Construction and Visualization of 3D Landscape

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Abstract—In order to know the operation condition before working, and reduce the risk of serious accidents of coal production industry. In this paper, by analyzing the characteristics of the environment of underground mine, using virtual reality technology, combined with the 3d Max modeling techniques and VC++ calling the OpenGL graphics interface techniques, the models are well optimized based on progressive mesh LOD algorithm for edge collapse. Using high-tech computer technology to simulate realistic mine production environment and realization of a friendly man-machine interactive virtual mine application system.

Keywords-Virtual Reality Technology; 3d Max; OpenGL; LOD algorithm

I. INTRODUCTION

With the development of virtual reality and related technology,3D digital geometric model has become a new generation of digital media types after digital audio, image and video, widely used in transportation, industrial manufacturing, military simulation etc. The optimization of 3D model is one of the key problems in the field of computer graphics and digital geometry processing. Based on the requirements of the application of digital mine geometry modeling, this paper aims at the problems such as the convenience of modeling, the diversity of modeling and the flexibility of classification, studying the modeling of digital mine and the organization of data and the simplification of data, a progressive mesh LOD algorithm based on edge collapse algorithm is proposed, which can optimize the virtual mine system model, improve the loading speed. Add the collision detection technology, collision detection technology, combined with 3d Max modeling technology and VC++ call OpenGL graphical interface technology to develop a set of digital mine application system, really and vividly reflect the mine operating conditions.

II. VIRTUAL REALITY TECHNOLOGY BASED ON MODELING

Virtual reality (VR) is a kind of advanced human computer interface, which can simulate and interact with many kinds of sensory channels, such as sight, hearing, touch, smell and taste. It makes full use of computer hardware and software technology, through the computer integrated technology to simulate the virtual three-dimensional space,providing a real-time virtual environment, with immersion and interaction and conception.

The core of the modeling method is to build the virtual model. The establishment of virtual model can use different modeling software, such as CAD, Autodesk Revit, 3d Max and so on. Taking into account the realistic degree of modeling and the realization of virtual mine application system on the VC++ platform and OpenGL interface, the 3d Max is used to build the model.

III. CONSTRUCTION AND VISUALIZATION OF 3D MODEL OF OPENGL

In the development of the system, through the combination of 3D Max software and OpenGL, we can reduce the complexity of the system. The key part of constructing the virtual mine model is the modeling of the underground scene. According to the state characteristics of

the mine scene model, it can be divided into dynamic entity model and static entity model

A. Construction of static entity model of virtual mine

The mine static entity includes the mine shaft, the mine track in the mine, the mine pipeline, the circuit and the self rescue system and so on. Static modeling is mainly based on the physical characteristics of the physical model and the physical model of the physical environment. The physical modeling of the static entity model is mainly about the different solid textures caused by the external environment. The geometric model of the static entity model is the entity model of its own shape. In the process of geometric modeling of static solid model, depending on the complexity of the collected entity model data, for regular static entity model, 3D Max can be used to build the model, for irregular entity model, AutoCAD is used to modify the model outline, and then the model is established by 3D Max.

B. Construction of dynamic entity model of virtual mine

In the process of constructing mine system model, it is possible to change the internal structure of the original model when constructing the moving part, therefore, we should increase the degree of freedom of the link in the model file, set corresponding positioning coordinates, based on the degree of freedom, the motion of the model is analyzed to determine the kinematic relationship.

As an important part of virtual mine system model, the modeling process of dynamic entity model is:① Using 3D Max to construct the static entity model and dynamic entity model, in the process of building dynamic model, the degree of freedom increases; ②Enhanced dynamic entity model animation effect; ③The flash effect of dynamic model is presented in the model of virtual mine system

IV. OPTIMAL DESIGN OF 3D LANDSCAPE SYSTEM MODEL

Because of the complexity of the mine scene, when loading the model, complex model will cause the system CPU load is too large, the system will not work in coordination, the model output delay and picture frame refresh are too slow, which reduces the effect of the mine system. As shown in figure 1, for the two spheres of the same radius and the number of patches is not equal, the required system CPU load and memory capacity are different, as shown in Table 1.
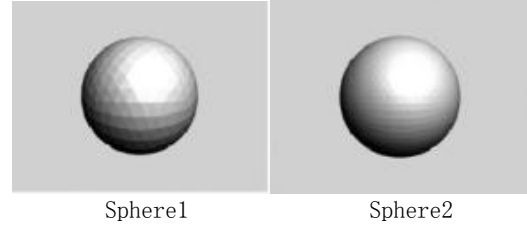

Sphere1   Sphere2

Figure 1.   Different facets of sphere model

TABLE I. SYSTEM CPU LOAD COMPARE WITH MEMORY COMPARISON UNDER THE NUMBER OF DIFFERENT PIECES

Model name	Patch number	Occupied memory
Sphere 1	1000	18MB
Sphere 2	3500	28MB

In order to speed up the output of the scene model and ensure the real-time performance of the virtual scene, need to simplify the complexity of the scene. For the objects in the mine scene far away from the observer, there is no need to describe the details, the appropriate combination of some triangular surface of the object, the visual effect of the picture did not have an impact. The model details of virtual mine system are simplified by correlation, reduce the detail level of the model, After the treatment of the model can be selected according to specific occasions, and there is no need to select the full details of the model in any situation, and the number of triangles in scene model is greatly reduced. When the LOD algorithm is used to optimize the mine model, it is necessary to judge whether the scene objects need to be simplified and what level of detail should be used to represent the object, According to the characteristics of the complex structure of the virtual mine system, this paper proposes a progressive mesh LOD algorithm based on the edge collapse algorithm, the virtual mine system model is optimized by this algorithm.

A. Optimization of progressive mesh LOD algorithm based on edge collapse

1) The basic idea of progressive mesh

The basic idea of progressive mesh is the mesh simplification algorithm based on edge collapse, The

triangular mesh edge collapse operation is shown in figure 2, a set of dual operations includes a side folding operation and a corresponding vertex splitting operation, Edge collapse operation is the edge (a, b) synthesis vertex {a},and delete the triangle {a, b, c} and {a, b, d};Contrary, Vertex splitting operations split vertex {a} into edges (a, b), and generate new triangles {a, b, c} and {a, b, d}.
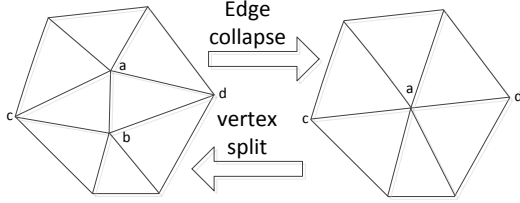

Figure 2.   Sketch map of edge collapse operation

The feature of this method is that the local mesh elements are changed by each iteration, a vertex, an edge, and two triangles, therefore, it is possible to produce very regular information sequences. A set of edge collapse operation sequences will generate a set of continuous approximate grid sequences, can be expressed as

$$M_n \xrightarrow{\text{edgecol}_{n-1}} M_{n-1} \xrightarrow{\text{edgecol}_{n-2}} \cdots M_1 \xrightarrow{\text{edgecol}_0} M_0 \quad (1)$$

Vertex split conversion, through the simplest grid to get the subsequent high-level grid of detail, in theory, these two operations are reversible, can be expressed as

$$M_0 \xrightarrow{\text{vsplit}_0} M_1 \xrightarrow{\text{vsplit}_1} \cdots M_{n-1} \xrightarrow{\text{vsplit}_{n-1}} M_n \quad (2)$$

2) Error measure of edge collapse

Error measure of edge collapse is the new vertex to a related set of plane and the square of the distance after edge collapse. This method is simple, small memory, and fast, the quality of the simplified mesh is very high. It is an ideal error measure which takes into account both the speed and the quality of the model.

In Euclidean space, the expression of the plane is

$$n^T v_0 + d = 0 \quad (3)$$

$n = [n_x n_y n_z]^T$ is plane normal vector, is constant.

The square of the distance from point $v = [xyz]^T$ to the plane can be expressed as

$$D^2 = (n^T v + d)^2 = (v^T n + d)(n^T v + d) = v^T(nn^T)v + 2dn^T v + d^2 \quad (4)$$

Can define three tuples $Q = (a,b,c) = (nn^T, dn, d^2)$, to express D^2, Such as (5)

$$D^2 = Q(v) = v^T a v + 2b^T v + c \quad (5)$$

Where a is a symmetric matrix of 3*3, b is a 3 dimensional vector, c is a constant.

The 2 error measure can be used to facilitate error accumulation, such as formula (6)

$$Q_1(v) + Q_2(v) = (Q_1 + Q_2)(v) \quad (6)$$

Among, $(Q_1 + Q_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$ 。

Sum the error matrix corresponding to each correlation plane of the vertex, The error matrix of the vertex is obtained.

In the grid, The sum of the error matrix of the two vertices of the edge of each edge is $Q = Q_1 + Q_2$,The two error value is $Q(v)$.

B. Implementation of the algorithm in virtual mine model optimization

Optimization model M_0 , M_1 , M_2 …need to maintain a certain degree of similarity with the original mesh model, the key is on the selection of edge collapse and the location of the target points after the edge collapse, These depend on the edge collapse cost. It is best to meet three conditions: ①Simple operation; ②Simplified record of original model to simplified model; ③Most mesh models can be simplified.

Based on the above criteria, in order to meet the actual needs of the mine, The effect of deleting a shorter edge on the overall model shape, the influence of a shorter edge on

the shape of the whole model and the influence of the two error value on the flatness of the model are also discussed, this paper proposes a method to measure the edge collapse cost by using the product of side square and the two error value.

Edge collapse cost can be calculated as follows:

$$edgecobst(v) = Q(v) \times L^2 \qquad (7)$$

In this type, $edgecol\cos t(v)$ is edge collapse cost; $Q(v)$ two error value for the folded edge; L is the length of the side being folded.

Selection of folded edges: The choice of each edge collapse should be folded at the cost of $edgecol\cos t(v)$ from small to large order. In view of the special situation of the triangle shape distortion caused by the folding operation, So it is necessary to check the triangle mesh model which is generated after the edge collapse. If the new mesh model is reasonable, the edge collapse operation can be implemented, In the case of distortion and other special circumstances, the upper and lower edges of the set of edges are folded.

The location of the target point to be generated after the folded edge is selected. For large objects, a large amount of data for a wide range of 3D models, in order to improve the efficiency, the virtual mine model directly uses the original data. The original point is the folded edge vertex in a lower cost. Calculate the sizes of $edgecol\cos t(v_1)$ and $edgecol\cos t(v_2)$. Because the L is the same, in fact, compare the size of the $Q(v_1)$ and the $Q(v_2)$, select one of the smaller fold .

The algorithm is used to simplify a mine car in virtual mine, the data shown in Table 2. Figure 3 is the model grid of the mine, Among them (a) is the original details of the mine level diagram, and (b) is a rough layer model which is simplified by the algorithm. The result showed that the number of vertices and the number of triangles on the surface of the car are obviously reduced after simplification.

TABLE II. THE MODEL DATA OF DIFFERENT LEVELS OF CAR

cars model	Vertex number	Number of triangles
Before simplification	2672	5236
After simplification	413	718
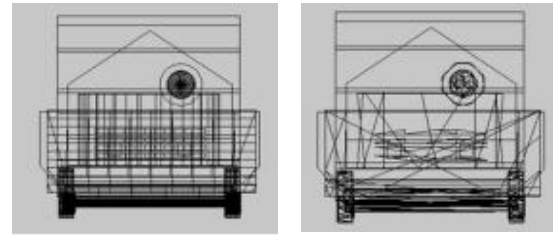
(a) Fine mesh   (b) Rough mesh

Figure 3.   The mesh hierarchy of tramcar

V. REALIZATION OF VIRTUAL MINE 3D ROAMING

Virtual mine roaming system is through a camera to simulate the human eyes to observe the scene in the scene. In OpenGL, we mainly use gluLookAt (...) function to observe the virtual mine scene, which is used to change the position of the viewpoint in the Virtual Mine Scene. The position of this view represents the location of the user's eyes. When the user controls the main view roaming in the virtual mine scene, to see the distant scene model is more and more close, it shows that the position of the viewpoint in the virtual mine scene has changed. The gluLookAt（…） function is as follows:

gluLookAt(GLdoubleeyex,GLdoubleeyey,GLdoubleeyez,GLdoublecenterx,GLdoublecentery,GLdoublecenterz,GLdoubleupx,GLdoublupy,GLdoubleupz)

The gluLookAt（…） function is used to control the camera, the first three parameters indicate the location of the camera, the middle of the three parameters that represent the location of the point of view, the following three parameters represent the orientation of the camera, through the three sets of parameters to move the camera position, change the viewpoint to achieve camera roaming, The roaming effect is shown in Figure 4.

(a) mine shaftbottom   (b) coal mine roadway

Figure 4.   The effect chart of mine roaming

VI. CONCLUSION

1)Analysing the characteristics of the mine environment, the whole scene of the 3D virtual mine and the modeling of some equipment models are realized by using 3ds Max software. Combined with LOD algorithm, the progressive mesh simplification algorithm is improved. This paper proposes a progressive LOD algorithm based on edge collapse, which can realize the operation of edge collapse. It can meet the requirement of rapid generation of progressive mesh model, simple operation, fast loading, less memory.

2)Analysing the virtual mine system, a reasonable framework of the virtual mine system is established, which realizes the visualization of the 3D tunnel and the friendly interface, and completes the development of the virtual mine system.

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