Research and implementation of 3D reconstruction base on multi-contours

Kunliang Liu[1], Jinming Huang[2*]

[1]*School of Computer Science and Software Engineering, Tianjin Polytechnic University, Tianjin 300387, China*

[2]*Development and Research Center, China Geological Survey, Beijing 100037, China*

Received 22 May 2014, www.tsi.lv

Abstract

3D Reconstruction often faces to a serial of 2D contour lines but not to volume data, which as we often processed, so study of 3D reconstruction based on multi-contours has important practical values. In the process of 3D-reconstruction based on multi-contours, contours correspondence, contours splicing, branch problem, and terminal contours closing are all its key technologies. In this paper we give the concrete solutions on every step of 3D construction of multi-contours. According to winding issue of contours we provide means of gauging sum of angles of contour's edges adjacent to each other, which avoided error judging of winding of contours. As to branch issue of one contour corresponding to several contours, we give the way of splitting contour based on ratio in circumference of corresponding contours. We also give the mean of maximal field angle to reduce the calculation time on triangulating terminal contours. The solution we provided can give correct result of contours splicing under any kind of contours. It proves that every step of the solution is correct and effective. The solutions we designed are more general than other solutions.

Keywords: contour, 3D reconstruction, Delaunay triangulate, convex hull

1 Introduction

We consider a 3D-Reconstruction problem, in which a sequence of contour lines is to be sewed up to construct a closed surface; with the surface, we can obtain three-dimensional shape of geometric objects. 3D-Reconstruction problem based on multi-contours arise in a wide area of applications, including medical data visualizing, 3D geological modelling and biological science displaying. In practical application, the data information we get often not a volume data using which we can construct object shape easily base on MC algorithm, but a serial of contour lines information. For instance, in the process of medical data visualization, if the distance of two medical slices of CT or MRI image is much greater than the image resolution, that is, the sample interval in Z direction is very sparse. In this case, we should outline contour lines to enclose the region we are interested in on every image slices and reconstruct the triangulation network model from the serial contour lines. Another example is in the field of medical image three-dimensional data visualization, though the distance between two adjacent tomographic images are very small, the computer cannot distinguish different co-exist material from one to another based on current material classification techniques. Therefore, we need medical specialist to outline the areas of interest. In the medical treatment system, In order to ensure the accuracy and reliability of the treatment we should firstly outline organs (blood vessels, nerves, etc.) contour lines, and then reconstruct the tissue surface via these contour lines. Therefore, the tissue surface reconstructed from organs contour lines can assist medical diagnosis greatly, provide a reliable basis for the elaboration of best surgical options to improve surgical quality, reduce malpractice [1]. Again also in 3D geological model reconstruction technology, the solution should interlink the contour lines of adjacent geologic sections to generate the 3D geological model. Therefore, under the need of the practical application of the above, the study of three-dimensional reconstruction has very important practical value. In the process of 3D-reconstruction based on multi-contours, contours match, contours splicing, contours divergence handling, and terminal contours closing are all its key technologies. In [2], contours splicing are based on OBB projection transformation, authors first determine the vertices of the polygon convexity, for concave vertex, convert it to the corresponding convex hull, then calculate the Oriented bounding box of convex hull, rotate and pan the bounding box, compute the inscribed ellipse of bounding box, project proportionally every vertices of contour lines on this oval, splice the contour lines base on project vertices, tell correspondence between the vertices of adjacent contour lines; Finally, restore the actual coordinates, perform a three-dimensional reconstruction of the original model. The approach can resolve the problem of cross-stitching better than the shortest diagonal method, but under certain circumstances, this approach can also occur distortions, for the reason of not considering

*** Corresponding author** e-mail: 2003_asecliu@126.com

contour centre alignment problems and the changes of the contour size, the model sometimes will be even worse compared with the original model, and that the method did not solve the problem of splitting of contour lines too. In [3] Although author considered the centre alignment and contours size change and proposed contours branch solutions, When processing branch issues the solution required manual intervention, reducing its automatic and did not deal with the end of the contour line plugging problems which would result in empty in the end of the contour lines, so the spliced results can not to form a closed surface. Current splicing resolutions of multi-lines provided by all the paper involved focused to achieve some particular steps, resolve some particular problem. It only suit limited scope and is not universal. This paper, aiming at the reconstruction problem of contour lines, effectively resolved the cross-cutting issues in stitching contour lines, achieved the automatic processing of branch contour and closing of terminal contour.

2 Pre-treatment contours

As for adjacent contours lines, if the centre is aligned, the shape resembling and the twining direction is identical, Splicing results generally cannot go wrong. In fact, the contour lines for three-dimensional reconstruction have diversity shape, in order to improve the effect of reconstruction, avoid wrong connection, it is necessary to pre-process them before stitching.

2.1 CENTER ALIGNMENT AND SIZE ADJUSTMENT OF CONTOURS

Adjacent contour lines shape and the centre position may be largely different, so in order to correctly splice the contour lines it is necessary to convert the contour lines by panning and zooming coordinates, so that the centre is identical to each other and the size ratio coincides with each other, otherwise, it will produce cones phenomenon, as Figure 1 shows. Assuming two adjacent contour lines are Contour1 and Contour2, whose enclosing rectangle centre coordinate are center1(x1,y1) and center2(x2,y2), in which PanFactor and ZoomFactor denote the translation distance and scaling factor of the contour line, then there is formula as Equation (1) shows.

$$\begin{cases} PanFactor.x = x2 - x1 \\ PanFactor.y = y2 - y1 \\ ZoomFactor.x = width2 / width1 \\ ZoomFactor.y = height2 / height1 \end{cases}. \quad (1)$$

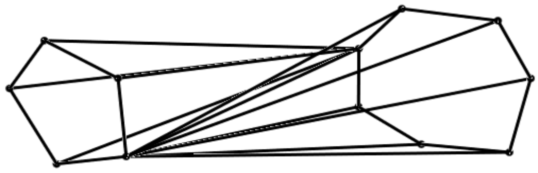


FIGURE 1 Incorrect splicing, resulting in cones

All coordinates of Contour line of Contour 1 maintains unchanged, each point coordinate of Contour 2 are adjusted as Equation (2) shows.

$$\begin{cases} Contour2.x = (coutour1.x + PanFactor.x) * ZoomFactor.x \\ Contour2.y = (contour1.y + PanFactor.y) * ZoomFactor.y \end{cases}. \quad (2)$$

2.2 TWINING DIRECTION CONSISTENCY ADJUSTMENT OF CONTOUR

For adjacent contour lines, after their position and size have been adjusted, if their twining directions are not identical, some of the contour lines direction should be reversed to make their twining direction identical. These judgments and treatment are problems often encountered in computer graphics processing, pattern recognition, CAD and other areas. In most cases, calculating the contour line normal vector if the adjacent contour lines' normal vector are inconsistent, then the twining direction of contour line are different, so there needs to reverse the twining direction of some contour lines, this can be obtained by reverse the control points' arrangement. As the contour lines shape are diverse, the contour line may be convex polygon or concave polygon, the method judging the twining direction via contour line's normal vector only suits for convex polygon, there is likely to get wrong result when contour line is concave polygon, one solution is firstly projecting concave polygon onto it's convex hull, then calculating the normal vector of it's convex hull, but this method increases the amount of computation. This paper adopts the method of judging the sum of angles to solve the twining problem. This method suits for diverse shapes of contour line, without having to calculate concave polygon's convex hull. When using this means each edge of the polygon of contour lines can be seen as a directed edge whose direction coincides with the direction of the vertex arrangement. After calculated the sum of deflection angles between current edge and the next edge of the contour line, then judged the signs of adjacent contour lines' deflection angle sum, if their sign are identical, their twinning direction coincident, otherwise inconsistent. In order to get deflection angle sum, the normal vector direction of the plane in which the contour line lies should be ensured identical, then computing respectively the dot product and cross product of the two adjacent edge of the contour line, based on dot product the angle between two adjacent edges of contour line can be ascertained, based on the cross production of the two adjacent edges of contour line and the normal vector of the plane the sign of the angle can be ascertained, if cross production vector has the same direction with the plane normal vector the sign of angle is positive otherwise negative. No matter concave polygon or convex polygon the accumulative sum of deflection angle of contour line is or near 2π or near -2π. The process is as Figure 2 shows and the formula is as Equation (3) shows. In which M_i is the dot product of two adjacent edges, N_i is the cross product of two adjacent edges, N_{face} is the plane normal vector in which the contour line lies. The value of angle (i) is positive if N_i and N_{face} have the same direction, otherwise, negative.

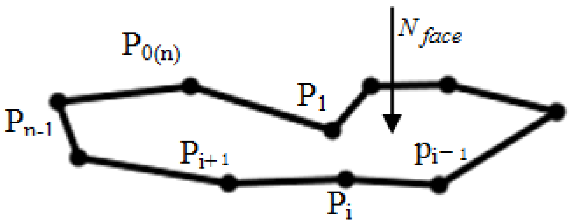


FIGURE 2 Calculate deflection angles sum

$$\begin{cases} M_i = p_{i-1}p_i \bullet p_i p_{i+1} \\ N_i = p_{i-1}p_i \times p_i p_{i+1} \\ Angle(i) = \pm ar\cos\left(\dfrac{M_i}{|p_{i-1}p_i| \bullet |p_i p_{i+1}|}\right) \\ SumAngle = \sum_{i=0}^{n} Angle(i) \end{cases} \quad (3)$$

2.3 COMPUTING CONVEX HULL OF CONTOUR AND PROJECTING COORDINATES TO CONVEX HULL

Convex contour can be stitched directly using splicing technique, but concave contour needs to firstly computing its convex hull, and then projects its concave vertices on to the convex hull. The contour lines of connection area of ore body delineation and stratigraphic section are usually concave polygon, so it needs to disposal concave polygon to convex polygon.

Convex hull is an important tool when describing the shape and extracting the feature of object. It has been widely used in the research field of pattern recognition, image processing etc. The definition of convex hull is very simple, as for an arbitrary point set s or a polygon p, the convex hull is the minimal convex polygon that can encircle the points set s or polygon p. we design and implement the algorithm to convert arbitrary contour into convex one, the main algorithm framework is as Figure 3 shows.

After having computed the convex hull of concave contour line, we project points, which are concave points of contour onto the line segment, which is determined by the two nearest convex points of the contour line; we can obtain a convex contour from an arbitrary contour. There are two projection modes, one is according to the length proportion, and the other is vertical projection. Due to vertical projection has the result of folding line, so we select length proportion projection based on the ration, that the distance between current concave point and the previous convex point compares to the distance the previous convex point and the successive convex point on contour line. Compared to the vertical projection mode the length proportion project can effective avoids the problem of cross-stitching due to folding line.

$$\#define\ ConvexDeg(v_i, v_j, v_k) \quad (v_k.x - v_j.x)*(v_j.y - v_i.y) - (v_k.y - v_i.y)*(v_j.x - v_i.x)$$

```
void CalConvexHull(V, n, &S)
input: contourline's vertexset V, vertexnumber n
output: contourline's convexhullvertexset S
{
  InitStack(S);
  push(S,v0); push(S,v1);
  k = 2;
  a = v0; b = v1; c = vk;
  while( k != 1)
  {
    while(ConvexDeg(a,b,c) <= 0 & & ( Top >= 1)
    {
      Pop(S);
    }
    a = S[Top]; priorpointin V
    b = S[Top];
    c = S[Top]; subsequentpointin V
    while(ConvexDeg(a,b,c) < 0 & & Top >= 1)
    {
      V = V - vk;
      k = (k+1)% n
      a = S[Top - 1];  b = S[Top];   c = vk;
      while(convexDeg(a,b,c) > 0 )
      {
        V = V - vk;
        k = ( k+ 1 )% n
        c = vk;
      }
      Pop(S);
    }
    Push(S,vk);
  }
  a = S[Top - 1]; b = S[Top]; c = v1;
  if( convexDeg(a,b,c) < 0)
    Pop(S);
  a = S[Top]; b = S[1]; c = S[2];
  if( convexDeg(a,b,c) < 0 & &
    S[1]is the first pointin V)
    for( i = 1; i < Top - 1; i + +)
    {
      s[i] = s[i + 1];
    }
    Pop(S);
}
```

FIGURE 3 Main algorithm of converting arbitrary contour into convex one

3 Contour line splicing

Assuming two adjacent parallel planes each have a contour line, the upper contour line point array is $p_0, p_1, ..., p_{m-1}, p_m$ (in which p_m and p_0 are the same point), the lower contour line point array is $q_0, q_1, ..., q_{n-1}, q_n$ (in which q_0 and q_n are the same point), the point array is arranged in counter clockwise. Every line segment $p_i p_{i+1}$ or $q_i q_{i+1}$ is called line segment of contour line. We can get a Triangular facets through connecting two control points of one line segment to an adjacent contour's control point, as Figure 4 shows.

We define the line segment, which connects the point on upper contour and the point on lower contour as span. Obviously, a contour line segment and the two spans, which connect the two control points of the line segment to the adjacent contour line's control point form a triangle facet, it is called elementary triangle facet. The two spans are called left span and right span respectively. The three-dimensional shape reconstruction based on two convex contour lines is to use a series of triangular facets interconnecting the upper and the lower contour lines. But how to guarantee the connected three-dimensional shape reasonable and has a good properties are the issues that need careful study. The numerous elementary facets interconnecting the upper and the lower contour lines must compose the interconnected three-dimension surface and must not intersect each other inside the triangular facets.

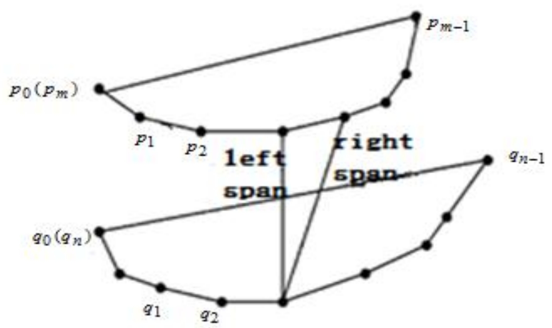


FIGURE 4 Connecting control points

Therefore, if the triangular facets are reasonable they must satisfied the two conditions as follow:

1) A contour line must and can only appear in an elementary basic triangular facet. Therefore, if the two upper and lower contour lines respectively have m and n line segment, the reasonable three-dimension surface of reconstructed shape must have $m+n$ elementary triangular facets.

2) If the span is the left span of an elementary triangular facet, it must and only be the right span of another elementary triangular facet.

The triangular facets meet the above criteria set are acceptable body surface. For two adjacent contour lines and points array on it, the acceptable body surface meets, the above criteria can have a variety of different combinations. In so many combinations of acceptable surface, in order to determine a combination of need, through the development of different optimization objective function, many scholars proposed different optimization methods. For example: H. Fuchs proposed the algorithm of smallest surface area; E. Kepple proposed the algorithm of maximum volume; Ehristiansen proposed the algorithm of shortest diagonal; Gannapathy proposed the algorithm of adjacent contour lines synchronously advancing [6]. Among them, the maximum volume algorithm, the shortest diagonal algorithm and the adjacent contour lines synchronously advancing algorithm belong to heuristic method; the minimum surface area algorithm and the largest volume algorithm are all global optimum surface reconstruction algorithm which need large amount of calculation and more time-consuming; The shortest diagonal algorithm and the adjacent contour lines synchronously advancing algorithm belong to a local optimum determination algorithm which need the smaller amount of calculation and can improve computing speed. The shortest diagonal algorithm suite the situation of the upper and the lower contours' size and shape are similar and centre points are relative close. The shortest diagonal algorithm chooses a shorter one of the two diagonals $p_1 q_2$ and $p_2 q_1$ of the quadrilateral $p_1 p_2 q_1 q_2$ as the next triangular facet's edge to generate the triangular facet, as Figure 5 shows.

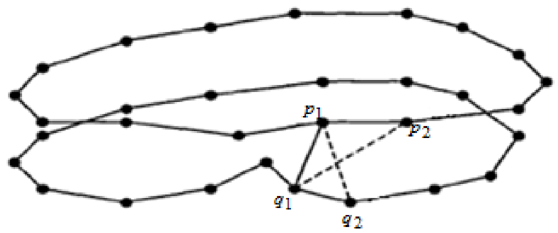


FIGURE 5 The shortest diagonal algorithm

After pre-processed the adjacent contour lines, their size and shape are relatively approximate and centre points are relative close, so they suit the shortest diagonal algorithm.

When stitching the adjacent contour lines using the shortest diagonal algorithm, we start from the first point p_0 of contour line which has the less control points in the two contour lines, then find the nearest point q_i in the corresponding contour line to the point p_0, look the line segment $p_0 q_i$ as starting side, and execute the shortest diagonal algorithm.

4 Branching problem

When the number of two adjacent contour lines is unequal, there needs to solve the branch problem. When solving the branching problem caused by a number of non-overlapping contour lines there is need to transfer multi-branch problem to a group of single branch problem. Contour lines merging and contour lines splitting are two means to solve the branch problem, the way of contour lines merging is to merge the multiple contour lines into one contour line, then to splice the contour lines one corresponding one; the way of contour lines splitting is to split a single contour line into multiple contour lines via particular means, then to splice them one corresponding one.

4.1 THROUGH INTERPOLATED EDGE SOLVING BRANCH PROBLEM (WHEN BRANCH NUMBER=2)

The way of solving the branching problem via introducing interpolated edge belongs to contour lines splitting method. It is suitable for solving the problem of independent branching. The method utilizes a perpendicular bisector to split single contour line into two contour lines, then corresponds the two contour lines to adjacent two contour lines. When using this method under the circumstance of the shortest distance between the adjacent contour lines and the difference in size are relative great, the majority region of a single contour line connects to the smaller one among adjacent contour lines, thus reducing the accuracy of reconstruction, moreover, when there are too many branch, it will be very difficult to implement the method.

4.2 SOLVING BRANCH PROBLEM BASED ON RATIO OF CIRCUMFERENCE (WHEN BRANCH NUMBER ≥ 3)

Since the adjacent contour lines' distance is small and the shape of the upper and lower contour line should have a certain similarity, so we can transfer multi-branch problem into several single branch problem by using the ratio of the circumference of multiple contours. Assuming there is only one closed contour line in lower layer and there are several closed contour lines in upper layer, then we should split the single contour line in lower layer into several contour lines with the number same to the number of contour lines in upper layer according to the ratio of circumference of the upper contour lines, then we splicing the contour lines according to the followed algorithm steps. As Figure 6 shows, we assuming there are three contour lines C_1, C_2, C_3 in upper layer and there is one contour line C_0 in lower layer, then method of splitting contour line is as followed:

Step1: Computing barycentric coordinates of contour lines C_1, C_2, C_3, assuming to be B_1, B_2, B_3, and calculating barycentric coordinate of contour line C_0, assuming to be A_0.

Step2: Computing the barycentric coordinate of the polygon whose vertices are barycentric B_1, B_2, B_3, assuming to be B_0.

Step3: connecting the line segments B_0B_1, B_0B2, B_0B3.

Step4: making line segments A_0A_1, A_0A_2, A_0A_3 parallel to line segments B_0B_1, B_0B2, B_0B3 in contour line C_0.

Step5: computing the circumference of contour lines C_1, C_2, C_3, assuming to be P_1, P_2, P_3.

Step6: computing the coordinate of point M_1 in contour line C_0, making M_1 splitting the A_1, M_1, A_2 in contour line C_0 based on the circumference of contour lines C_1, C_2, that is $A_1M_1 : M_1A_2 = P_1 : P_2$. Using the same way, Splitting $A_1, M3, A3$ and A_3, M_2, A_2 each into two parts respectively based on the circumference of contour lines C_1, C_3 and $C2, C_3$.

Step7: matching contour lines C_1, C_2, C_3 with $M_1A_0M_3A_1M_1$, $M_1A_0M_2A_2M_1$ and $M_2A_0M_3A_3M_2$, which are split parts of contour line C_0.

Step8: Reconstructing the 3D entity using the way of 3D reconstructing of single-contours.

Note that: The split contour lines must be pre-treated also prior to splicing the contour lines.

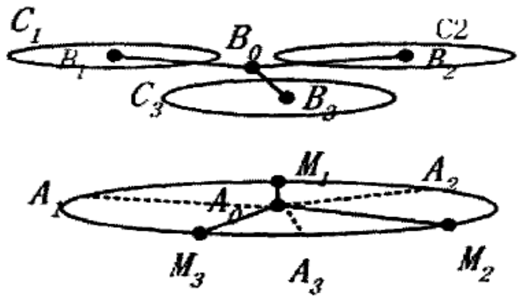
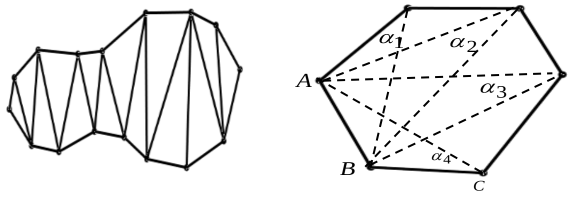


FIGURE 6 Splitting when one line corresponds to multi-lines

5 Closure processing of the end contour lines

In order to achieve the closure processing of the end contour lines, the paper designed and implemented an arbitrary polygon triangulation algorithm. In implementing the algorithm, we look on contour line as an arbitrary polygon and triangulate the contour line resorting to the triangulation algorithm of arbitrary polygon. As for details of arbitrary polygon triangulation algorithm, we can refer to the literature [7]. In order to reduce the amount of calculation, as this paper implements the algorithm we use the maximum opening angle triangle method in search of the triangle which has the minimum circumscribed circle radius, that is to say that the point which has the maximum angle to the current edge is to be the selected point, as Figure 7(a) shows. As for line segment AB, there are angles α_1, α_2, α_3, α_4 between the line segments and the other points, in which the angle of α_4 is maximum, and so we select point C and the line segment AB to form a triangle.

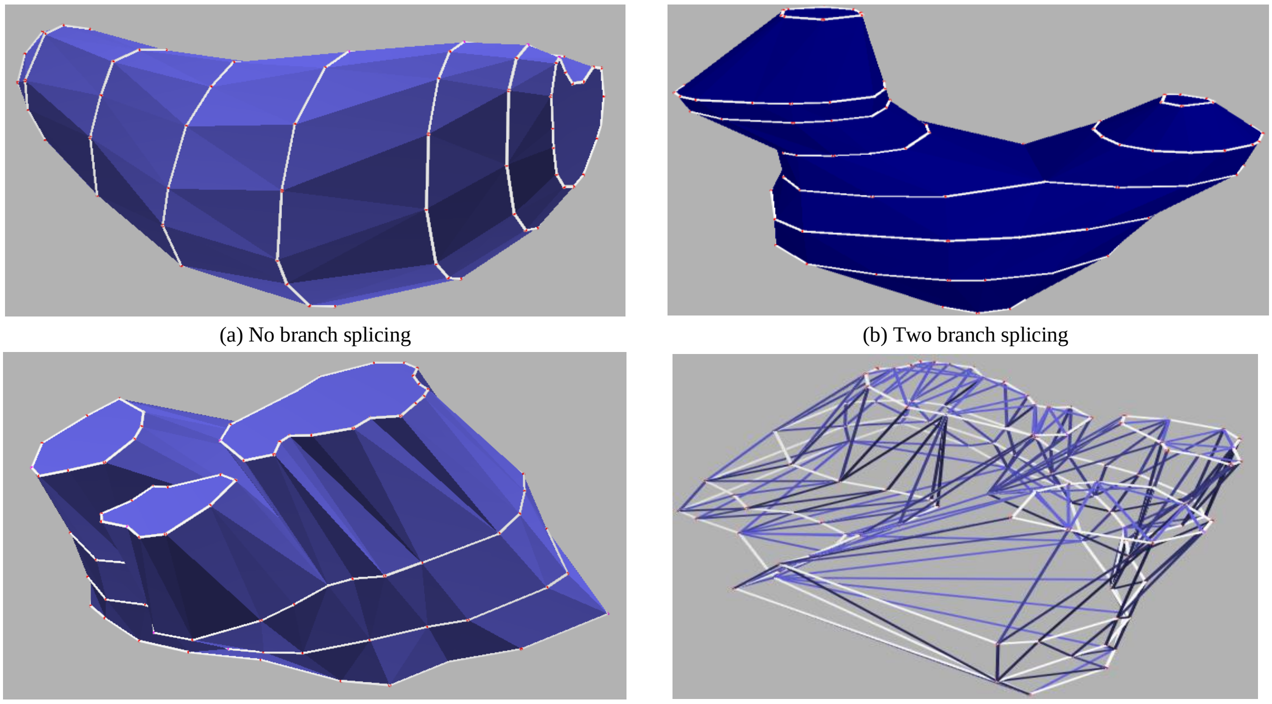


(a) Selecting point (b) Triangulation result

FIGURE 7 Triangulating contour line

6 Achieving result

This paper selects VisualC++2010 and OpenGL as development tools. Using a series of contour lines data obtained by 2D inversion in the field of solid mineral resources development, after contour lines pre-processing, contour lines branch, contour lines splicing and the end contour lines closing we get the closed three-dimensional shape model, as Figure 8 shows. The stitching models of various form of contour lines are correct, avoiding the phenomena of cross-stitching. The case of one corresponding to multiple contour lines as Figure 8(b) and Figure 8(c) shows (when one contour line corresponding to more than three contour lines this method is also effective.) can automatically achieve a single contour divided by the ratio of the circumference of contour lines, completely avoiding manual intervention. The segmentation results meet engineering requirements. Various form of the end contour lines are regarded as the arbitrary polygon. Using the triangulation algorithm of arbitrary polygon presented in this paper, the triangulations of end contour lines are as Figure 8(a), Figure 8(c) and Figure 8(d) showing, achieving the processing of closing the end contour lines, and there are no empties and triangulated triangles intersections. The time complexity of the algorithm is the same to the algorithm of literature [7], about $O(N^2)$, but when searching for triangle with the smallest circumcircle radius, using the method above can reduce the amount of computing, the reason is that obtaining the radius needs square root demanding large amount of calculation, and the maximum opening angle triangle method requires only multiplication and division demanding less amount of calculation, and when in search of candidate points under the circumstance of engineering field in which the control point coordinates absolute value is very large but relative value is very small, due to calculation accuracy problem, the minimum circumcircle radius method will triangulate in error and arise empties or triangulated triangles intersection.



(a) No branch splicing (b) Two branch splicing

(c) Three branch splicing (d) Mesh line of splicing

FIGURE 8 Contour lines splicing and triangulation result

6 Conclusions

This paper studies the contour lines corresponding, contour lines stitching, contour lines branching, the end contour lines closing and other key technologies used in multi-contour reconstruction, and provides the specific solution of every implementation steps in three-dimension reconstruction. For contour lines winding direction problem the paper provides the method of detection sum angle of polygon avoiding the misjudgement of the contour line winding; First projects the concave polygon onto its convex hull then splices the contour lines in the process of stitching of contour lines avoiding the cross-stitching; the paper provides the method of basing on circumference ratio of contour lines to solve the branching problem; as for the end contour lines, we uses the arbitrary triangulating algorithm to implement the closure of them, when searching for minimal circumradius of triangle we uses the method of maximum opening angle triangle in triangulating reducing the amount of calculation. It proved that the methods above are practicable, intuitive, fast, versatile compared with other contour lines stitching method. When contour lines are not parallel, we can firstly convert them to parallel or approximately parallel contour line relative to the reference point or reference plane in the pre-processing stage, then convert the coordinates to its' original coordinates after stitched the contour lines using above method to get the correct reconstruction result. In the future, we will study the three-dimension shape reconstruction under the circumstance of the contour lines not parallel and the smoothing of reconstruction result to make the reconstruction algorithm more general and the result of reconstruction more natural and beautiful.

Acknowledgments

This paper belongs to the project from Institute of Geophysical and Geochemical Exploration. Task Book Number: Science [2008] 05-03-18, Project Number: 1212010660305

References

[1] Huang Yong-li 2004 Theory and technology research of 3D *reconstruction based on slice-images data Master Degree Thesis* 5
[2] Li Yun-feng, Liu Xiu-guo 2011 Algorithm of contours splicing based on OBB projection transformation *Journal of Computer Applications* **31**(12) 3353-6
[3] Mao Xian-cheng, Lu Xiao-qin, Xu Zhi-qiang 2009 Triangle tiles reconstruction from drill data-based complex contours *Journal of Computer Engineering and Applications* **45**(23) 179-81
[4] Ma Hong-bin, Guo Jia-teng 2007 Cut-and-Sew Algorithm: a New Multi-Contour Reconstruction Algorithm *Journal of Northeastern University (Natural Science)* **28**(1) 111-4
[5] Wu Zhong-hai, Ye Cheng-qing, Pan Yun-he 1997 An Improved algorithm of convex hull computing *Journal of Computer-Aided Design & Computer Graphics* **9**(1) 9-13
[6] Tang Zhe-sheng 1992 Visualization of 3D spatial data sets Beijing Tsinghua university press
[7] Tu Zhi-hong, Sang Nong 2005 Delaunay Triangulation Algorithm of Arbitrary Polygons with Visual C Language *Computer & Digital Engineering* **33**(1) 34-6
[8] Li Mei, Mao Shan-jun, Ma Ai-nai 2006 Building Orebody Solid Model from Planar Contours, *Journal of Computer-Aided Design & Computer Graphics* **18**(7) 1017-21
[9] Shu An, Ran Shu-hang, Wu Zhang-wen, Zhang Li, Huang Liang 2009 Three dimensional surfaces reconstruction based on shape of adjacent layer contours *Journal of Computer Applications* **29**(2) 450-2
[10] SeungWon Shin, Damir Juric, 2002 Modeling Three-Dimensional Multiphase Flow Using a Level Contour Reconstruction Method for Front Tracking Without Connectivity *Journal of Computation Physics* **180** 427-70
[11] Charles Soussen, Ali Mohammad-Djafari 2004 Polygonal and Polyhedral Contour Reconstruction in Computed Tomography *IEEE Transactions on Image Processing* **13**(11) 1507-23
[12] Huang Jin-Ming, Liu Kun-Liang 2011 Design and Implementation on Volume Data Visualization System *Advance Material Research* **433-440** 5680-5

Authors

Liu Kunliang, born in 1976, Shandong, China

Current position, grades: lecturer
University studies: Computer Application Technology
Scientific interest: Analysis and Design of Algorithms, 3-D Data visualization

Huang Jinming, born in 1970, Jiangxi, China

Current position, grades: Senior Engineer
University studies: Geodetection and Information Technology
Scientific interest: Geodetection and Information Technology, Computer Graphics