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Application of Hidden Line Removal Algorithm in 3D Geological Model of Digital Mine

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Abstract: Due to the data characteristics of the 3D geological model of digital mine, the "T-F" (Visible is True or False) hidden line removal algorithm is proposed on the basis of depth sorting. The "T-F" algorithm first marks out the visible segments of edges with T or F on the basis of the hiding relationship between edges and planes. Then, we merge the visible segments of every edge to realize the goal of blanking. Finally, the proposed algorithm is successfully applied to 3D geological model cases on the platform of Microsoft VS2008.

Key words: Digital mine, 3D geological model, hidden line removal, "T-F" blanking algorithm, obscure judgement

INTRODUCTION

Recently, mine disaster happens frequently in China. On the one hand there are a wide range of mining enterprises with uneven levels of mining safety management. On the other hand China has a complex mining geological structure which leads to a vital arduous working environment. According to the statistics of National Bureau of Statistics of China and State Administration of Work Safety (2008), there are 27416 coal industry accidents from 2000 to 2007 and the death toll is 45162. A lot of worldwide mining powers include China tend to attach importance to the technology of digital mine, to improve national mining safety management and the efficiency of rescue organization after a mining accident and minimize the damage. Digital mine technology involves 3D geological modeling and visualization technology, reserve evaluation, mine design, mine safety, environmental protection, land reclamation, monitoring and control and so on (Du *et al*., 2010; Lixin *et al*., 2000, 2003; Lixin, 2000; Qing *et al*., 2004; Wei *et al*., 2004). By the research on the technology of 3D geological modelling and visualization, we could re-appear the virtual 3D underground mine. Then it is easy to organize rescue when accident happens. This study focuses on the hidden line removal algorithm which is one of the main algorithms of the technology mentioned above.

A lot of hidden line removal algorithms with different characteristics have been developed (Yuanjun, 2006; Jiaguang and Changgui, 1998; He *et al*., 2010; Wei and Xingyuan, 2009; Xiaoling, 2002). Sutherland *et al*. (1974) divided the polygon based algorithms into three types: Object space, image space and list-priority algorithms. While the object space methods compare every plane in the scene with other planes, then figure out the hiding relationship between all of the vertices, lines and planes. The performance of object space methods depends on the complexity of the scene.

Due to the data characteristics of the 3D geological model of the digital mine, the "T-F" (Visible is True or False) hidden line removal algorithm is proposed on the basis of depth sorting. The proposed "T-F" algorithm improves the efficiency of the existing blanking algorithms. At the same time, the output of the algorithm can be applied to many other environments.

DESCRIPTION OF 3D GEOLOGICAL MODEL

3D geological modelling is becoming more and more popular in the field of geosciences at home and abroad, especially for the mining field. People make use of the geological 3D visualization technology to display the extremely irregular entities intuitively, like geological structure, orebody, exploration engineering, tunnel and so on. The technology could instruct the development of mining effectively and decrease the risks of mining (Enke and Lixin, 2002; Litao and Qing, 2006; Daiyong and Zhangang, 2004; Wei *et al*., 2004; Breuning, 1999).

Data structure is the reflection of data model and the basis of blanking algorithm research. The data structure of 3D geological model can be divided into four types

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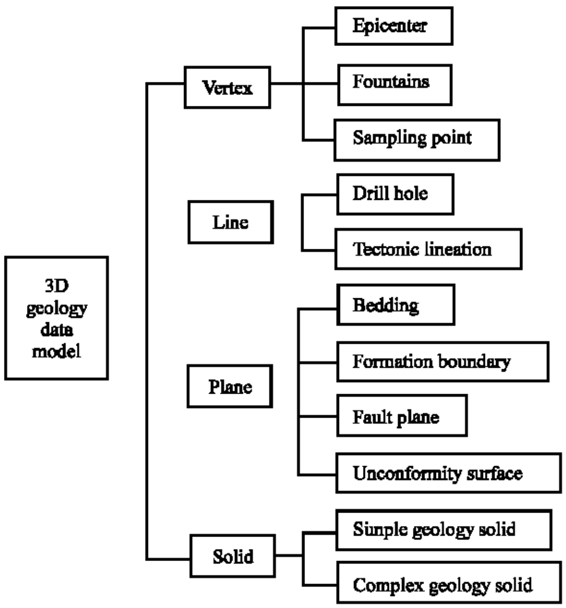

Fig. 1: The data structue of 3D geological model

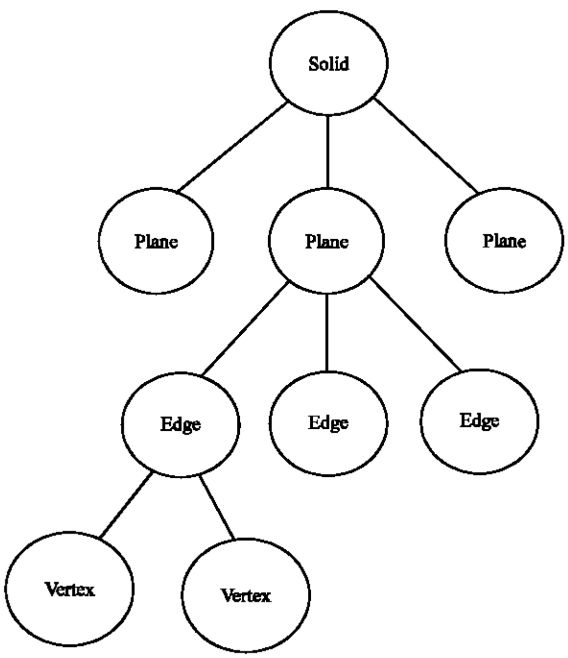

Fig. 2: Tree structure of 3D geological data

from the geometric point of view. They are vertex, line plane and solid. Vertex involves epicenter, fountains, sampling point and so on; line involves drill hole trace tectonic lineation and so on; plane involves bedding formation, boundary, fault plane, unconformity surface and so on; solid involves simple geological body and complex geological body. The data structure can be shown in Fig. 1. The tree structure used in storing the 3D geological data is shown in Fig. 2.

To introduce the hidden line removal algorithm, we should figure out the equation of every line and every plane first. The equation of the line can be easily figured out by coordinates of head vertex and tail vertex of the line, we won't discuss it here. Let's see how to get the equation of the plane. We assume that the plane's equation is:

$$Ax + By + Cz + D = 0 \tag{1}$$

Select three non-collinear vertices of the plane and substitute them in Eq. 1, we will get the equations:

$$\begin{pmatrix} x - x_1 & y - y_1 & z - z_1 \\ x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ x_3 - x_1 & y_3 - y_1 & z_3 - z_1 \end{pmatrix} = 0$$

The solution is:

$$A = \begin{pmatrix} y_2 - y_1 & z_2 - z_1 \\ y_3 - y_1 & z_3 - z_1 \end{pmatrix} = 0$$

$$B = \begin{pmatrix} z_2 - z_1 & x_2 - x_1 \\ z_3 - z_1 & x_3 - x_1 \end{pmatrix} = 0$$

$$C = \begin{pmatrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_3 - y_1 \end{pmatrix} = 0$$

$$D = -(Ax_1 + By_1 + Cz_1)$$

"T-F" HIDDEN LINE REMOVAL ALGORITHM

The hidden line removal algorithm involves 4 steps:

- Figure out every object's obscure sets
- Figure out every edge's visible segments by applying the self-blanking algorithm to every object
- Compare every edge with the objects involved in the obscure sets and figure out the visible segments
- Merge the visible segments of every edge

The first step involves two procedures: First figure out every object's obscure sets roughly by the depth value coordinate figure z, then get a more precisely obscure sets through the comparison of coordinate figures x and y. For example (Fig. 3) through the first procedure mentioned above, we conclude that square C has a obscure set of {A, B}, while the abscissa's maximal value of C is less than the abscissa's minimal value of B, so B will not obscure C. therefore, the final obscure set of C is {A}.

The 2,3 steps are the most important and complicated parts of the algorithm, they both involves the process of

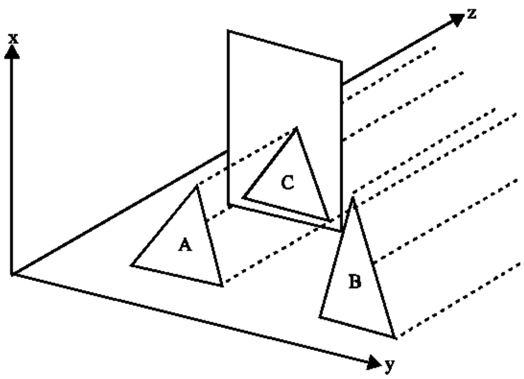

Fig. 3: Example of obscure judgement

obscure judgement. In the algorithm of "T-F", we divide the situation into 3 types according to the relationship between edge and plane. The detailed algorithm is showed as follows:

- Edge is in front of plane. Plane will not obscure edge, so the edge is visible
- Edge lies on the surface of plane. Edge may lies on the positive side or the negative side of the plane. If the adjacent vertices of the head vertex and the tail vertex of the edge are both on the negative side of the plane, the edge is invisible, else visible
- Edge is in back of plane. Edge is obscured by plane. The invisible segments will be the public parts of edge and plane, when they are projected to the projection plane (Fig. 4). Figure out the intersection points of the edge and the plane, put them into a list and insert the head vertex and the tail vertex into the list, then delete the repeat points of intersection
  - If the head vertex and the tail vertex of the edge are both inside of the plane, the edge is invisible
  - If the head vertex is inside of the plane, while the tail one is outside, there must be 3 vertices in the list, we mark them as F´ T´ F, else T´ F´ T
  - If the head vertex and the tail vertex are both outside of the plane, the amount of the vertices in the list must be 3 or 4. If the number is 3, we remove the middle one and mark the rest vertices as T´ F, else T´ F´ T´ F
- Edge penetrate into plane (Fig. 5). First finish the same task as is shown in step 3 and get the vertices list
  - If the head vertex and the tail vertex of the edge are both outside of the plane, there will be 4 intersection vertices in the list, mark them as T´ F´ T´ F
  - If the head vertex and the tail vertex of the edge are both inside of the plane, or one in one out, there must be 3 vertices in the list. If the head vertex is in front of the plane, we mark them as T´ F´ T, else F´ T´ F

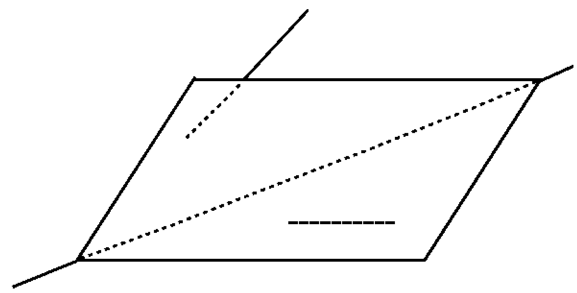

Fig. 4: Edge behind plane

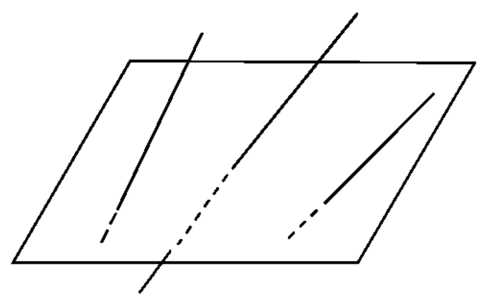

Fig. 5: Edge through plane

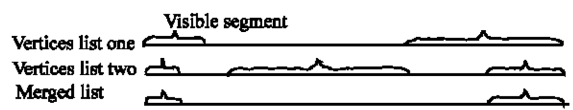

Fig. 6: Visible segments emerge

Finally, we merge the visible segments of the edges (Fig. 6) to reach the goal of blanking.

APPLICATION ANALYSIS

We apply the "T-F" algorithm to these two cases, they are mining tool miner lamp and 3D geological model block caving. The data information of these cases are shown in Table 1.

The effect pictures of hidden line removal is shown in Fig. 7-9.

Table 1: Data info of 3D geological model

Model	Nodes num	Planes num	Solids num
Miner lamp	252	362	4
Block caving	26950	23214	8

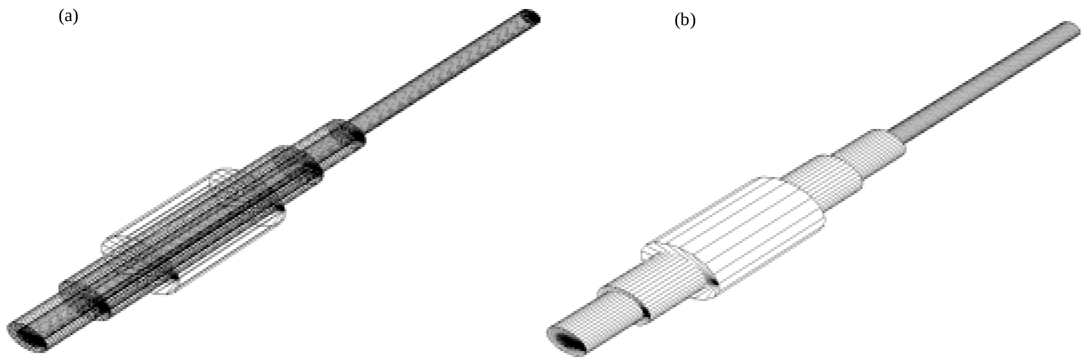

Fig. 7: Miner lamp's effect pictures of hidden line removal process; (a), Before hidden line removal process and (b), After hidden line removal process

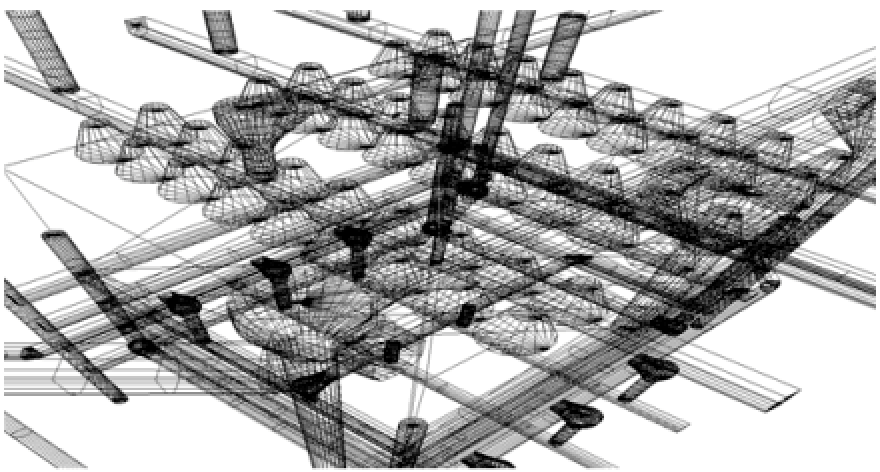

Fig. 8: Block caving model before hidden line removal process

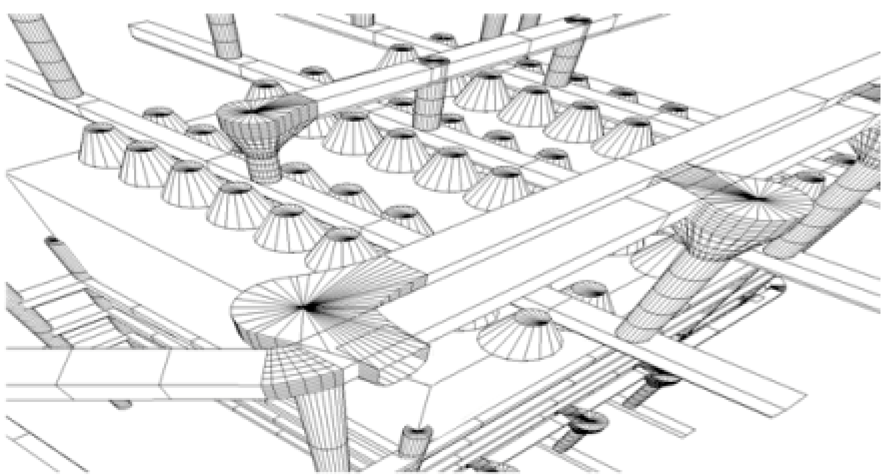

Fig. 9: Block caving model after hidden line removal process

The algorithm is implemented on lenovo computer and the programming platform is Microsoft VS2008, the programming language is C sharp.

CONCLUSION

The main advantages of this study are listed as follows:

- The "T-F" blanking algorithm runs fast and meets the need of actual application
- We use less time in accessing the 3D geological data during the process of "T-F" blanking algorithm

In this study, we put forward an improved hidden line removal algorithm: "T-F" algorithm. This algorithm is especially used in 3D geological models. We realized this algorithm on the platform of VS2008 and successfully applied it to the cases of 3D geological data models.

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