# Spatiotemporal model of open-pit based on 3-D deposit model

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**Abstract**：A new method was put forward to make up the three-dimensional deposit model, and the spatiotemporal models of open-pit with temporal dynamics were also studied combined with the corrected models of multilevel ground states so as to bring the three-dimensional open-pit model at different time and its model serial formed from the evolvement into the management of temporal dimension in order to realize the spatial three-dimension and temporal dynamic for the mining management in open-pits，which makes this model easy to query and analyze 3-D information, also help surface mining replaying and stope evolution forecasting. Finally, the time-spatial model was established to show the dynamic mining on some open-pit under the windows XP and VC++ environment.

**Key words:** 3D model of deposit; three-dimensional model; mixed model; temporal model; open-pit

## 1 Introduction

Mining is a continuum technological process of exploitation, extraction and discharge linked up each other in open-pit. In essence, it is a dynamic changing procedure to 3-D geographical spatial information in time dimension for the open-pit, which determines that the information-based production and management in open-pit must have two characteristics, 'three-dimensional' and 'temporal dynamics' [1]. In three-dimensional, it is needed to establish a mine information model with the three-coordinates as the fundamental factors to describe all of the information about each point in the mine and provide the 3-D searching, analyzing, computing and displaying in efficient, convenient and direct-viewing way, which realizes the various controls for the information based model to meet the needs of geology, survey, design, production and management. As to 'Dynamic', it is required to express the models and their changing relationship each other in arbitrary time (say, the end of each month) to carry through the history inquire and the stope evolution forecast. Hence, this work which takes the time as the main direction by bring the 3-D mine model serial in different period into the

management of time-dimension to form the four-dimensional spatiotemporal model of stopes for measuring and spatial analyzing to meet the needs of various open-pit mining production well.

To establish 4-D spatiotemporal model for the open-pit, firstly, based on itself spatial characteristics of the open-pit, a suitable 3-D information model should be chosen with its spatial expression. Then based on the production process, a fitting temporal model is selected to manage the 3-D spatial model to establish the spatiotemporal database of open-pit with 4-dimensional expression, which actually is a temporal issue about 3-D geological information model.

Mentioning the 3-Dgeological model, and its modeling theories and techniques have been studied near 40 years until the after the block model appears in 1960s. But so far there is not any information management fitting the mining needs for various mines although about 20 methods of spatial modeling are suitable to geology and mining field [2]. In the recent 20 years, a lot of theories of spatiotemporal expression and modeling are developed by the scholars overseas and domestic in various fields from the different cognitive approaches through five developing stages, i.e. the static data model expansion based on tradition, the objective-oriented

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expression, the based event sequence, the spatiotemporal integration and the procedure as the core. Because of the complexity and diversity of geographical entity, it is not possess a strong universality to the present spatiotemporal expression and modeling theories usually based on the specific applied field and aimed at the specific scientific design which mainly centralized on some two-dimensional management fields of cadastral management, land management and so on and less on the spatiotemporal management of mine 3-D geological model [3]. In this work, the 4-dimensional stope model of open-pit is mainly approached.

## 2 Expression of three-dimensional model

The open deposit shows usually a layered distribution with a geological structure of fault, cleavage, drape and so on. The deposit consists of terrane and coal seams. To the single terrane or the coal seam there is quite clear top and bottom surfaces. The deposit ground surface of open-pit is changed surface which is exposed outside or is the top surfaces of the coal seam being of sidestep character. The precise engineering survey can be carried through on the ground surface of open-pit to establish the fine ground DEM model. However, only the simulation of integer structure for the part under the ground can be carried through the manner of spatial interpolation by using the data of drills etc.

The following three basic conditions must be fulfilled that can integrally describe the 3-D information model of open-pit deposit. Firstly, the interface state of layer geological body can be described. Secondly, the inner structure and the relationship between the layers of geological bodies can be expressed. Thirdly, the description for the stope ground surface is enough accurately. Therefore, the mixed model is adopted which combines the vector boundary model with the analogical right triangular prism model [4−8]. Since the vector one expresses the layer contribution of the deposit with high precision, the real 3-D model by the subdivision of irregular tetrahedron or analogical right triangular prism is established basing on it not only suits for presenting the grade change in metal mines, but also makes up the lack for the description of topological relationship in vector boundary model.

### 2.1 Establishing for vector boundary model

Aiming at the layered geological structure in open-pit deposit, it can be applied to describe each individual layer that the top surfaces and bottom surfaces of rock/coal seams along with the side torus determined by the boundary of them. The establishment of vector boundary model of each layer can be divided into three components.

1) EDM modeling by stratifying. The data from drilling points in a group, which is corresponding to each interface, is acquired by processing to the drilling data to establish Delaunay triangular net, i.e. D-TIN by using interpolation method of point by point.

2) Establishing of side EDM. The shortest diagonal lines are searched to form the triangular facet by determining two points as the datum points, in which the distance is the shortest one among the boundary points corresponding to the TIN net of top and bottom layers. Thus the side D-TIN can be established by changing the datum point continually in the program.

3) Establishing of surface-fined EDM. The establishing of restricted Delaunay triangular net is carried through in the restricted condition of side-step lines [9−10].

At last, using the corresponding crunodes on the interface the vector boundary model of the deposit is formed by coupling above layered EDM. Generally, the deposit consists of different body-shape layers. The body-shape layer is enwrapped by the D-TIN of top, bottom and side to become a entity, in which the topographical characteristics of total stope is expressed by the fine EDM on the top surface in the top body-shape layer.

### 2.2 3-D subdivisions for body-shape layer

Every body-shaped layer in coal mine can be subdivided in 3-D by means of analogical right triangular prism (ARTP) for the sake of requirements in excavation quantity computation and production management. Firstly, the union of sets is needed to obtained for the points in the TIN nets of top and bottom interfaces, that is, the elevation of the new point is achieved from linear interpolation since the points on the top and bottom surfaces are corresponded one to one through mapping [4]. Then, the local triangular nets are restructured to form the new TIN nets by keeping the characteristics of original TIN nets unchanged on the whole, so that the top and bottom interfaces will have the opposite faux TIN structure. Now by linking the corresponding vertexes a serial of voxel of analogical right triangular prism s (ARTP) is formed based on the triangles corresponding to the faux TIN net.

The voxel of analogical right triangular prism is a tri-prism with the triangular plane of top and bottom surfaces being not parallel, the triangular plane on the bottom can be expressed as the subjective corresponding relation among the layers and the plane quadrilaterals on the voxel side can be describe as the spatial adjacency relation of the interior in the same layer. As shown in Fig. 1, the modeling components consist of 6 basic elements: crunodes, TIN sides, TIN planes, side lines, side planes and ARTP voxels.
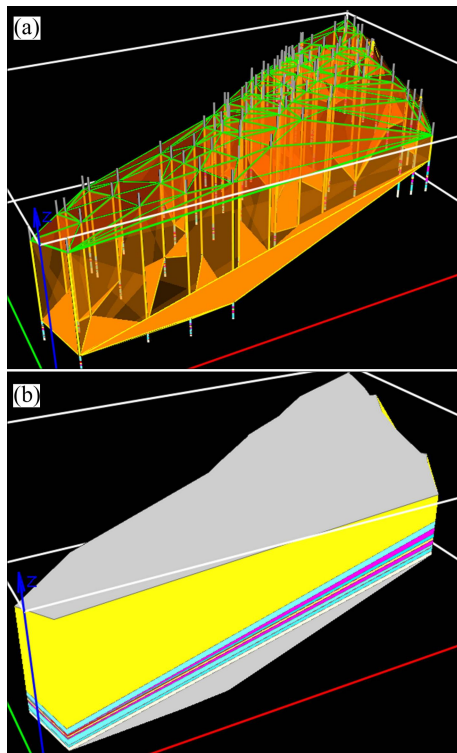
**Fig. 1** 3-D deposit model of open-pit: (a) ARTP subdevision of deposit; (b) 3-D geological model for some deposit

## 3 Establishing of open-pit temporal model

Aiming at the actual management requirements in open-pit, the multi-ground state modified model object-oriented is established to store and manage the spatiotemporal data of open-pit stopes based on some spatiotemporal models in existence.

### 3.1 Expression of objective-oriented spatiotemporal data

The structures of stope data in different time are specifically applied the structure forms of spatiotemporal data based on the database time according to the actual requirements of management in open-pit. In the spatiotemporal data model of object-oriented, the spatiotemporal data structure of any object may be generalized as:

Object A:{
   ID;        //object identifier
   Attribute[t];  // attribute transform array
   Spatial[t];   // position transform array
   Temporal[Td];// life course of object
   Operation;  //various operations of object
};

In the actual application of open-pit 4-D model, there will exist a magnitude of temporal data redundancy if each object including point, line, surface and volume is to be established a corresponding data structure. Because

the changing object is mostly the surface TIN in the open-pit mining, and the difference in old and new surface TIN is just the excavated volume, so that the spatial changed data can record the surface TIN, and the organization of spatial data can be structured based on the database time. The object structure can be expressed as:

Class surface: ID–s1–T0, ID–s2–T1, ···, ID–s–Tn where O-ID-XT0 is the original state of object, O-ID-XTi is the state of database in time Ti, and O-ID-XTn is the present state.

In this data structure form, the changing of any object (identified O-ID-X) is abstractly corresponding to a unique chain table of database time O-ID-X: O-ID-XT0<==>O-ID-XT1<==> ··· O-ID-XTn, and the chain tables are arranged according to the object database time to describe the history process of expression, updating and processing of objects in the database. In the chain tables, there exists discrepancy between two spaces and non-spatial attributes of any border upon items, but there is not exist state changing in the time period between near items or it can be neglected.

### 3.2 Structure of multi-ground state spatiotemporal data

In the practice, the acceptance survey for the stope is carried through once a month and the results are the 3-D coordinates of discrete points on the ground in the changing area and used in the computation of excavation quantity this month and the precise expression of the 3-D stope. However, If all data of 3-D model for each month is to be stored, it will produce a magnitude of redundant data to establish the continues snapshot spatiotemporal database; if the establishing of spatiotemporal database is based on the ground state modified model, it will be very miscellaneous to compute the present model at the original state. Hence, the constructing of spatiotemporal data is carried through by using the ground state modified storage method based on the ground state modifying method and the dynamic multi-levels index manner [11−14].

The least time granularity is a month, determined by the stope acceptance survey period, in the spatiotemporal database of open-pit to record the total changing of model TIN surface of 3-D open-pit between the two adjacent months, i.e. the deference files are created for a period of a month and the snapshot model to totally expresses the 3-D model is established in one year as a unit to promote the speed restructure and express ability. The simulation of 3-D stopes for each month is based on the 3-D snapshot model in a year unit in the manner of ground state modification to realized. The structure is shown in Fig. 2.
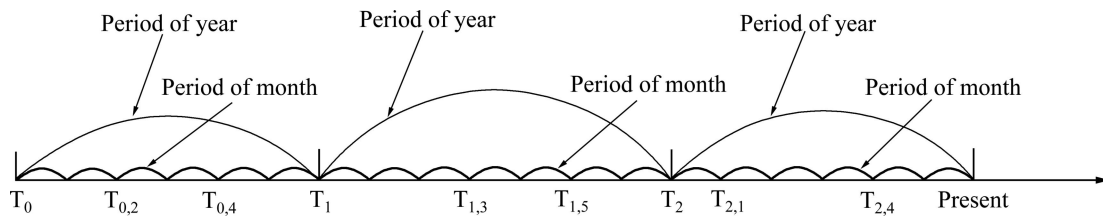
**Fig. 2** Structure manner of spatiotemporal database in open-pit

## 4 Application of model

The excavation quantity can be precisely calculated for any period based on the open-pit model with four-dimensional spatiotemporal attribute, which can carry through the mining payback and preview in advance.

### 4.1 Computation for excavation quantity of present month

The 'lamina' model is established taking the stope local TIN in the former period as top surface and that in later period as bottom surface, which can be taken as the 3-D restructuring of local geological body. The implementation method for local body is the same as that of entire one. Then the excavated body is to be subdivided in 3-D in the manner of analogical right triangular prism to form a serial of unit blocks of analogical right triangular prism. So that

$$P = \sum_{i=1}^{n} V_i d \tag{1}$$

where $P$ is the excavated quality, $V_i$ is the volume of the unit clock of analogical right triangular prism (m²), and $d$ is the density of ore (t/m³).

### 4.2 Simulation of stope excavation

The tope excavation can be simulated expediently in establishing of stope spatiotemporal, including mining playback and preview in advance. Since the aforehand computation method is applied, the excavation body model is stored in a month as a unit, and mining playback is to obtain the 3-D model by subtracting of the excavation body models with other model in adjacent period and playback it in the time sequence. This can be carried through the logic addition of excavated body because the adjacent excavating bodies have the same adjacent surface.

The advanced preview is based on the engineering scheme and simulates the prospective state of the stope according to the excavating positions estimated and quantity values. While the multiple advanced previewing, the excavated bodies can be calculated by using the method of difference computation of the local restructured bottom surface TIN and the original surface TIN in turns to realize the advance preview of production schedule and aftertime state based on the data.

## 5 Conclusions

1) A mixed model is put forward in this work by combining the vector boundary model with the analogical right triangular prism model, and then brings it into the framework of the spatiotemporal management by means of object-oriented multi-ground states spatiotemporal data models. By the mixed model it can resolve routine problems of production management in geology and surveying of open-pit with the improved accuracy and efficiency.

2) For validating this model, the stope spatiotemporal information system is designed under the environment of windows XP by VC++, which can simulate the dynamic mining process in the stope and realize excavated quantity computation and the 3-D displaying for the excavating procedure.

3) At present, it is still not a perfect 3-D modeling method which is effective for the mine digital management and the unity model with 3-D and time dimension needs further research.

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**(Edited by YANG You-ping)**