The Displaying LoD Model Foundation Of Point Feature In Electronic Map

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Abstract: When the capacity of data is very large, the displaying of vector electronic map will usually overlap and overlay, and effect the definition and beauty of electronic map, bring user difficulty of reading map. This paper introduces the LoD technology of computer 3D scene into the displaying of electronic map, uses Delaunay triangulation and Voronoi diagram, discusses the foundation of displaying LoD model of point feature independent of data.

Key Words: electronic map; LoD technology; Delaunay triangulation; Voronoi diagram

1 Introdution

Electric map is a new kind of map using computer aided cartographic technology in 80s 20th century. Compared with paper map, electric map has many virtues, such as interaction, unlimited scaling, random rambling etc. [1]. But because of the difference of minimum picture element and the size of map, the visual load (it is the reader's visual loading caused by map) of electric map is bigger than that of paper map. So, when representing all the elements, which are resented on the paper map with computer monitor, many symbols will overlap together, and reader cannot recognize the meanings of symbols; the effect of information transmission is declined. Especially when the displaying span is about several paper maps or more, the contradiction of particularness and legibility becomes acute. The zoom of electric map cannot solve this contradiction fundamentally, because with the zooming of electric map, the graph is enlarged too, the same graph has the different visual loading to reader in different amplification. So there must be a certain way to solve this problem. Nowadays, GIS and electric map system are usually set an internally invariable parameter, or the parameter is set by user interactively, therefore the effect of displaying is so bad and the operators are so complexity. In addition, the parameter is set according to the classification of database, the visual load will bounce when displaying.

This paper inducts the LoD technology of 3d model simplification to the displaying of electric map, tries to actualize "the bigger the amplification is, the more detail reader can see; the smaller the amplification is, the less detail reader can see" through a certain algorithm and some knowledge rules, meanwhile, read can see the most rational map in any amplification. This paper gives emphasis to the algorithm of the foundation of point feature' LoD model.

2 The relation of point feature's LoD, the displaying span and scale of source data (paper map's scale)

Because the minimum picture element of electric map is smaller than that of paper map, the conception of paper map's scale is not fit to electric map, and the very important factor is amplification of electric map, so we can't use the target of paper map. When programming, we set a parameter named "LoD" to every feature on the map, in order to record the amplification when this feature is displayed. In fact, the feature's LoD has important relation with the displaying span, scale of source data (paper map's scale) and the position and character of the feature itself. We will discuss the relation of the feature's LoD and the position of itself in next section, and then we will discuss the relation of point feature' LoD, the displaying span and scale of source data (paper map's scale).

As we know, the minimum picture element of paper map is about 0.1mm (even smaller), but the minimum picture element of monitor is a pixel, and the normal monitor's pixel spacing is about 0.3mm (the smallest pixel spacing is about 0.2mm)[3], according to this, we know that the paper map can show more details than electric map, the fineness of electric map is about 1/3 of paper map. The resolution of computer monitor is usually about 1280 * 1024 or 1024 * 768, so the size of monitor is smaller than that of the paper map. Thus there must be a number as the maximum LoD parameter based on the certain displaying span. And we find the relation of point feature's LoD, the displaying span and scale of source data (paper map's scale) as following:

$$LoD_{MAX}(\text{the maximum LoD parameter}) = Min\{LoD_H，LoD_V\}；$$

There,

LoDH = (DRH * LM * 3) / (DSH * 0.03);

LoDV = (DRV * LM * 3) / (DSV * 0.03);

DRH is the horizontal distance of the displaying area (unit：km) ；

DRV is the vertical distance of the displaying area (unit：km) ；

DSH is the width of monitor's drawing area(unit：pixel)；

DSV is the height of monitor's drawing area(unit：pixel)；

LM is the arithmetic product of the paper map's scale and 100 thousand(unit:cm)[7]；

Suppose: the pixel spacing of monitor is about 0.3mm.

When the amplification equals to LoD_{MAX}, electric map has the same particularness and legibility as paper map.

3 The research on the algorithm of point feature's LoD modeling

The point feature's LoD modeling can be looked as the extension of point feature's simplification. So the algorithm of point feature's simplification can be modified to fit this problem. There are some simplifying algorithm, such as gravity modeling, distribution-coefficient-control, and convex simplification etc. Consider that the problem of point cluster distribution is a part of spatial neighbor problem in computation geometry, and the result of simplification should keep the character of point cluster distribution, we choose the Voronoi diagram and its dual graph net of Delaunay triangulation to solve this problem, because the Voronoi diagram has the great virtue of spatial halving, it can reflect the spatial occupancy of a point and the point's contribution to point cluster distribution.

3.1 The algorithm of Delaunay triangulation

The net of Delaunay triangulation is the dual graph of Voronoi diagram, in order to get the Voronoi diagram, the net of Delaunay triangulation should be built first. At present, there are two kinds of algorithms: one is the static algorithm, and the other is the dynamic algorithm. The static algorithm is that in the course of net building, the net that has been built will not be changed when the new point participates in; on the contrary, the dynamic algorithm is that the net that has been built will be rebuilt to meet the Delaunay condition when the new point participates in. In this paper, we use convex-insertion method belonged to the dynamic algorithm, there are three main steps: convex hull building, convex hull triangulation and point insertion, at the same time the topology among point, edge and triangle is built [7][9][10].

1) Convex hull building

Step 1: Get the initial convex hull list constructed with four points sorted with anti-clockwise, which have the minimum or maximum value of x plus y or x minus y.

Step 2: To every edge of convex hull list, insert the point into convex hull list that is right to the edge and has the maximum distance to this edge.

Step 3: repeat step 2 until there is no point right to the convex hull list.

2) Convex hull triangulation

Step 1: Find the triangle whose vertex is three neighboring points on the convex hull list, and there is no point on the edge of triangle and the same in the triangle. Delete the middle point from convex hull list, and then the convex hull list is updated.

Step 2: Repeat step 2 until there are three points in the convex hull list.

Step 3: Make the triangle using the last three points.

3) Point insertion

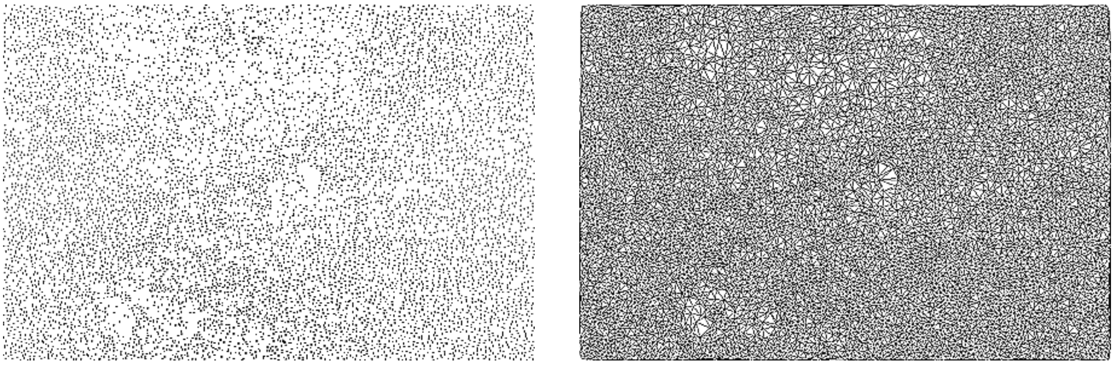
Point insertion is the key technology of Delaunay triangulation, the efficiency of point insertion is the bottleneck problem of the algorithm of Delaunay triangulation, and all the steps are listed as follows:

Step 1: Find the triangles whose circumcircles include the inserted point, and form the influence region.

Step 2: Delete the common edges in the influence region, and make the influence polygon.

Step 3: Connect the inserted point with every vertex of influence polygon; make the new triangles, in addition to correct the topology correspondingly.

Finding the triangles whose circumcircles include the inserted point is the key to improving the efficiency of algorithm. We used the method named "grid index" to build the index of triangles, edges and points, and this method improved the speed of quest greatly. Meanwhile, we found the number of rectangular grid had great influence to the speed of quest, if the number is too small, its function can't embody, if too big, the speed of quest will be reduced. We think when every grid average 12 points, the speed of quest is the fastest (See Fig. 1).



Original data，sum of points: 8551 Delaunay Trianglation

Fig. 1

3.2 The algorithm of dynamic Voronoi diagram building

3.2.1 The foundation of Voronoi diagram

It is simple to make up the Voronoi diagram if the net of Delaunay triangulation has been built. In the course of Delaunay triangulation, the triangles which are connected with a point have been recorded, and the center of a circumcircles has been calculated, so what will do is just connecting the centers of circumcircles into polygon in anti-clockwise, and recording the number of polygons which have same edges with the polygon.

3.2.2 The foundation of dynamic Voronoi diagram

The dynamic Voronoi diagram means that when some points are deleted, the Voronoi diagram should be modified locally. There are some mature algorithms to this problem, such as decrement method, Delaunay simplification etc. We used Delaunay simplification, which is after the local modification of the net of Delaunay triangulation, rebuild locally the Voronoi diagram, and the experiment suggested that this method has higher efficiency. The steps are listed as follows:

Step 1: Get the triangles that connected with the deleted point, and form the influence region. Then Delete the common edges in the influence region, and make the influence polygon.

Step 2: Triangulate the influence polygon according to the Delaunay rules, and then change the topology correspondingly.

Step 3: Optimize the triangles whose dual graph has the common edge with the deleted point's Voronoi polygon.

Step 4: Rebuild all the points' Voronoi polygon mentioned above.

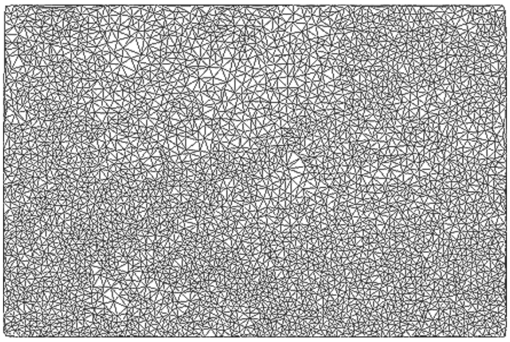
(The contraposition of multi simplificated net of Delaunay triangulation and Voronoi diagram see Fig. 2)

3.3 The algorithm of point feature LoD modeling

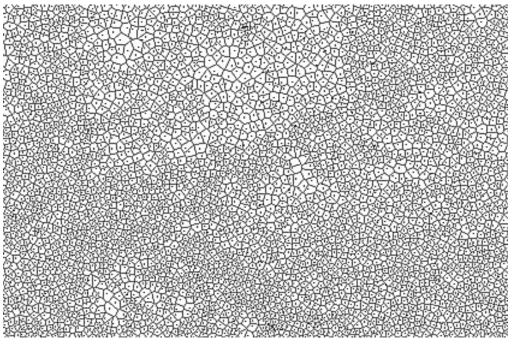
With the support of the two algorithms mentioned above, point feature LoD modeling can be realized without any difficulties. The key to this algorithm is in contact with concrete features, and then builds the fitful model to the certain displaying span.

3.3.1 The algorithm of point feature LoD modeling without any other feature's influence

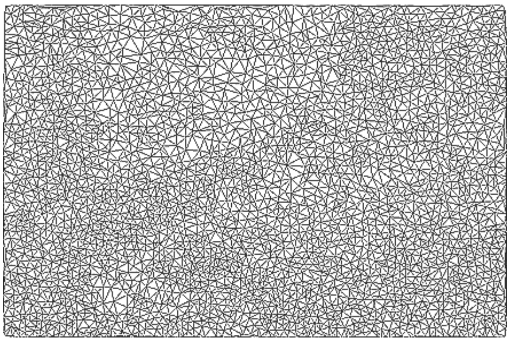
The foundation of point feature LoD model can be looked as another kind of description to point



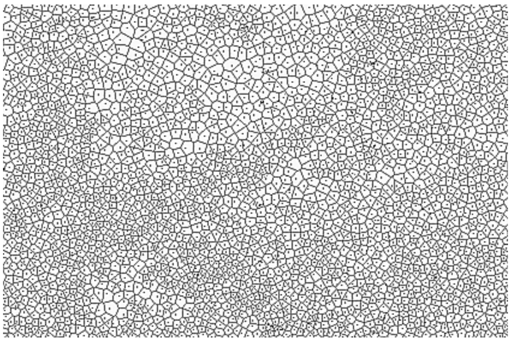
Two times simplification，sum of points: 5968
Delaunay graph



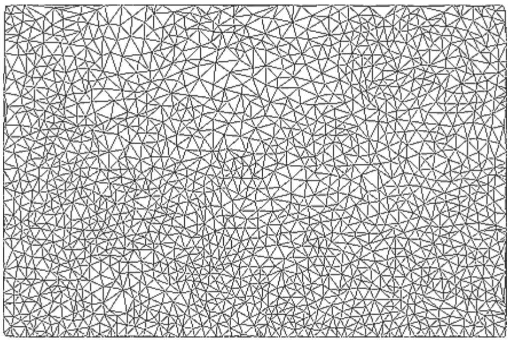
Two times simplification，sum of points: 5968
Voronoi graph



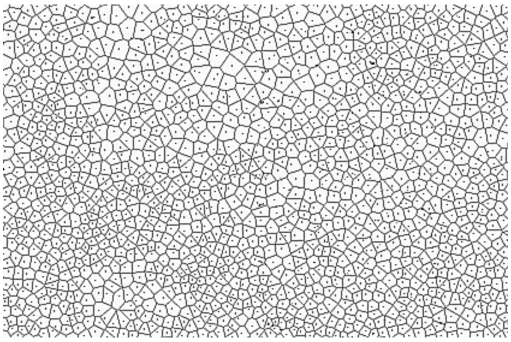
Third times simplification，sum of points:4247
Delaunay graph



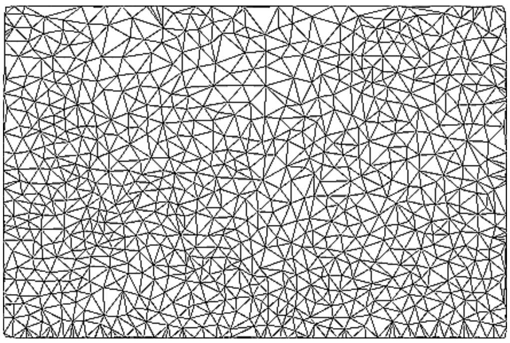
Third times simplification，sum of points:4247
Voronoi graph



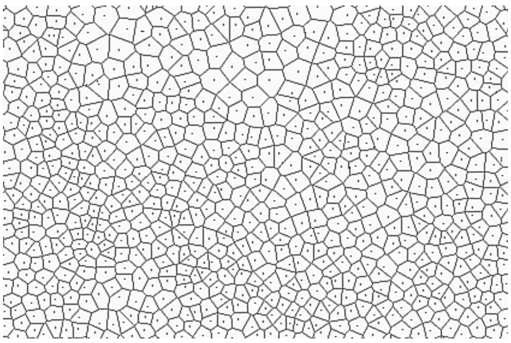
Third times simplification，sum of points: 2143
Delaunay graph



Third times simplification，sum of points: 2143
Voronoi graph



Third times simplification，sum of points: 1065
Delaunay graph



Third times simplification，sum of points: 1065
Voronoi graph

Fig. 2

cluster's spatial occupancy. We used the idea in reference [3], thought that the essentiality of a point is based on the spatial occupancy of the point. The spatial occupancy of a point is small means the point make little contribution to the point cluster's spatial distribution, so the point's LoD can be set a big number, that is it will be display only when the amplification is bigger than its LoD. The area of the point's Voronoi polygon can measure the spatial occupancy of the point. In the first section we have discussed the relationship between point feature' LoD, the displaying span and scale of source data, so we can get the LoD_{MAX}, then according to the area of the point's Voronoi polygon, the point cluster can be predigested for multi times, so we can get the model of points' LoD. The steps are listed as follows:

Step 1: Calculate LoD_{MAX} and the area of every point's Voronoi polygon; sort the area from small to big.

Step 2: Find the point whose area of Voronoi polygon is the smallest, and add (LoD_{MAX} - u) to its LoD, here u is the for loop variable, then make other neighbored points pegged.

Step 3: Repeat step 2, add (LoD_{MAX} - u) to all the points that are not pegged LoD.

Step 4: Delete the points whose LoD are added from the net of Delaunay triangulation and Voronoi diagram. Using the algorithm of dynamic Voronoi diagram building mentioned above, rebuild the net of Delaunay triangulation and Voronoi diagram.

Step 5: Repeat the former 4 steps until u equal to LoD_{MAX}.

3.3.1 The algorithm of point feature LoD modeling with other feature's influence

In fact, the other features effect the distribution of point feature. For example, the distribution of punctual habitation is influenced by inhabited area, and river, road etc., so only when these factors are considered, the foundation of point feature's LoD model is reasonable. Therefore, we add the infection to point feature's LoD.

1) The algorithm of the influence caused by linear feature and areal feature

Step 1: Get the triangles, which are traversed by a linear feature or an areal feature.

Step 2: Get the distance between the triangles' vertexes and the linear feature or the areal feature, if the distance is smaller than threshold value; subtract the vertex's LoD with a certain value.

2) The algorithm of point feature LoD modeling with linear feature and areal feature influence

Step 1: Calculate the influence of linear feature and areal feature.

Step 2: Using the algorithm in 3.3.1 to build the point feature's LoD model.

4 Conclusion

We have take the algorithms mentioned above into practice, and the point feature's LoD model can be built. Then the displaying of point feature will become more legible with multi levels, and the effect is good. The research on this paper is based on the assumption that the points have the same class, so only the position is calculated. In fact, the points have different classes, so the difference of class can be calculated as weight with LoD, thus the attribute and position can be considered together.

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