A Direct Filling Algorithm of Isogram in Complex Boundary

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***Abstract*—On basis of summarizing the existing isogram filling algorithm, this paper puts forwards a direct filling algorithm of isogram in complex boundary. Compared with the point-by-point scanning method and algorithm of area filling, this new algorithm has no necessity not only in point-by-point calculation of interpolation, but also in tracing inclusion relation between equivalent areas and determination areas, which makes filling speed faster. It is proved with practice that the new method can fill isopleth map in milliseconds.**

Keywords- isogram; complex boundary; scanning line; filling; algorithm

I. INTRODUCTION

Isogram is used widely in water conservancy, meteorology, geology and flood control and drought relief, is an imagining presentation of discrete data. Isogram is drawn with grid method by means of discrete data gridding, even point calculating, line smoothing and labeling. But the isogram made from the above methods is not intuitionistic. If isogram can be enclosed into different areas filled with different colors, physical characteristics of data changes can be shown more clearly and data analysis can be more direct and convenient.

Filling methods of isogram consists of isogram generation and isogram filling, that is, first generating isogram by some calculation, then filling isogram. As for isogram generation, it is made with gridding method and triangulation method. The specific drawing methods of isogram can be found in relevant references. As for isogram filling, it includes method of boundary point trace [1]-[6] and method of part polygon [7]. The core of the former is to insert boundary points into non-closed isogram to form closed isogram by tracing boundary, at last to fill isogram. The latter means, first filling polygons in the cells (small gridding after dissected) according to even points, then filling color in polygons according to colors of cell vertex and even points, at last making all cells ergodic to finish isogram filling with the same method.

This paper puts forwards a method of direct filling of isogram based on scanning lines, which can help to determine the filling colors according to topology relation between scanning lines and scanning isogram, and help to make quick filling by using correlation among scanning lines without calculating every color value of filling points. So it has the features of fast filling speed and high efficiency.

II. IMPORTANT NATURES OF ISOGRAM

① Isogram mustn't intersect except cliffs and rift zones.

② All isogram is either end-to-end forming closed isogram, or the head and the tail forming non-closed isogram. The endpoints of non-closed isogram must be on boundary.

③ The interval of isolines, L, of isogram is equal. That is, any numerical differences of two adjacent isolines (interval of isolines) are consistent.

III. BASIC PRINCIPLES OF ALGORITHM

Suppose the coordinate maximum and the minimum of Y-- the isogram endpoint in isoline set, are ymax and ymin , when scanning line y=a (ymin≤a≤ymax)，scanning line and isoline would form "n" intersection points (As shown in figure 1) which cut scanning lines into n-1 line segments. If every line segment carries different colors, different areas will be filled with different colors when scanning lines scan the whole isogram map. Thus the isogram map can be finished [8].

The general filling rules of isogram map are: first to fill the non-closed isogram, then to fill closed isogram. If many isolines are homocentric, the outer homocentric areas should be filled first, then the inner parts. Thus it can be ensured that closed areas would cover non-closed areas and inner areas would cover outer areas. So different areas would show different colors.According to the first nature of isogram, the above can just meet with the filling rules.

IV. DESCRIPTION OF DIRECT FILLING ALGORITHM OF ISOGRAM

As mentioned above, filling methods of isogram consists of isogram generation and isogram filling. During isogram generation, all isogram can be got by tracing isogram and smoothing, which can be named "isogram set". The present key is how to choose a group of color tables and how to fill the whole isogram set.

A. Setting Color Tables

A color table consists of two fields: numbers and color values. Generally, first set only two color values—the deepest one and the lightest one, then interpolate color to form color tables, at last set up the congruent relations between isogram values and color values to form mapping tables which is the reference to fill necessary colors. The same isogram values correspond with the same filling colors and adjacent isogram is filled with adjacent colors. Thus how to choose filling colors can be turned into how to determine isogram values.

B. Filling Scanning Lines

After determining the color tables, its colors can be used to fill the isogram maps. Before introducing its algorithm, first let's think about how to fill one scanning line. Figure 1 shows the topology relation between a horizontal scanning line and the isogram. First make out the intersection points of scanning lines and isogram, then rank them from small to large according to x-coordinate, next determine the filling colors between two adjacent intersection points according to the topology relations of isogram. Figure 1 shows us two points: (1) The isogram values of front-to-back intersection points are different and their difference is one interval of of isolines, L, like p0 and p1. (2) The isogram values of front-to-back intersection points are the same, like p2 and p3.

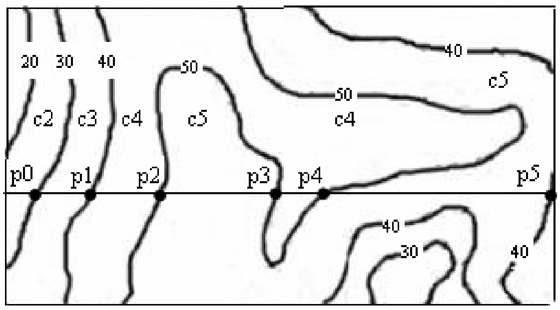

Figure 1. The topology relations of intersections between scanning lines and the isogram

As for the first case, it is easy to determine colors, like p0 and p1, because the front-to-back difference is an interval of isoline. So the value of p0 isoline--v(p0) can be chosen as the color value to scan this sector, that is c3 from Figure 1.

The second case is relatively complex because there is no difference between the front-to-back intersection points which leads to difficulty in determining filling colors. Here are two cases:

Case 1: The equal values of isoline appear for the first time, like p2 and p3. Thus the previous color value is needed to help determination. For instance, when filling p2 and p3, v(p2) of p2 isoline can be chosen as the color value to scan this sector, that is c5, because the value of p1 isoline and the value of p2 isoline are 40 and 50 while the current filling values of isoline are 50 and 50 which shows that the current color levels of intersection-point-pairs are higher than the previous ones.

Case 2: The equal values of isoline appear continuously, like p3 and p4. After the equal values of p1 and p2 isoline appear, the equal values of p3 and p4 isoline appear. Such a conclusion can be reached according to Nature 1: If the intersection-point-pairs with the same values of isoline appear continuously, the color values of the intersection-point-pairs must change alternately. So the color values of p3 and p4 must be lower than that of p1 and p2, that is filling color should be c4.

In practice, in order to unify algorithm, such tips can be used: suppose the previous intersection-point-pair is pi and pj while the current intersection-point-pair is pj and pk. Define a variable m, record the times of equality of v(pj) and v(pk).If v(pj)≠v(pk), v(pj) would be the filling color. Otherwise, if "m" is an odd number, v(pi+L) would be the filling color; while "m" is an even number, v(pi-L) would be the filling color.

C. Filling the Isogram Maps

As mentioned above, how to fill one scanning line has been introduced. If all scanning lines of one isogram map can be filled according to the above algorithm, the filled isogram map would appear. But filling speed is slow because every scanning line needs to intersect with all isogram while x-coordinate of intersection points need to be sorted from small to large which leads to large calculation and much time. In fact, one scanning line could only intersect with certain side of some isogram and would maybe intersect with both the previous scanning line and the next scanning line (continuity of sides).So relativity exists among scanning lines which can be used to improve filling speed. The following introduction includes data structure and algorithm process needed in algorithm.

1) *Data structure:* In order to economize relativity of scanning lines, the following data structure need to be set up in direct filling algorithm of isogram.

a) *Table of Sides of Isogram:* Every isogram is made up of many sides whose basic information can make up a table of sides of isogram.

```
struct EdgePt
{
    long Yemax;   // the side maximum endpoint "y-coordinate"
    long Xemin;   // x-coordinate corresponding with "y-coordinate" -the side minimum endpoint
    float Dx;   // increment of x-coordinate when scanning lines enlarge one unit
    float Value;  // value of isogram
}EdgeList;
EdgeList CoutourEdgeList(s);   //s the number of scanning lines intersected with certain isogram
```

CoutourEdgeList Sort from small to large according to (Yemin-Ymin). Yemin is the side minimum y-coordinate.

b) *Table of Isogram:* Tables of isogram list basic information of every isogram.

```
struct ContourPt
{
    long Ymax;  // the maximum "y-coordinate" of isogram
    Coutour* pCoutour  // indicator pointing to isogram
    CoutourEdgeList* pCoutourEdge   // indicator pointing toTable of isogram sides
}listCoutour;
listCoutour CoutourList(s);  //s the number of scanning lines
```

CoutourList Sort from small to large according to the minimum y-coordinate of every isogram.

c) Table of Flexible Isogram: This table stores all recording indicators of isogram that intersect with the current scanning lines.

d) Table of Flexible Sides of Isogram: This table stores all recording indicators of sides, which intersect with the current scanning lines., in the side- isogram-table.

2) Description of Algorithm

Step 1:Initialize Table of flexible isogram, Table of flexible sides of isogram and Table of isogram. Set Table of isogram and Table of flexible sides of isogram to null. Traverse isogram set to generate a record in Table of isogram for every isogram and insert this record into Table of isogram according to the minimum y-coordinate.

Step 2: Operate every scanning line I (i=1,2,⋯,s) like this:

①Check whether there is new records about scanning line i. If yes, generate Table of sides of isogram corresponding with this scanning line and insert the corresponded isogram address into Table of flexible isogram.

② Traverse every record in Table of flexible isogram and check whether there is new records about scanning line i in Table of sides of isogram corresponding with this isogram. If yes, insert the new side position in Table of sides of isogram into Table of flexible sides of isogram.

③ Fill this scanning line by using Table of flexible sides and filling algorithm of scanning lines.

④ Traverse Table of flexible sides and check whether Yemax field with side records is equal to y-coordinate of scanning lines. If yes, delete this side record or modify Xmin field of this side (Xmin=Xmin+Dx).

⑤ Traverse Table of flexible isogram and check whether Ymax field of isogram is equal to y-coordinate of scanning lines . If yes, delete this record.

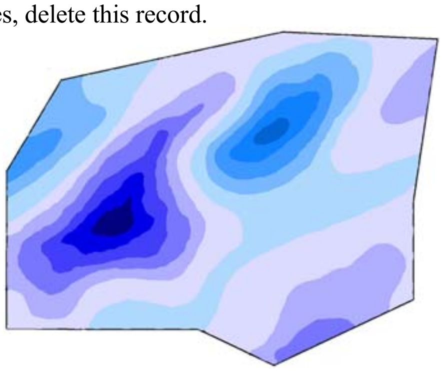

Figure 2. Practical case of algorithm

The complexity of algorithm is the same as filling algorithm of polygon of scanning lines [6] to reach O(s×n×m) (among them, s is the number of scanning lines while n is the number of isogram and m is the maximum number of sides included by isogram. Figure 2 is the isogram map filled with the above algorithm. From the filling effect, color levels are proper without wrong filling and missed filling.

V. CONCLUSION

On basis of summarizing the existing isogram filling algorithm, this paper puts forwards a direct filling algorithm of isogram in complex boundary. On basis of achievements of tracing and smoothing isogram, it realizes the direct filling of isogram by using basic ideas of area filling of scanning lines. This algorithm needs no point-by-point interpolation filling, no tracing inclusion relations between equivalent areas and determination areas, but to determine the colors by topological relation between scanning lines and isogram, which leads to fast filling speed. Practice proves that this algorithm can finish general filling of an isogram map in milliseconds.

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