

Crack Texture Generation Algorithm Based on Process

Yang Guangming, Hao Yupeng, Dong AoShuang, Yu Chunyang

Multimedia Technology Institute, Software College of Northeastern University

Shenyang, China

yanggm@swc.neu.edu.cn, haoyupeng0729@163.com, dongas@swc.neu.edu.cn,
yucy@swc.neu.edu.cn

Keywords: component; Voronoi diagram; Crack; Reality

Abstract. In order to complete a realistic strong body crushing process and has some high ground real-time, simulation methods was proposed to simulate impact on the destruction of the object-based process. Firstly, the physical properties of different materials of glass, concrete and marble, through continuous test generation seeds conform to fit the object properties. In accordance with the definition of delaunay triangulation, voronoi diagrams are generated.

Introduction

At the same time in the objects with a broken left by the crack on the object is to present the whole simulation process of the authenticity of the key steps. In the society and the vast majority of the areas involved in the study of natural science, we can find examples of voronoi diagram polygon mesh applications. Voronoi polygon is a point to create it can affect the scope of a polygon area. In such as ecology, it often involves the scope of the study the effect of organisms, like the forest trees, each tree will compete for moisture and light; Like every lion has its own territory; meshing of fluid mechanics and so on. Voronoi diagram can be a good description of this type of problem, and to conduct further in-depth analysis of these issues.

Voronoi diagram and Delaunay triangulation

As shown in figure 1 the voronoi diagram, voronoi diagram is also called tyson polygons, Dirichlet figure, mainly composed of some irregular polygon. The edges of the polygon is the adjacent points (hereafter called the seeds of tyson figure, figure 1 a,b,c,d four seed point) of the connection between perpendicular bisector. Tyson has certain characteristics, within each tyson polygon contains only one seed. The distance of any point of inside each tyson graphics to the graphics inside contain the seed of point is the point to the graphics for all the seed point in the distance of the shortest one. That is to say an arbitrary point inside a polygon to the seed point contains the distance is to other recent seed point distance. Equal distance from the seed point on both sides of the pattern of Tyson point on edge to edge.

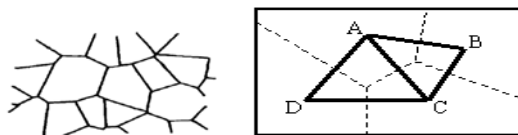


Figure 1 Voronoi map (ref. 1)

In Figure 2, equipped with two points on the plane P1, P2, L is between the two vertical bisector, by l the whole plane is divided into two parts LL and LR. The plane points in LL has the property of:

$$d(pL, p1) < d(pL, p2)$$

$D(pL, p1)$ represents the distance between two points, which means that any point in the LL plane distance to P1 is less than this point distance of p2. Any point in the L line to P1, P2 was equal to the distance. The following H (P1, P2) represents the plane of LL, and LR with H (P2, P1), H represents a plane in the plane, and the distance of any point of this plane to the first point than to

the second point the more closer. Using $V(P_1)$ represented by P_1 as the center of the Voronoi diagram.

According to figure 2

$$V(p_1) = H(p_1, p_2), V(p_2) = H(p_2, p_1)$$

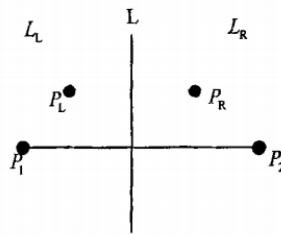


Figure 2 $V(P_1)$ and $V(P_2)$

Definition 2.1 Given a point set in the plane $S, S = \{p_1, p_2, \dots, p_n\}$.

$$V(p_i) = H(p_i, p_j)$$

$V(p_i)$ is a plane on the surface of a point closer to p_i . The plane is the intersection by not more than $n - 1$ half plane.

At present there are two main methods used to generate the voronoi diagram, a geometric method, obtained by geometry of precise calculation; Another is the cell growth method. This method is mainly used for computer simulation of Mongolian general Carlo method (Ref. [2]). This paper only discusses the precise model building, the use of delaunay triangulation to construct polygons.

From the definition of the voronoi diagram we can build model, complete the following steps:

1) In the plane randomly generated n points, hereinafter referred to as the seed point, the n point demanded don't get too close to each other, and these points can't be on a straight line. These seed points would be tyson the center of the polygon.

2) Optionally a seed point, connecting the seed points and $N-1$ seed points, got $n-1$ line. Making these lines respectively perpendicular bisector, the obtained perpendicular bisector will meet together, these intersect together constitute a lot of polygonal line. These lines leaving the seed point nearest line, which is able to put the seed point encirclement of the smallest polygon. Constantly finding out all points of a polygon, a total of $n - 1$, the $n - 1$ constitutes voronoi polygon network.

As can be seen from the above steps, this method is used to calculate the connections and lines perpendicular bisectors of all the points, but also to make the last remaining inside the polygon can contain only one seed point. We can see that this method should be judged conditions, the corresponding data saved too. This method is not easy to achieve. We can use the delaunay triangulation Voronoi diagram to simplify the process of implementation.

Delaunay triangle also has some features:

Delaunay triangle is composed of three adjacent seed points, and the circumcircle of the triangle must conform it does not contain any seeds except for three vertices of a triangle. Figure 4 triangles ABD circumcircle contains no other seeds. Triangle DCE circumcircle contains the seed point B. The ratio of the radius of the circumcircle of the triangle and the radius of the inscribed circle to be within a certain range, meaning that the triangle which consists of the seed point closer to equilateral triangles as possible. In addition to the above, delaunay triangles must comply with the principle of maximizing the minimum angle. The principle is adjacent to four seeds composed of two adjacent triangles, after an exchange of its two diagonals of this quadrilateral six interior angles of the triangle will not increase Figure 4, the method by exchanging the diagonal method so as to satisfy the principle of is a local optimization method proposed by Lawson (LOP - Local Optimization Procedure). Because of the nature of the delaunay, no matter from which a seed starting point will eventually form a delaunay triangular grid, the uniqueness of this property called Delaunay. In 1977, Silbson proved a point set of two-dimensional circumcircle criterion and maximize the minimum angle principle are equivalent, and conformed to the rules of only one triangle subdivision.

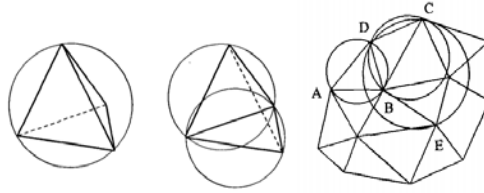


Figure 3 maximize the minimum angle and circumcircle criterion

There are several ways to generate delaunay triangulation:

1. Point to insert

Lawson made first proposed the idea of using incremental insertion triangular mesh generation. Lee and Schachter, Bowyer, Bowyer, Pareschi, Macedonio and Sloan, etc., have all been improved on this method perfected.

The basic steps are as follows:

Step 1 Locating the initial polygon, the polygon can contain all of the seeds (often for the minimum bounding rectangle);

Step 2 In the initial polygon we generate the initial triangle consistent with maximizing the minimum angle criterion;

Step 3 We insert a seed point P, find P fall within which triangle of triangulation. Identify the three vertices of the triangle, respectively, at the point P is connected, so that they generate three new triangles;

Step 4 We use the LOP method to generate triangle optimization;

Step 5 We repeat steps 3 and 4 until all the seeds fully inserted;

Step 6 At length we remove the triangle contains initial polygon vertex.

We can see from the above steps, the idea of this method is relatively simple, first establish an initial polygon and the initial triangulation, and then inserted in order into all the seeds. Using the LOP algorithm makes the generated grid delaunay criterion. Obviously this method is very simple, but its time complexity $O(n^2)$.

2. Growth triangulation method

Sibson was the first to use similar cell growth to generate Tyson map. Brassel and Reif also made similar papers. McCullagh and Ross using the seed point sorting improve search way, reduces the search time, so as to improve the efficiency of the growth method.

Step 1 To any one of the seed point as the starting point, and then we will find the seed point nearest the seed point, then connect the two seed points, put the edge as one of delaunay triangle edges;

Step 2 According to the delaunay triangle rule to we find third point with the current edge;

Step 3 To the current two endpoints of the edges are respectively connected with the find points, this also formed two new edge;

Step 4 We repeat steps 2 and 3 until the completion of delaunay triangulation.

Above steps show, growth method is to find the shortest distance between two points together into one edge, on the basis of the edge as a baseline to discover the rules of the third point, and connect and new generation two edges, in turn to the new generation of two edges of the search, until we complete the grid mesh.

3. Divide and Conquer

Hoey and Shamos raised this idea, thought source is recursive. The point set is divided up into three seeds, and in accordance with the guidelines of delaunay triangles. Then these triangles are integrated to form a large Voronoi network.

Divide and conquer method steps:

Step 1 Point set is sorted in ascending order by the abscissa ordinate;

Step 2 Point set is divided into two approximate subset;

Step 3 Two subsets in turn divided;

Step 4 Until the recursion is satisfied with only three points;

Step 5 We have a recursive return with merging with LOP optimization method for the combined network optimization;

Step 6 Completed recursion, the returned result is consistent with the rules of delaunay triangulation mesh.

The above described steps, divide and conquer is to simplify the problem, merges the results obtained after solving. Although its time complexity is $O(n \log n)$. But it is in the case of large point set and the memory requirement needed very big.

After finished the delaunay triangle subdivision, the circumcircle center of delaunay triangle are connected in turn around each seed point, thus formed the graphics.

Graphics random perturbations

In the process of the generation of graphics, because of the results generated by the relatively rigid, So we join the random disturbance, which makes its generated graphics more vivid.

$$\overline{\Delta r^2} = \frac{kT_s}{2\pi\eta r_s} \Delta t = c \Delta t$$

Figure 4 random perturbation formula

R represents the distance that disturbance with the original point after the addition of random disturbance. The direction is the direction of the original random point.

3 To achieve Delaunay triangulation and Voronoi grid

In the scene we use three kinds of material selection of glass, concrete and marble. We want to analyze the effect of after the object by the crack force depending on the material.

Because of delaunay triangular mesh met the criteria for air inscribed circle. Therefore, the seed point is not in a straight line, and the distance between each seed point can not be too close. When generating the delaunay triangulation we try to ensure that the resulting sum length of the sides of a triangle is the smallest.

Implementation of delaunay mesh and Voronoi mesh algorithm:

Step 1 Generating point set, firstly, according to the speed and quality of the impact object momentum $P=mv$ impact is calculated. The Normal distribution were fitted with a distribution of point set. And the stress range radius is calculated according to the momentum and the impact of the object material. Got a circle of influence, the radius of the circle is divided into 20%, 30% and 50% which the inner circle and the two rings. Variance with the normal distribution of materials on behalf of nature, respectively, in 20%, 30% and 50% press $0 * \sigma$, $1 * \sigma$ and $2 * \sigma$ into the formula as the radius r;

$$N = \frac{P}{\sigma \sqrt{2\pi}} \exp\left[-\frac{r^2}{2\sigma^2}\right]$$

Figure 5 the calculation formula of seeds

Step 2 Starting arbitrary point of point set, we Find the nearest distance point to the the point. Connecting line taken into the side chain table, this side of the flag is 0, seed point mark array records a corresponding the frequency of use of seed points, incremented by one each use;

Step 3 We take out the edge its flag value is not 2 from the edge list.

Case 1: Flag value is 0, which on behalf of this side is just a side has not yet become the triangle edges. We find a nearest point from this edge and the composition of the current triangle, determine whether conform to the rule of empty inscribed circle. If that accords with empty inscribed circle criterion, the newly generated two edges join Edge list which flag values are set to 1, and we need to record these three edges to point. In addition to recording edge to point, but also to each edge as a vector to determine the current triangle on the left or right of the current vector, this information is recorded in the current variable of this edge. If not, we should find the next nearest point and judge. If there is not a point in line with the conditions, the flag value of the edge is set to 2. Go to step 3;

Case 2: Flag value is 1, which on behalf of the edge is already edge of a triangle, in the delaunay triangle network an edge can only have a maximum of two triangular for public use this edge. So according to the recorded edge to point, finding the nearest seed point in another direction of the edge (judging by the three order determinant), and we do judgment and operation such as 1 after;

Step 4 We search the entire list while until the flag of all edges for 2;

Step 5 When list of all edges flag was 2, in the seed point mark array corresponding to the frequency of use of the seed point finding out seeds which it's value is 0, we take out the seeds to go to Step 2;

Step 6 Seed point marker array don't be found the number to zero;

Step 7 Completed the delaunay triangulation;

Step 8 We turn out seed point p[i]:

1. Traversing triangle list, we take out a triangle contains p[i];

2. According to the recorded edge information of the triangle to find the next triangle around the seed point clockwise direction, until we find the last triangle clockwise, or take out previous step triangle;

3. According to the last triangle found on previous step, we find out the triangle around the seed point counterclockwise, and calculate the circumcircle center of triangle, and connect the circumcircle center counterclockwise order;

Step 9 Generated the Voronoi polygon.

Experimental results and effect analysis

Experimental environment is OpenGL and visual studio 2013. Processor hardware platform is Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz 3.40GHz、8.00GB RAM、NVIDIA Quadro K600 Graphics.

After testing we found that the effect is consistent with the laws of physics about crack of different materials, with a strong sense of reality crack.

TEXTURE SIMULATION PERFORMANCE PARAMETER TABLE

Seed Points	Number Delaunay triangles	Voronoi polygon number	Running time / S
1000	989	1000	1
2000	1936	1999	1.5
3000	2978	3000	2.5
4000	3954	3979	4.5

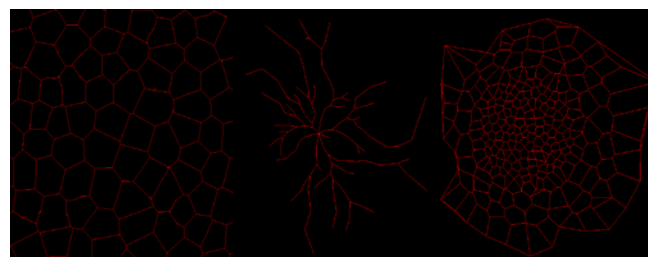


Figure 6 crack effects of three different materials

It is seen from the chart that the glass qualities is more brittle and dispersed after force. But the concrete and marble after bearing force the center will be more intensive and some. After testing in the worst case time complexity is $O(n \log n)$. It is very suitable for voronoi graphics generation with a large number of seed points. The real-time of the algorithm has not only high, but also high simulation of authenticity for various materials.

Conclusions and Outlook

This article proposes one kind of improvement based on growth method, using normal distribution in the seed point generation. By adjusting the variance of the distribution and seed distribution parameter fits different materials after the analysis of properties of different materials. In order to prevent the triangle mesh stop growing, when edge of the edge list due to does not conform to delaunay rules. At the same time, for preventing no used seed point, I record the use frequency of

the seed point by adding an array, when the grid does not conform to the rules, through that array to identify unused seeds and beginning to grow.

However, this algorithm is also a little flaw when the thickness of the crack should take into account.

Due to this algorithm realized in two dimensions we got good results. My next step will be that this algorithm is extended to three-dimensional space, which the three-dimensional space is divided based on voronoi diagram.

References

- [1] R Buyya and M Murshed. GridSim: a Toolkit for the Modeling and Simulation of Distributed Resource Management and Scheduling for Grid Computing [J]. *The Journal of Concurrency and Computation: Practice and Experience(CCPE)*,2002,14(13-15):1175-1220.
- [2] H Xia, H Dail, H Casanova and A Chien. The MicroGrid: Using Emulation to Predict Application Performance in Diverse Grid Network Environments [C]. *Proceedings of the Workshop on Challenges of Large Applications in Distributed Environments (CLADE'04)*. Honolulu, Hawaii: IEEE Computer Society Press,2004.52-63.
- [3] H Casanova. Simgrid: a Toolkit for the Simulation of Application Scheduling [C].*Proceedings of the First IEEE/ACM International Symposium on Cluster Computing and the Grid(CCGrid 2001)*. Brisbane, Australia: IEEE Computer Society Press, 2001.430-437.
- [4] Liu Lina,Xu Yun,Jia JinDong,Wang Peng. Boundary for discrete point Delaunay triangulation of simple polygon and visualization research. *Surveying Science*,2005,30(3):86~87.
- [5] Xu Haiming,Zhang Yanbin,Yao Wenshuan. An improved Delaunay triangular subdivision method. *Journal of university of petroleum*,2001,2 (21) : 34~37.