Application of tetrahedral mesh model based on neural network in solid mineral reserve estimation[1]

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Abstract

Mineral reserve estimation involves large amounts of geological data, and the traditional manual computation method is a heavy and fussy work. Computing mineral reserve with 3D orebody modeling can increase the efficiency heavily of reserve estimation and management. On the basis of analyzing several 3D orebody modeling methods, this paper choose tetrahedral mesh model to construct orebody, and introduces a mineral reserve estimation method based on neural network. The main advantages of this technique are an according management for orebody boundary and inner grade distribution, as well as its precision. Therefore, this technique has an academic and practical value.

Keywords: Tetrahedron, Reserve estimation, Orebody modeling, 3D

1. Introduction

Mineral reserve estimation is to compute the valuable deposit quantity according to the mineral deposit data gotten by geophysical surveying. Computing mineral reserve with 3D orebody modeling can increase the efficiency heavily of reserve estimation and management.

When calculating reserve through these traditional orebody modeling, we usually use geometric average method which is replacing the irregular body by regular body to calculate volume. And the result is not enough precise. To solve the precision problem, this paper propose tetrahedral mesh model for orebody modeling and reserve estimation.

Tetrahedron is the simplex in 3D, and it's the most basic element to express the geometric topological relationship in 3D. Tetrahedrons can describe the surface and inner together, make 3D interpolation and visual analysis effectively, and illuminate the topologic relationship by the adjacency among tetrahedrons.

Having researched in tetrahedral model deeply, this paper introduces an orebody modeling algorithm through tetrahedral mesh based on neural network.

2. 3D tetrahedral orebody modeling with neural network method

There are mainly three methods in tetrahedral mesh generation, that is, advancing front method[1], Octree method[2] and Delaunay method[3]. The first one is suitable to body with boundary representation; the second one is a graphic data structure by recursive definition, and the mesh number is large relatively; the third one is also called empty sphere method, and its result network has good mathematic character.

Here we take a tetrahedral mesh generator inspired by a dynamic feed forward neural network[4] to model the initial orebody. The algorithm is as follows:

(1) Data acquisition. Firstly, we abstract the mineral deposit as a grade data field in consecutive space. Then disperse the total data field by interpolating the original drill hole data to get the discrete deposit grade data. Thirdly, we divide the grade data into some segments from low value to high. The segments' number is defined by user. So we can get the discrete point set P[i] of each grade segment.

Let n denote the number of points in P[i]. Let M(j) denote the matrix M at step j. In the algorithms, the tetrahedrons at step j are contained in TL(j), and the initial j is equal to 4.

(2) Initialize the lower and upper tetrahedrons, TL(4) and TU(4), with the indices of the first four points, so that

$$\mathrm{TL}(4)=\mathrm{TU}(4)=\begin{bmatrix}1\\2\\3\\4\end{bmatrix}$$

(3) Initialize the equations of the circumspheres LS(4) and US(4) which is S(x) = $\sum w_i x_i + w_{d+1}\|x\| + w_{d+2} = 0$ for the lower and upper tetrahedrons respectively.

For j = 5 to n do the following.

(4) Test the new point on LS(j-1) and US(j-1), the circumspheres.

(5) If the new point lies inside (respectively outside) a circumshere of a tetrahedron, i.e., the output of the neuron for that tetrahedron is positive (respectively negative), corresponding to a lower (upper) tetrahedron, then that tetrahedron needs to be changed. The column corresponding to this tetrahedron needs to be removed from TL(j-1) (respectively TU(j-1)) and appended to a list A(j) comprised of tetrahedrons to be adjusted. TL(j) and TU(j) consist of the remaining columns of TL(j-1) and TU(j-1), respectively. Also delete the neurons associated with simplexes in A(j), and remove their associated equations from LS(j-1) and US(j-1) to obtain LS(j) and US(j) respectively.

(6) From A(j) obtain a list C(j) of candidate three facets by deleting each point of each tetrahedron, one at a time, storing the deleted point in a list T(j). Clearly, the number of three faces for each tetrahedron is four. Keep only those that are unique in this list. The resulting lists contain the "outer" three faces of the tetrahedrons in A(j) and their test points.

(7)The new tetrahedrons will be formed with each three faces and the new point. This is done by appending the new point to each three faces in C(j). From the updated C(j), obtain CS(j) the equations of the circumspheres of the new tetrahedrons. One new neuron for each new tetrahedron is necessary and the weights and biases of the new neurons are contained in the equations describing CS(j).

(8) Test the circumsphere of each new tetrahedron with the corresponding point in T(j). If the output of a neuron is negative (respectively positive), i.e., the test point lies outside (respectively inside) the circumsphere, append the corresponding tetrahedron to TL(j) (respectively TU(j)) and the equation of the associated neuron to LS(j) (respectively US(j)).

3. Solid mineral reserve estimation flow based on tetrahedral mesh model

Solid mineral reserve estimation based on tetrahedral mesh means to simulate orebody with tetrahedral mesh according to the information acquired from exploitation so as to estimate scientifically about the orebody shape, quality, grade, ore quantity and metal quantity. The estimation flow is as Figure 1.

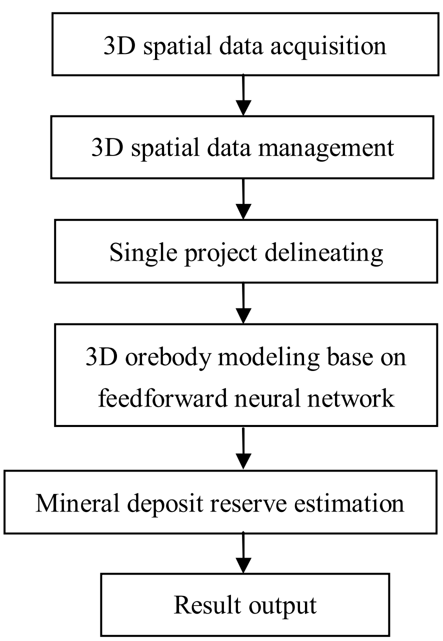

Figure 1 Solid mineral reserve estimation

3.1 3D spatial data acquisition and management

Data included in solid mineral reserve estimation are various and abundant, for example, the basic geological data, geological classified data, sampling data, middle and final result data in reserve estimation, the 3D orebody model data, and so on. These data can be classified into spatial data stored as map and attribute data stored as table. After regularization, they can be stored and managed conformably in a commercial spatial database engine such as MAPGIS SDE.

3.2 Single project delineating

For a single exploitation project, we must delineate the orebody's shape, thickness and position of the sample data by industrial indexes (includes boundary grade, minimum industrial grade, minimum mining thickness, dirt admit thickness, etc.) so as to delineate the boundary points, show the orebody's continuity and prepare for the orebody connection at the prospecting line profile. Traditional single project delineating is usually done manually. That's a fussy and heavy work. So it's better to do this aided by computer and let user modify the result interactively.

3.3 Reserve estimation

After building the tetrahedral mesh of orebody as part two described, compute the reserve by calculate the tetrahedrons' volume. The expression is as follows:

$$V = g\sum_{i=1}^{n}(Vi \times Ci)$$. Thereinto:

n is the number of tetrahedrons;

g is the average orebody weight;

$$Vi = \frac{1}{6} \times \begin{vmatrix} 1 & 1 & 1 & 1 \\ x1 & x2 & x3 & x4 \\ y1 & y2 & y3 & y4 \\ z1 & z2 & z3 & z4 \end{vmatrix}$$. Thereinto:

(x1, y1, z1), (x2, y2, z2), (x3, y3, z3), (x4, y4, z4) are the four vertices of each tetrahedron.

3.4 Result output

We can manage the mineral deposit reserve by classification and generate grade tonnage statistics, reserve distribution map, reserve isoline map, grade tonnage model, reserve classification statistics, economic value analyze table, and so on.

4 Conclusions

Mineral reserve estimation method based on tetrahedral mesh introduces a new technique for the computation and analyze of orebody volume, reserve, grade and economic exploitation so that it has academic and useful value.

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