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Generation of Realistic Terrain Based on LOD Simplification and Fractal

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Abstract – Based on the study of Digital Elevation Simplification Model and fractal theory, this paper put forward a new method to simulate complex terrain. That use simplified DEM data to construct terrain frame based on the quad tree at first, and then use fractal to generate the details of every node of the tree. In the process of construction, the LOD theory is used to simplify the terrain and get its typical data. According to the change of view position and direction, the paper gives a new way to judge the visibility of the surface patch. Experimental results show that this algorithm is simple, efficient and supports the real time dynamic simulation of terrain model.

***Keywords*: Level of detail£®LOD£©,Fractal theory, Realistic terrain, Rendering**

1. Introduction

This Realistic 3D terrain is one of the important components of virtual reality system and real time emulation. With the widely use of virtual reality and emulation, the creation and modeling of high realistic terrain becomes more and more important. Terrain is one of the most complex natural scenery, so it is difficult to simulate it efficiently. In general, two different ways of method are used to simulate it, one way is applying real data, such as DEM data. Since it is the reappearance of our real world, it must be of high reality. Though this set of method is of high precision, it is hard to be carried out on personal computer because of its complex data structure and low speed. So it is unpractical to use it to generate large terrain. Generally speaking, people don't care very much about how to render the terrain in the visualization process, they pay attention to the sensory effect of simulation terrain. There for the second way of method named stochastic render terrain with the fractal theory is adopted. Here we call the terrain. generated by this way as the simulation terrain. But the biggest shortcoming of this way is its strong randomness. It is unable to forecast and control the terrain shape [1]. This paper combines both methods above and presents a new method to generate terrain. Firstly, simplify the DEM data with the level of detail technology to get a roughly terrain which has the original shape of terrain, then use the simplified characteristic data to construct the framework. At last, generate the details based on the fractal theory and get a realistic terrain.

The advantages of this method are obvious. It can not only resolve the problem that the terrain data take up too much storage space, but also can guarantee the authentic and foreseeable of the terrain. Using this method, it can select the appropriate terrain-rendering model according to the distance between the viewpoint and each surface patch of the terrain. In process of terrain generation, in order to enhance the efficiency of the real time dynamic simulation, visible-surface determination is carried on according to the direction of viewpoint. Experiment results show that this new method obtains best performance and high efficiency

2. Fractal theory

Fractal theory is a new branch of mathematics that developed rapidly in the recent years, its study object is nature, un-smooth and irregular geometry object in the nonlinear system. It uses the fraction dimension phenomenon and self-similar characteristic that is ubiquitous in the nature to carry on a lifelike simulation to the natural scenery. The fractal technology has been used to simulate the cloud, tree, flower and other natural scenery clearly, so it get widely used. Fractal Brownian movement (FBM) is an important stochastic process in the modern nonlinear succession analysis, it can not only express many nonlinear phenomenon of the nature effectively, but it is the best stochastic process that can describe real terrain until now [2]. Supposes X(t) is a one-dimensional stochastic process.In space, tl, t2 are random independent variables, the increment of this process $\Delta X(t)=X(t_1)-X(t_2)$ is the Gaussian distribution, its variance is proportional to the 2H th power of the independent variable difference, the fourmal is as following :

$$E(\Delta X(t))=E(|Xt_1-Xt_2|)\propto|\,t_1-t_2|^{2H} \quad (1)$$

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Here, H is the fractal parameter, 0 < H < l, when H = 0.5, it is the ordinary FBM. Those stochastic processes which satisfy the equation(1) named FBM. The above FBM can also be extended to a high dimensional space. Supposes a multi-dimensional stochastic process

$X(t_1,t_2,\ldots,t_n)$ and $t_i(i=1,2,\ldots,n)$ is an independent variable, then it has following natures:

Increment $\Delta X = X+(t_1,t_2,\ldots,t_n)-X(s_1,s_2,\ldots s_n)$ is the random variable which obeys the Gaussian distribution, and its mean value is zero. t_i, s_i are independent variables.

Increment's standard deviation σ_x and the distance T_s satisfies the relation (2).

$$\sigma_x \propto T_s^{2H}, T_s = \sqrt{\sum_{i=1}^{n}(t_i - s_i)^2} \tag{2}$$

The function $X(t_1,t_2)$ can be used to simulate the natural scene clearly.

The common used method to realize FBM is random midpoint displacement algorithm (MPD). There are two kinds of MPD algorithm now: triangle boundary recursive-subdivision law and square recursive-subdivision law. Because the triangle boundary segmentation law is easy to cause cracks, this paper use the square segmentation law [3], it can avoid cracks better than the other, and greatly reduce cracks appearance probability.

3. Generation of Realistic Fractal Terrain Based on Viewpoint And LOD

First make characteristic extraction to the DEM data obtained based on quadtrees, get the typical data which can describe this terrain region roughly, terrain framework constructed by triangle surface patch was shown in Fig. 1, the process of terrain render was as follows.

Step 1 : Construct the framework using the simplified DEM data.

Step 2 : Fractal iterative computation. The terrain was divided into many patches with equal size according to its characteristic. The value of index H and the variance δ in the fractal process were determined. Fractal iterative computation to each tree node was carried on, so different surface patches were obtained and also data of them were stored.

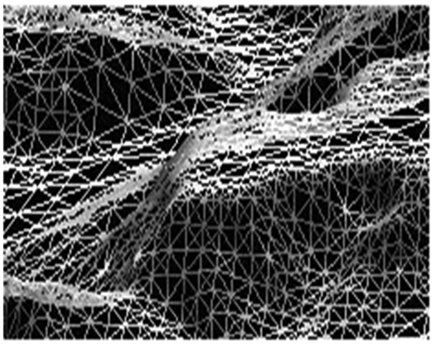
Step 3 : Visibility determination. Judge the visibility of meshes according to the change of view position and direction. Those invisible meshes will not be drawn. Then, according to the level of detail algorithm, judge the distance between the current viewpoint and the central patch, and determine the number of fractal iterative times executed to this block. The iterative time is fewer when the distance is far. Otherwise, it increases.

Step 4 : Connect surface patch to grid and complete the terrain render.

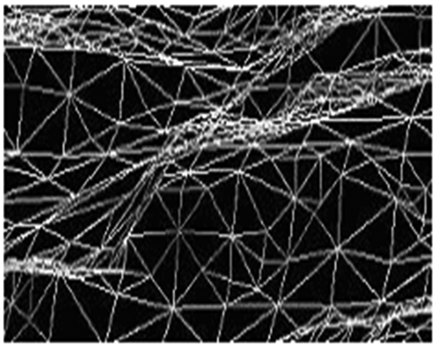
3.1 LOD Model And The Threshold Value

Level of detail (LOD)[4] model refers to obtain a group model with different details from the identical scene or scenery object for rendering. For vicinity observation object, this paper use the fine model, but for distant, it use the rougher. The LOD simplification technology reduces the scene complexity through the successive superficial detail reduction under the condition of not affecting the picture vision. Thus it enhanced render efficiency very much. Based on this characteristic we can apply it to our terrain render algorithm. According to the distance between the current viewpoint and the central piece, determine whether the terrain needs further subdivide.

To get the threshold value, the sight of the terrain should be determined firstly. According to the viewpoint coordinates and the line of sight direction, the visible region is calculated which is the intersection region of the ground view body and the terrain average horizontal plane. As shown in Fig. 2, XOY is the terrain average horizontal plane, E is the viewpoint, M is intersection point of line of sight EM and terrain average horizontal plane, the projection of the viewpoint E on XOY is M_0, 4 points of intersection of ground view body E-ABCD and the plane XOY are A', B', C', D', then the visible region is quadrangle A'B'C'D'. In order to compute the



(a)



(b)

Fig. 1. (a) The initial DEM terrain, (b) The terrain simplified 48.76%.

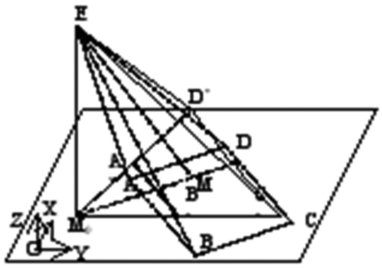


Fig .2. Visible region ABCD.

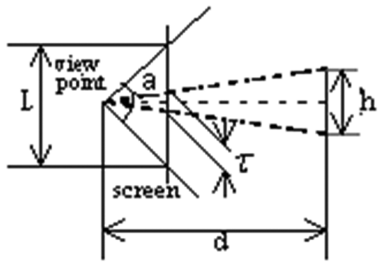


Fig. 3. Changing method of viewpoint

distance between viewpoint E and some block within the sight region easily, the under angle of viewpoint is always supposed as 0, namely the line of sight is always parallel to the X-Z plane, as shown in Fig. 3. The flare angle of the viewpoint and the border length of projection plane a and L, the length of the line segment be projected is h, the distance from the viewpoint to the center of this line segment is d, the viewpoint and the projection plane are paralleled, the projection length is τ. Given the error threshold value ε, the minimum value of d is eq.(3), d is used as the final threshold value [5].

To heighten the real time render efficiency, Those patches we can't see will not be drawn by the visibility determination.

3.2 Visibility Determination Method

The visibility of surface patch can be judged by the angle between the viewpoint and the normal vector of the surface patch, the method is as follows:

This algorithm uses the square segmentation law to draw the surface patch. A quadrangle is divided into two triangles, then read three apexes on each triangle surface patch separately through counter clockwise. This article provides an extremely easy division method [1]: Compares the four vertices' elevation value of each quadrangle, then line the two vertices with smallest value. Like this, two triangles are geted which conforms to the quadrangle's actual characteristic best. Supposes three vertices of one triangle surface patch M are A, B, C, then M's outside normal vector {a, b, c} is:

$$a=(B.y-A.y)\times(C.z-B.z)-(B.z-A.z)\times(C.y-B.y);$$

$$b=(B.z-A.z)\times(C.x-B.x)-(C.z-B.z)\times(B.x-A.x);$$

$$c=(B.x-A.x)\times(C.y-B.y)-(C.x-B.x)\times(B.y-A.y);$$

If the viewpoint's reversed direction vector is {d, e, f}, The M's visibility determination can be judged by the value gotten from $G=a\times d+b\times e+c\times f$. If $G<0$, this patch is not visible; If G0, determines its visible degree in the next step.

3.3 Connection Disposal

Despite of its fast speed and good real-time performance, the terrain simulation technology we put forward has its disadvantages considering the fact that the terrain rendered does not strictly follow the increment stability of the FBM [5]. The instability of increment brings about different statistical data of center points in different recursive segmentation stages, this consequently leads to obvious cracks in the final terrain, which is similar to the crease problem of the triangular synthesis. Although it can be alleviated by the quadrilateral subdivision, other cooperative measures are required.

4. Experimental Results

Based on the fractal and LOD simplification technology, we get a real and real-time terrain simulation result, the final effect as shown in Fig. 4.

This algorithm has two advantages:

(1) This algorithm use real terrain data replacing the stochastic data to construct the terrain frame, simulation terrain, it can enhance the roaming effect greatly and can satisfy the people's sense need.

(2) Uses the level of detail simplification technology based on viewpoint to simplify the framework. This enhances the real-time protraction with greatly efficiency.

5. Conclusion

The algorithm merely uses the real data to construct the framework, it is very suitable for certain specific terrain simulation. But if we want to obtain the terrain with very high reality, we need to give the precise terrain data and construct fine terrain framework. The cost corresponding is storing massive terrain data and sacrificing the speed. Therefore it is necessary to concern the need of time and data storage space. This algorithm is extraordinarily suitable for simulation experiment and virtual reality

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