3D Modeling of Open Pit Based on AutoCAD and Application

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Abstract

3D geological model of open pit is an information platform in the construction of digital mine, which plays a significant role in the engineering design and production management of open pit. In the AutoCAD 2008 platform, take an open pit for example, it is required to construct a geological database, to construct fault wire-frame model according to the fault lines, to construct a terrain model according to the present situation map of stope and topographic contour map, to construct coal solid model according to the borehole data and interpolation points, and realize a visible display of 3D geological model for the open pit; to construct a block model according to the coal & rock solid model, and add the attribute and assign some value to it, and then apply it to the calculation of stripping and mining quantities of open pit. Compared with traditional calculation method, this method is simple in operation, which enhances its calculation speed and precision.

Keywords: 3D geological model; open pit; block model; application;

1. Introduction

During the process of mining investigation, design & construction, a great deal of geological data must be processed and gave a feedback to the practical production. The storage management of geological data in traditional mining engineering is mainly based on characters, drawings and charts, and it is

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inconvenient for the modification, query and analysis of the information, and furthermore the traditional method uses 2D plane to represent 3D geologic body, is lack of spatial concept, and the application of traditional method falls short of visual and efficiency, is unable to realize reasonable planning of mine, optimal design and optimal mining[1].

3D geologic model of open-pit mine is lifelike, intuitive, accurate, dynamic and informative, improving geological professionals’ understanding of geological data, increasing the utilization of the information and motivating the professionals’ analysis as well[2]. Meanwhile, more significantly, it has the functions of accurate mining design and production planning[3]. Therefore, the research on 3D geological modeling of open pit is of actual significance and practical value. Basic geologic data of an open pit coal mine will be adopted in this paper. It takes AutoCAD 2008 as a software platform and uses C#.NET for secondary exploration of the platform to construct its 3D geologic model used in engineering.

2. Construction of geological database

Geological data are the basis for the construction of 3D geological model of open pit[4], thus to collect, organize and store geological data with uniform format via geological database could not only guarantee the continuity and accuracy of the data but also combine them with 3D space, which is favorable for the analysis and utilization of the data in 3D space.

In the process of constructing 3D geological model of open pit, the common geological data mainly includes borehole data, profile data, contour data, measurement acceptance maps and production planning maps, etc. Prior to modeling, collection and arrangement of geological data were required, which mainly involved input of borehole data into Excel sheet in a certain format, vectorization of some original maps, checking and deleting redundant points and lines, etc[5]. Access 2003 was used as database. The blank database was constructed first of all, and then the geological data from the Excel sheet was exported to the blank database, followed by logical check of the imported results to avoid errors that might occur during data input. After the checking is done and accuracy is ensured, the geological database was constructed.

3. Spatial interpolation technique

Various geological data of open pit is obtained by means of geological exploration. Due to the limitation by factors such as terrain conditions, capital etc, all the geological data obtained is so sparse, limited and irregular that it is hard to describe the actuality of the geologic body of the mine; therefore, it is essential to select specific interpolation methods to construct geologic models meeting the accuracy requirements.

Common interpolation methods include: Tessellation polygon method, polygon projection method, distance power inverse ratio method, Kriging method, trend method, weighted least square method, etc. For different interpolation methods are applicable to different conditions, the appropriate interpolation methods shall be selected according to the geologic body’s own characteristics to ensure appropriate accuracy.

4. Construction of 3D geological model

Geological model generally includes the three types: wire-frame models, such as fault model; and surface models, such as terrain model; and solid models, such as rock mass and coal seam model. The three models form 3D geological model for the open pit.
4.1. Fault wire-frame model

The fault wire-frame model does not only play an important role in the solid model construction and spatial form analysis of coal seam, but also has an impact on the arrangement of the mining engineering. The fault lines in contour map of coal seam roof & floor are mainly applied to construct the fault wire-frame model as follows: firstly, 2D fault lines are transformed into 3D ones; secondly, the data points of coal roof & floor are extracted from geological database to assign elevation to fault lines; lastly, the spatial position of fault lines is extracted and the fault wire-frame model is constructed. The constructed fault wire-frame model is shown in figure 1.

![Fault wire-frame model](image1)

Fig. 1. Fault wire-frame model

4.1. Terrain model

The terrain model of open pit includes the original ground surface and stope situation, the construction of 3D terrain model can intuitively and clearly display the spatial relationship among the ground surface of mining area, stope situation of the open pit, coal seam and the geological structure. In this paper, the use of triangulated irregular network with constrains\[7\] to first generate unconstrained triangular net, and topographic isoline and bench line are took as constraint lines, and then the non-constraint triangular network is subdivided to construct the terrain model of open pit. This method has taken the characteristics of ladder-like surface distribution of the open-pit into full consideration. The constructed terrain model is shown in figure 2.

![Terrain model](image2)

Fig. 2. Terrain model
4.2. Solid model of coal & rock seam

The construction of solid model is the most important part during the whole process of modeling. The solid model not only has powerful 3D visualization function, but also is the constraints of constructing block model [8]. The solid model of coal & rock seam is constructed on the basis of mergence method, the modeling process is shown in figure 3.

Fig. 3. Modeling process of solid model

The modeling steps are as follows:

Geological database is linked. Data points of coal roof & floor are extracted from the database.
Delineating boundary bore holes in which coal is found to form modeling regional polygon through observing all the extracted data points.
Data points are interpolated by choosing proper interpolation method and grid interval.
Surface model of coal roof & floor will be constructed by interpolation points and fault lines.
The redundant triangulation net which is beyond the modeling region will be deleted, and then surface models of coal roof & floor are formed.
Boundary lines of coal roof & floor are produced by the models, and then surface model of coal side is produced by the boundary lines.
Solid model of coal seam is produced by combining coal roof & floor and side models.
The constructed coal seam solid models are shown in figure 4. The construction method of rock seam model is the same as constructing coal seam model.

Fig. 4. Solid modes of coal seam
5. Block model

The solid model only describes the spatial form of geologic bodies (such as rock mass, coal seam, etc), but it doesn’t reflect the internal characteristics or properties of the geologic bodies[9]. Not only a mastery of space position of geologic body but a mastery of intrinsic properties and its change law are required during the process of mining design and production, therefore, it is necessary to construct the block model. The modeling process of block model is shown in figure 5.

5.1. Construction of empty block model

Coordinate ranges of block model is determined according to spatial scope of solid model which will be estimated. Suitable size of block and secondary block are selected, and then the empty block model is constructed. But block model without attribute has no practical significance; therefore, block model should be added attribute. Block attribute can be used to reflect geological body's different properties of block element, such as bulk density, coal & rock types, reserves grade, coal rate, rock rate, sulfur content, calorific value, etc.

5.2. The assignment of block model

Assignment of block model includes two types: One is attribute value which is a certain value, which is directly assigned on the basis of extraction of the range of assignment by constraints, namely single
assignment. The other is attribute value which should be calculated by referring to some sample data according to certain rules, and then specific block will be assigned[10].

The attribute of coal & rock types is assigned by single assignment. The attributes of reserves grade and bulk density are assigned by polygon projection method, the reserves blocks in reserves calculation map are used as assignment polygon. The attributes of coal rate, rock rate, sulfur content, calorific value are assigned by distance power inverse ratio method according to sample data from geological database. The constructed block model is shown in figure 6.

6. Engineering application

Quantities of mining & stripping of open pit are calculated according to block model[11]. Take an open pit for example, to calculate the quantities of mining & tripping during August and September 2010. Surface models of stope status between August and September are constructed. The constructed block model is constrained by surface model of stope status in August, and the blocks below the surface model are taken. Then, the blocks above the surface model are taken by means of the second constraints of the blocks based on surface model of stope status in September. Mining-induced range of the open pit is generated by the twice constraint. The mining-induced range is shown in figure 7. Every block with the same attributes is added up and queried to calculate the quantities of mining & striping. The calculation result is shown in table 1.

Fig. 6. Block model of coal seam

Fig. 7. The mining-induced range
Table 1. The calculation table of quantities of mining & striping

| Coal rock types | Volume(m$^3$) | Weight(t)   | Coal rate  | Rejected rock rate | Bulk density(m$^3$/t) |
|-----------------|--------------|-------------|------------|-------------------|----------------------|
| Rock            | 4201600      | —           | —          | —                 | —                    |
| 3-1Coal         | 476756.62    | 653156.57   | 0.9868     | 0.0372            | 1.37                 |
| 3-2Coal         | 117876.65    | 167384.83   | 0.9332     | 0.1781            | 1.42                 |
| 2-2Coal         | 3138.17      | 4393.43     | 0.7369     | 0                 | 1.40                 |
| Total           | 597771.44    | 824934.83   | 0.8856     | 0.0718            | 1.40                 |

7. Conclusion

This article details the construction and applications of 3D geological model for open pit by taking a certain open pit as example and offers great values for both theoretical study and actual applications.

- The modeling method introduced above takes AutoCAD as a platform to construct wire-frame model of faults, terrain model and coal & rock solid model of open pit, and compared with traditional methods, it has powerful 3D visualization capability, which can vividly show the relationship of spatial locations among terrain, geologic body and geologic structure.

- Block model is constructed by adopting the solid model as constraints, by use of the block model quantities of mining & stripping of open pit can be accurately calculated. Compared with the traditional plane calculation method and profiling calculation method, it has quite a few features, such as simple, rapid, accurate and so on.

- The modeling method is simple and clear in thought and algorithm design is easy to implement. As a method worthy of a trial, it should be studied further.

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