified modeling process, and provides reliable supporting information for dynamic update. The recording format of the script file is stored in the form of plain code. In the following the process of establishing the groundwater level will be explained as an example,during which the script file is shown in Figure 3.

The script file in Figure 3 is explained as follows: numbers 1, 2, 3, 4, mean modeling steps; “:” (colon), “;” (semicolon) and “,” (comma) are separators. “:” refers to appear once after the step number, after it follows the operation property, for example, “Sel” represents data selection operation according to the property, “Fit” represents surface fitting operation, “Cut” represents curved surface shear operation. “;” is used to split the operating parameters, for example, step 1 is used to do selection operation (Sel), followed by parameters including the property (SWTRL: on behalf of the groundwater level data), the object class (Line represents line data, Polygon represents Triangle network data) and layers (Layer1). “,” is used to split a parameter category which can be checked, for example, in step 1 you can select both line and triangular network. Therefore the posttranslational operation of the above script is:

Step 1: object select operation (Sel), lines and triangle network data in Layer1 whose attribute is SWTRL are added to the selection set as the input of the subsequent operations.

Step 2: object fitting operation (Fit), the input data is the selected objects in previous step, fitting method using the way of combining Kriging interpolation (Kriging) and triangulation (Tri), the generated objects are put into Layer2 and set the curved surface property into “SWTRP” (on behalf of the groundwater level model).

Step 3: curved surface shear operation (Cut), the object cut comes from Layer2 whose property is “SWTRP” (groundwater level model), the cut object comes from Layer3 whose property is “BOX” (project area bounding box), the result after cutting are the object at the positive (P) of the cut object’s normal, object property and layer unchanged after cutting.

Step 4: curved surface shear operation (Cut), the object cut comes from Layer2 whose property is "SWTRP" (groundwater level model), the cut object comes from Layer4 whose property is "DEM" (terrain), the result after cutting are the object at the negative (N) of the cut object’s normal, object property and layer unchanged after cutting.

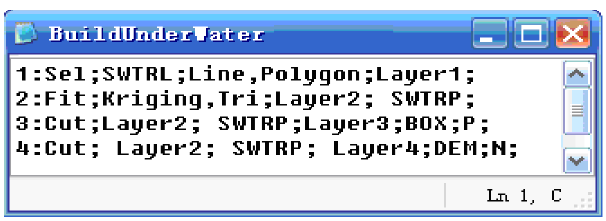


Figure 3 : Script instance file

Through the design and record of the above script file, the entire process of creating a model surface is recorded, or the entire process of establishing a 3D model is recorded in a script file.

REALIZATION OF DYNAMIC UPDATE

With the process record of the aforementioned script file, the system only needs re-reading the script file, and rebuild the model in accordance with the rules specified by the script file when modeling data has been updated, that is the realization of model dynamic update. The flow of 3D modeling and dynamic update is shown in Figure 4.

We can see from Figure 4 that the entire 3D modeling process is divided into the following steps: (1) According to the data processed, build the surface model, use the script to record the entire process and form a standard script file; (2) With the deepening of the project, new engineering data may join, or part of the raw data is error through the analysis of 3D model. At this time, the model needs to be modified to form new modeling data; (3) Reading the script, analyzing in accordance with the format specified; (4) Based on the analytical results of the script file, the appropriate modeling method will be automatically called to reproduce the process of building the surface model until no new modeling data merged.

This method is coded with IDL5.6, and it was integrated into the 3D geological information system of water resources and hydropower projects. Practical engineering applications are carried out, and the effect is obvious.

Analyzing the above modeling process, the 3D modeling process needs at least a complete work process, then if there is data update (add or modify), the 3D surface modeling process can be repeated, which eliminates the need for repeated work of rebuilding the surface model and improves work efficiency. Of course, this method also has deficiencies during application process, namely the entire modeling process will be repeated when the modeling method needs to be adjusted.

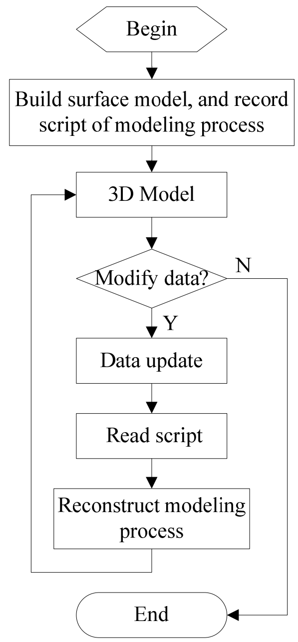
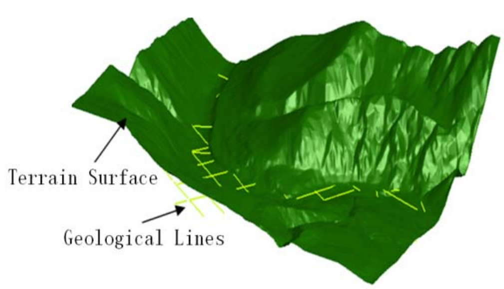


Figure 4 : Flow of 3D modeling and dynamic update

MODELING EXAMPLES

The method described in this article has an integrated application in the 3D geological information system of water resources and hydropower project. Firstly, we conducted a modeling experiment in 3D space with 33 sections' data using geological lines data, as shown in Figure 5 and Figure 6. Figure 5 is the terrain surface already established and geological lines in 3D space already edited. Figure 6 is surface water and groundwater level model which was formed by the combination of Kriging and surface shear technology except terrain. Figure 7 is the script file that records modeling process. As can be seen from Figure 7, the establishment of surface water and groundwater level was formed by building the whole model of the project area and being cut by terrain model. Figure 8 is the geological lines data model which was formed by adding 12 exploration profiles, 11 auxiliary profiles and boundary data on the basis of Figure 6. Based on data in Figure 8, the dynamic update was finished by reading the script file of Figure 7. The model formed is shown in Figure 9. Dynamic update time of this model is mainly spent on surface fitting and shear, which took only ten seconds of time to accomplish using ordinary machines. It shows that the method has played an important role to improve the speed of model update.

The author operated the dynamical update process of Figure 5 to Figure 9 practically. With six years' experience in 3D modeling, the model update experiments were carried out manually, and the dynamic update modeling method was used to verify it. The results are shown in TABLE 2. This experiment was carried out in the case that basic exploration data has been preliminary treated. The exploration section data has been proposed. 11 auxiliary sections have been increased mainly to improve the accuracy of the model, so time is used mainly in the processing of the auxiliary sections.



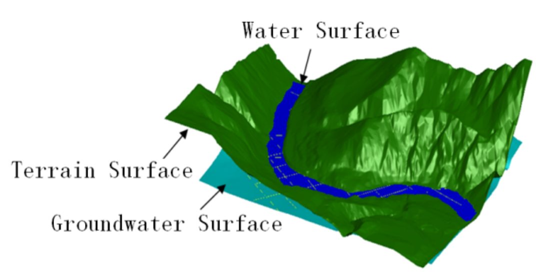


Figure 5 : Terrain model and geological line (1) Figure 6 : Groundwater and surface water level (1)

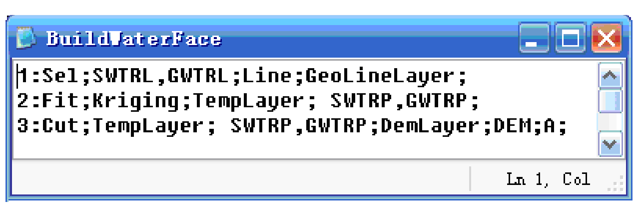
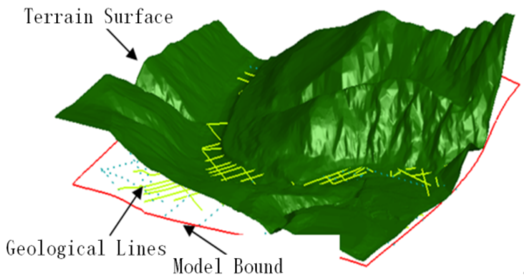


Figure 7 : Script file



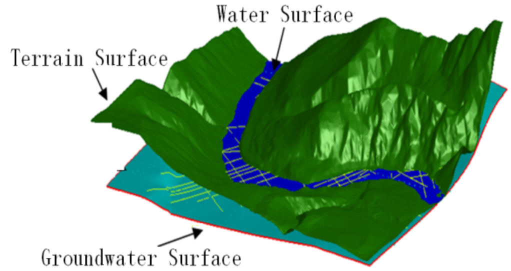


Figure 8 : Terrain model and geological line (2) Figure 9 : Groundwater and surface water level (2)

TABLE 2 : Model updating efficiency comparison

Operation mode	Data processing time	Model updating time	Total time
Manual	About 2.5 hours	About 0.5 hours	About 3 hours
Automatic	About 2.5 hours	13 seconds	About 2.5 hours

As can be seen from TABLE 2, the difference of total time is 0.5 hour, which is spent on model update. Automatic update reduces nearly 17 percent of the time compared with manual update, while the data processing is not the research content, but it is also the focus and difficulty of the follow-up study. As can be seen from the above conclusion, data processing time remains the same with minor adjustment of the model data, while the model update time (manual and automatic) will be greatly shortened, which reflects the importance of the research contents better.

CONCLUSIONS

Based on the summary and research of the repetition work in 3d modeling process, the author puts forward the dynamic update method of 3d model which is based on database technology and driven by the script, coded, and finally integrated into the 3D geological information system (GeoEngine) of water resources and hydropower projects. Throughout the whole 3D modeling process, it is a continuous cycle process: data processing – building 3D surface model – model calibration–data processing, until the model passes the validation. This study is a node of the whole cycle process, which is the building of 3D surface model. Establishing the 3D surface model is a link of the whole cycle. Although it doesn't improve the efficiency of data processing generally, the realization of the dynamic update of 3D model improves the efficiency of 3D modeling work. In conclusion, the method improves the efficiency of the 3D modeling to some extent and has a certain application value. However, the program implementation of the research needs to be improved in handling special data. And how to improve the efficiency of data processing is also the focus of the follow-up research work.

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REFERENCES

[1] Wu C L, Mao X P, Tian Y P, Weng Z P, He Z W, Li S H, Li X, Zhang Z T,25, 1 (2006).
[2] Wu C L, 23, 193 (1998).
[3] Li D R, Li Q Q, 26, 128 (1997).
[4] Liu Qingwu, Wu Chonglong, Li Shaohu, 25, 501 (2003).
[5] Roberto V, Chiaruttini C, 29, 460 (1999).
[6] Qu H G, Pan M, Wang Y, Xue S, Ming J, 42, 717 (2006).
[7] Li P J, 7, 271 (2000).
[8] Tian Y P, Yuan Y B, Li S H, Wu C L, 25, 191 (2000).
[9] Mallet J L; Geomodeling, Oxford University Press; Oxford, (2002).
[10] Calcagno P, Chilès J P, Courrioux G, Guillen A, 171, 147 (2008).
[11] Mallet J L, 36, 1 (2004).
[12] Li M C; 3D Modeling and Analysis of Engineering-Geological Information in Large Hydraulic and Hydroelectric Projects, PhD dissertation, Tianjin University, China.
[13] Wu C L, Liu G, Mao X P, Tian Y P; Introduction to geological information technology, Higher Education Press; Peking, (2007).
[14] Liu Z F; Research and Application of Arbitrary profile Based on GeoView3D Platform, Master.s Thesis, China University of Geosciences (Wuhan), Hubei (2008).
[15] Wei Z H, Liu Z F, 10, 62 (2010).