Research on the Algorithm of Automatic Branch Modeling in 3D Model Reconstruction from Parallel Contours

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ABSTRACT

3D model reconstruction based on parallel contour is a problem distributed in many application fields, which include main matter of correspondence, branch, tilling and fitting. The research situation of branch problem is described in this paper, and a definition is given according to the model features of branch. The contours in the adjacent plane are projected in the same plane, and divided into two classes through the region division method. Algorithm which to calculate the auxiliary branch geometry object is present in this paper with the polygon center line method. Finally, experimental study was carried out in 3D geological modeling, and experiments show that the algorithm in this paper can improve the modeling efficiency and precision.

Keywords: 3D visualization, parallel contour, branch model, 3D geosciences modeling

INTRODUCE

The 3D model reconstruction based on parallel contour line refers to the three-dimensional surface model which constructed by a sequence of parallel contours, which is one of the research focus in the field of computer graphics, computer vision, geometric modeling, geographic information system etc. It has been widely used in 3D data field visualization, reverse engineering modeling, mechanical modeling, medical imaging and 3D geological modeling etc. The modeling method can classify by the surface feature into two category of volume visualization and triangulation mesh. The model method of volume visualization with the feature of high degree automation, high precision, easy smooth processing, widely used in the field of medical imaging, but the its reconstruction process is difficult to additional control operation, therefore not suitable for complex interactive modeling occasions.

According to the problems of correspondence, branch, tiling and fitting, scientific researchers have carried out extensive research and achieved fruitful results, especially the problem of branch. Liao[1] proposal methods of "reference curve" and "normalized position" to solve the branch problem. Tang[2] and Li[3] present two way to add manual assistant line to control the branch position. Chen[4] create the new center contours to solve both correspondence and branch problem. All of these methods require manual intervention, and the operation process is complex with low efficiency. Barequet G[5,6] raised the automatic processing branch algorithm using dynamic programming method, but the interactive ability of modeling procession is weak. From the researches of above, automatic processing algorithm research of branch problem is particularly necessary.

AUTOMATIC BRANCH MODELING ALGORITHM

1.1 Definition of branch problem

The branch problem is that there are more than one corresponding relations between adjacent contour set, which can divided into two conditions of one-to-many and many-to-many, as shown in figure1.Because the many-to-many relationship is difficult to handle, so the complicated many-to-many operation usually convert to several relationships of one-to-one or one-to-many before branch modeling, and this can comb the relationship easier. In addition, the one-to-many relationship can also be regarded as a special kind of many-to-many relationship by the relationship theory.

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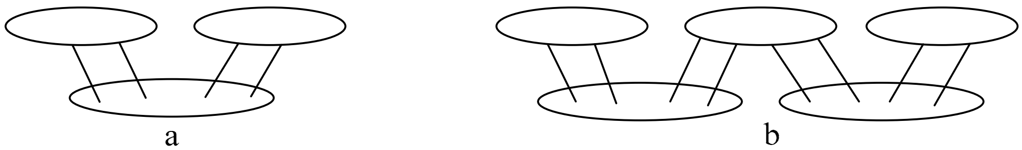

Figure 1. the relationship of branch

In order to descript the branch modeling algorithm more clearly, we give the following definition of branch problem.Pi（p1,p2,⋯，pn）is defined as a contour line which contains n points, and all point of this contour are on the plane i. (Pi, Pj) show that Pi has corresponding relationship with Pj, named corresponding pair. Si（P1，P2,⋯，Pn） is defined as a contour line set which contains n contours, and all contour in the set are on the plane i. If all contours in Si and Si+1 have the determined corresponding relationship to other contours in opposite plane, (Si, Si+1) can be defined as corresponding contour set. Conversely, if there is any contour not has the determined corresponding relationship, then the (Si, Si+1) is uncertain corresponding contour set. The calculation and determination of the corresponding relationship is not the content in this paper, so all contours in the modeling procession are required have the determined corresponding relationship. (P_i^j, P_{i+1}^k) shows that the contour Pj in plane Si is corresponded to the contour Pk in plane Si+1.In the corresponding contour set (Si,Si+1), if there any contour have more than one corresponding relationship with the opposite plane, so we regard (Si,Si+1) has branch problem.

Figure2 is a example of corresponding contour set (Si, Si+1) with corresponding relationship. The figure contains six corresponding pairs as:

$\{(P_i^1, P_{i+1}^1), (P_i^2, P_{i+1}^1), (P_i^3, P_{i+1}^1), (P_i^4, P_{i+1}^1), (P_i^4, P_{i+1}^2), (P_i^5, P_{i+1}^2)\}$

Contour P_{i+1}^1, P_{i+1}^2 and P_i^4 have more than one corresponding relationships.

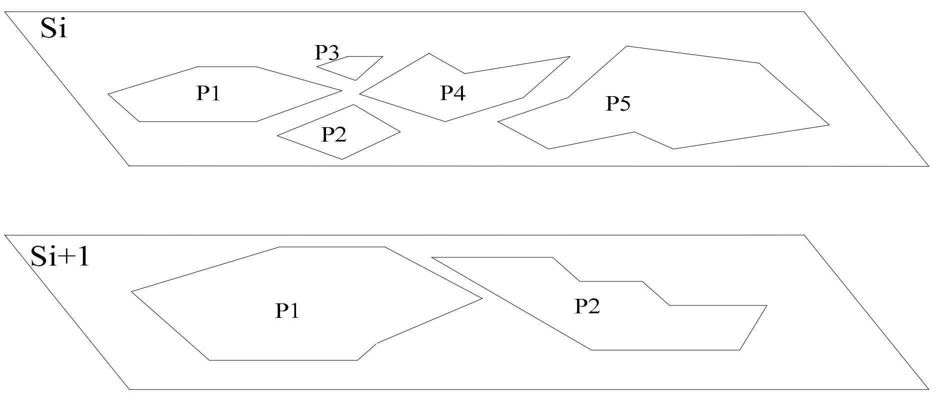

Figure 2. corresponding contour set with branch problem

1.2 Branch region division

Construction of all triangular between two contour set in one procedure is too complex, which can be divided into several area by the branch geometry feature, and this can help construct the whole model surface better. In order to simplify the calculation, the corresponding contour set (Si, Si+1) should be project onto the same plane. It should be pay attention to the direction of project, for example, we can choose the vector which start with the gravity center of Si and end with Si+1. The contours in Si projected onto Si+1 one by one, and to boolean with the corresponding contours in Si+1. The boolean calculation between two contour has three condition: separation, intersection and inclusion, shown as in Figure3. At ere, we regard the coincidence is a special case of intersection.

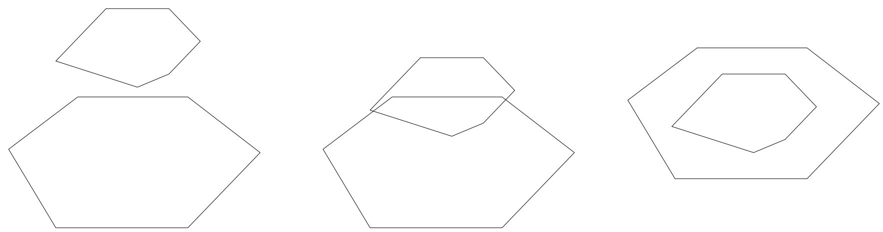

Figure 3. Three relationships between two contours

If there is corresponding relation between P1 and P2, P2 only corresponding to P1, and P1 has relation to other contour in addition to P2. If the two contour lines separate with each other, then take the following algorithm:

Step1: calculate the convex boundary contour Px which cover P1 and P2.

Step2: carry out boolean operation with Px and p1 Px – P1= Pm, with a slash mark shadow of Pm.

Step3: carry out boolean operation with Px and p2 Px – P1= Pn, with a normal shadow of Pn.

Pm and Pn is the result of division algorithm, as shown in Figure 4(A). If P1 intersect with P2, the calculation is similar to the above but to get Px with P1+P2 in Step1, as shown in Figure 4(B).

If P2 contained by P1, carry out boolean operation P1-P2 to get the division result area Pm directly, as shown in Figure 4(C).

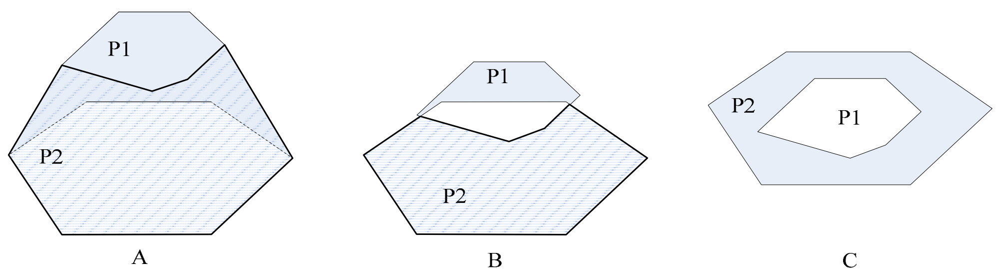

Figure 4. Region division of two polygons

When there is a many-to-many relationship in corresponding contour set, branch division sequence should be as follow:

(1)All contours in the corresponding pair only have single corresponding relationship.

(2)One contour in the corresponding pair has single corresponding relationship.

(3)All contours in the corresponding pair have more than one corresponding relationship, but they will sorted by the number of corresponding from small to large.

(4)There is containing relationship in the corresponding pair.

Here, we should notice that the sequence create by above rule is not unique. Use the above rule to dill with Figure 2, and the result is as follow:

$\{(P_i^5, P_{i+1}^2), (P_i^1, P_{i+1}^1), (P_i^2, P_{i+1}^1), (P_i^4, P_{i+1}^2), (P_i^4, P_{i+1}^1), (P_i^3, P_{i+1}^1)\}$。

Divide the whole Figure 2 graphs by the order of the above, the result is shown as Figure 5.

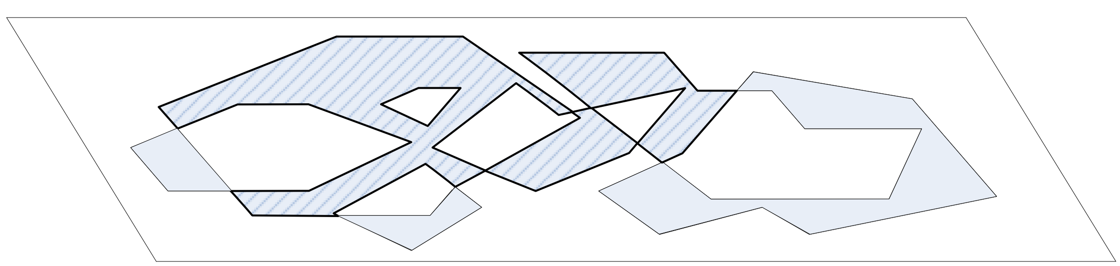

Figure 5. Complex branch region division

Here, we do not consider the contour with hole, because that is rare condition in branch modeling application. In addition, the hole can be converted into another type contour to branch modeling as above separately, which can be combined or calculated with other models. Therefore, the branch contour with hole also can be handled with the method in this paper.

1.3 Triangular mesh construction in Branch region

The branch model region has been divided into several small regions in the section 2.2. The small regions can be divided into two classes, one is covered by slash shadow with branch factor, and another is no branch factor covered by common shadow. It should take different triangulation algorithm to dill with the two regions talked above. In fact, there are many algorithms for polygon triangulation, and we will use Delaunay method in this paper.

The normal shadow region can be handled by the Delaunay triangulation algorithm directly. In order to deal with the slash mark region referred to branch factors, the polygon center line algorithm will be introduced as follow to calculate the center line between two separated polygons.

If Polygon P1 and P2 are not intersected, the center line between P1 and P2 calculated as follow steps.
Step1: calculate the minimum convex boundary Pm of P1 and P2;
Step2: carry out boolean operation Px=Pm-P1-P2, as shadow area shown in Figure 6;
Step3: the center points of the two link edges divided Px to two line segment Seg1,Seg2.
Step4: select one of the center point of line edge as start point, and another center point of line edge as end point, to calculate one center segment Segx;
Step5: set the both ends of Segx as ray which can extend the length of Segx.

The above calculation step is shown in Figure 6.

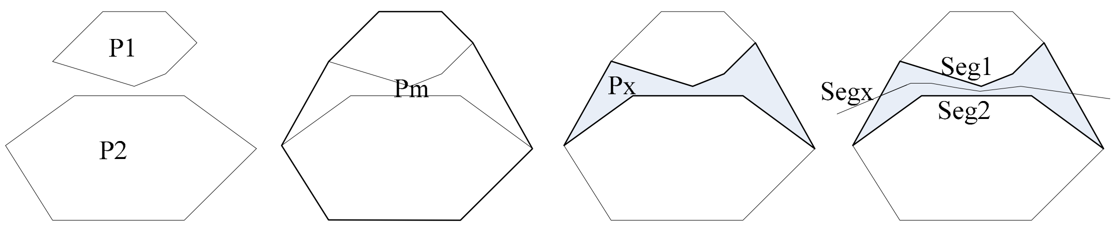

Figure 6 the calculation of polygon center line

The slash mark regions in the Figure 5 can be handled by the above algorithm to get the center lines between polygons, as shown in Figure 7. All the division regions would be handled by the Delaunay algorithm to get the triangular network, and the whole branch region triangular network has been setup. According the project of Si and Si+1, all the object in project plane can be restored to their origin three dimension coordinate system, then we can get the hopeful 3D branch model.

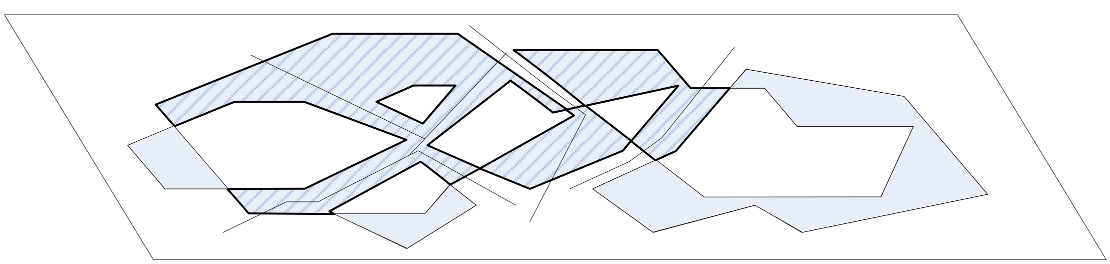

Figure 7. The center line of complex polygon region

EXPERIMENTS

3D geosciences modeling use computer technique in the three dimension environment to visualize and analyze the geological body. The solid model of geological body is from ore parallel contours, which is an typical application of branch model. The complicated geological structure cause great difficulties to 3D geosciences modeling, and one of the reason is it contains many branch models. A experiment system with the branch model method in this paper based on C++ and OpenGL technique is setup, which improve the efficiency and precision compared with traditional manual control branch model. The 3D geological body model of a deposit in Ma'ansh China is shown in Figure 8.

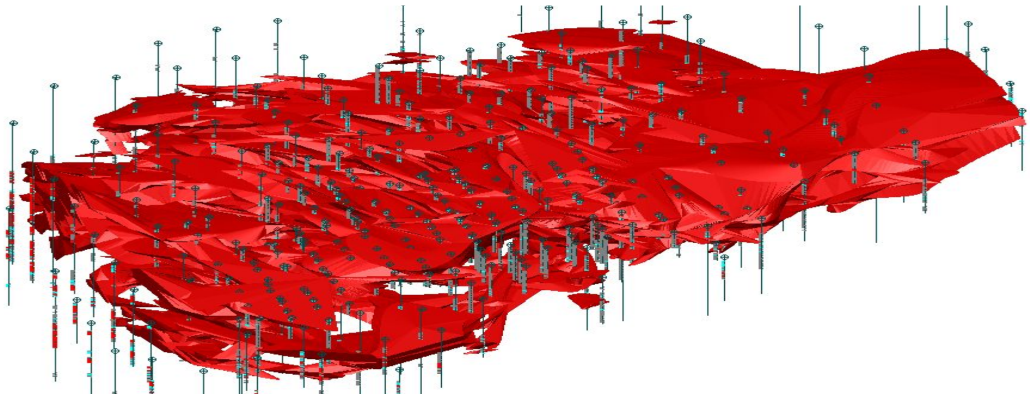

Figure 8. 3D geosciences modeling experiment

CONCLUSION

In this paper, based on branch modeling that the key problem of 3D reconstruction from parallel contours, several algorithms is proposed to solve the branch modeling, which is proved succeeded in the 3D geosciences modeling experiment. However, the modeling reconstruction from parallel contours is not satisfied because it is difficult to control the modeling precession freely. In fact, we almost have no way to edit the model after setup. So, algorithms easer to control the modeling procession and mode with editable parameter is a very important orientation in 3D model reconstruction from parallel contours.

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