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ADAPTIVE DOO-SABIN SUBDIVISION ALGORITHM

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ABSTRACT

At present most of the subdivision algorithm are 1-4 subdivisions. as the number of subdivision increases, the grid too-rapid growth in the number of patch and die after the breakdown of huge volume of data make it difficult to deal with, we proposed a radical Doo-Sabin Mode adaptive subdivision algorithm addressing the problem. As a measurement criteria, the average vector of the vertex and the angle between the intersecting surfaces of the vertex are used to divide the surface, and then make local subdivision. In this way, when the times of subdivision are fewer (the demand of smoothness is not too high) , the effect of subdivision has little difference , but efficiency of the algorithm can be greatly improved.

Keywords: *Surface Subdivision; Doo-Sabin Subdivision; Quadrilateral Grid; Threshold*

1. INTRODUCTION

After nearly 30 years of research, a large number of surface subdivision algorithms are proposed. In general, the most commonly used subdivision models in subdivision process, make the geometry elements on the control grid are growing exponentially, such as Catmull-Clark subdivision[1], as one subdivision, the number of quadrilateral mesh on the control grid becomes 4 times, even $\sqrt{3}$ subdivision scheme that its growth is slow[2], as one subdivision, the mesh plate number will increase to 3 times. In the even sub-operation process on the model of large amount of data, it requires a lot of storage space and computing time in order to save the geometric elements and topological information after subdivision, and this has great impacts on the time complexity and space complexity of the algorithm, also affects the use of algorithms. In practice, however, the geometric model needed to be subdivided is not completely rough, so you usually don't need to even subdivide the whole model each time to obtain the smooth limit surface, several sub-operations on the relatively uneven area on the model will make this area smoothing. However on the relatively smooth area, even more subdivisions cannot achieve more significant results, this only increases the amount of unnecessary data, wastes resources, reduces the processing speed of models and makes the model difficult to control in the subsequent operations. Adaptation subdivision algorithm can solute this a problem[3,4] , the thought is when the subdivision operation is processed on one layer, according to the actual need, used a threshold value criteria to determine which region(relative not flat) continues to participate next layer subdivision, which region(relative flat) stops subdivision, through this local subdivision both can get ideal smooth limit surface, and reduce the growth speed of data in subdivision process[5,6]. Adaptive Subdivision can use local grids to represent the high precision of subdivision surfaces, this characteristic on subdivision surfaces has important significance in the practical application.

2. DOO-SABIN SUBDIVISION SCHEMES

Doo-Sabin Subdivision's[7] thought is from the thought of Chaibin cutting-corner, and it is extended the method that produces the cutting-angle by the quadratic B-spline to the surface. It is an approximating splitting-point subdivision and applied to the quadrilateral mesh surface, in the extreme circumstances the surface we obtain is uniform biquadratic B-spline surface.

The first Doo-Sabin subdivision is only for rule quadrilateral mesh surface, and then, Doo and

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Sabin extended this thought to arbitrary topological meshes, and gave the subdivision rules on arbitrary topological meshes. Assuming the vertices of the grid are $P_i(1 \le i \le N)$ .F is an n-Edge face on the grid, the location of new vertex p_i^* which is generated by the vertex of P_i is

$$p_i^* = \sum_{j=1}^{n} \alpha_{ij} p_j \qquad (1)$$

and

$$\alpha_{ij} \begin{cases} \dfrac{(n-5)}{4n} & (i = j) \\ \dfrac{3-2\cos\left(\dfrac{2\pi(i-j)}{n}\right)}{4n} & (i \ne j) \end{cases}$$

The topology rules of Doo-Sabin Subdivision are shown in Figure 1:

New face-face (f – face) is the face connected by new vertices p_i^* in order.

New edge-face (e – face) is the face that connected by the new vertices in the adjacent faces of endpoints of each edge of p_i .

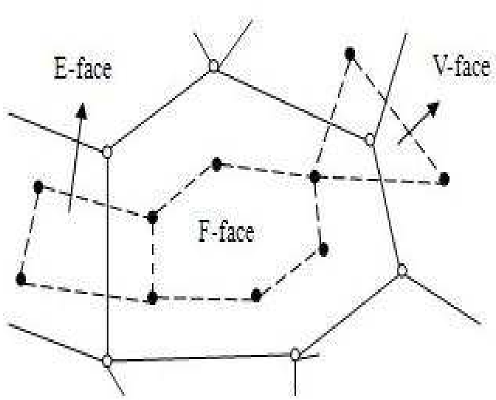

***Figure 1.** Doo-Sabin Segment Generates Three New Diagrams*

The three new surfaces are shown in Figure 1. We can see that after one Doo-Sabin subdivision, the degrees of all vertices of the mesh are 4 , and the number of singular point in the following subdivision process remains unchanged, and it is the sum of the number of non-quadrilateral of initial control grid and the number of vertices' degree less than 4. The new surfaces are C^1 continuous except in the singular points, and can interpolate the center of the initial control mesh.

To boundary problems of the open-mesh, Doo-Sabin adopts Chaibin methods to calculate, each vertex is spitted into two new vertices, and makes boundaries converge to bi-quadratic uniform B-spline finally.

3. ADAPTIVE DOO-SABIN SUBDIVISION

3.1 THRESHOLD CALCULATION

The thought of adaptive subdivision is subdivide the whole control mesh locally, and select the area which should be subdivided depends on the user's application purpose. In this article, the adaptive Subdivision algorithm selects those relatively uneven areas or the areas of relatively high curvature to participate in the next layer's subdivision. In this paper, based on the geometry criteria of the angle between the surface mesh[8], we propose the algorithm that use the average vector of the vertex and the angle between the intersecting surfaces of the vertex as the measure criteria to divide the surface, and then make local subdivision. In this way, when the times of subdivision are fewer (the demand of smoothness is not too high) , the effect of subdivision has little difference , but efficiency of the algorithm can be greatly improved.

Set V_i as the control vertex of the mesh. The outside normal vector of the control mesh faces on the 1-neighborhood of V_i , the area is S_i, and the formula of the average normal vector n_V of the vertex is :

$$n_v = \frac{\sum_{i=1}^{m} n_i S_i}{\left|\sum_{i=1}^{m} n_i S_i\right|} \qquad (2)$$

And, m is number of polygons on the 1-neighborhood vertex V_i in formula, as shown in Figure 2.

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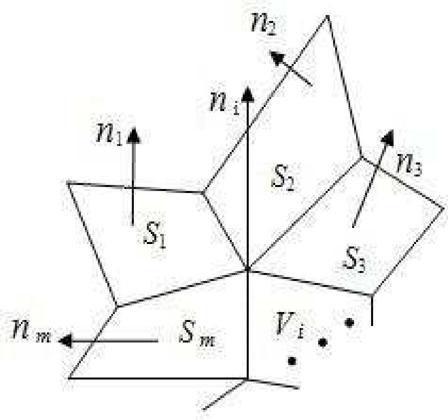


Figure 2 *Vertex Average Normal Vector Diagram*

Set threshold for ε_T and flatness for ε_V .The calculation formula is:

$$\varepsilon_V = \max_{i=1,2\cdots m}\{\arccos(n_i \cdot n_V)\} \quad (3)$$

The threshold value judging formula is:

$$\varepsilon_v < \varepsilon_T \quad (4)$$

When the flatness meets the formula (4), the face V corresponding with the face V_i after subdivision is dead-face. If both endpoints of an edge meet the formula (4), ant the face E corresponding to the edge after subdivision is the dead-face. If the adjacent faces of all edges on the surface F are dead-faces, F is the dead-face. The dead-face does not participate in the next subdivision.

3.2．ALGORITHM STEPS

The premise of adaptive subdivision is to ensure smooth of the surface. In this algorithm, it is by setting the threshold ε_T to control adaptive subdivision process.

The steps are as follows:

Step1. Traversing the entire surface mesh, according to the formula (2) to calculate the average vector of all grid vertices.

Step2. Traversing all surface patches, according to the formula (3) to calculate the flatness ε_v of each vertex. And then judge whether face V, face E and face F after subdivision are dead-faces according to formula (4). The method to produce the face V, face E and face F is the same as Doo-Sabin subdivision.

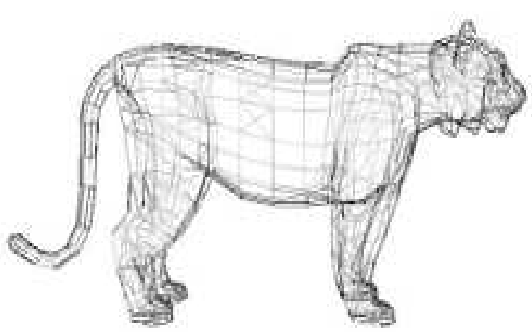
Step3. The vertices on the live-face continue to participate in the next subdivision, and for dead-faces, they don't participate in the lower segment.

Step4. Processing cracks generated in the subdivision, and make the subdivision depth of all adjacent mesh up to a difference of one.

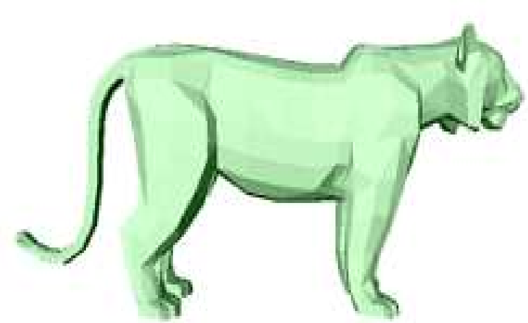
Step5. Continue to operate the above subdivision, until it meets the needs of users.

4. EXPERIMENTAL RESULTS AND ANALYSIS

In Windows XP system, using C + + programming language and OpenGL graphics library in VC + +6.0 compiler environment to achieve the proposed algorithm, and analyze 3D models.



(a) Initial control mesh



(b) Initial mesh renderings

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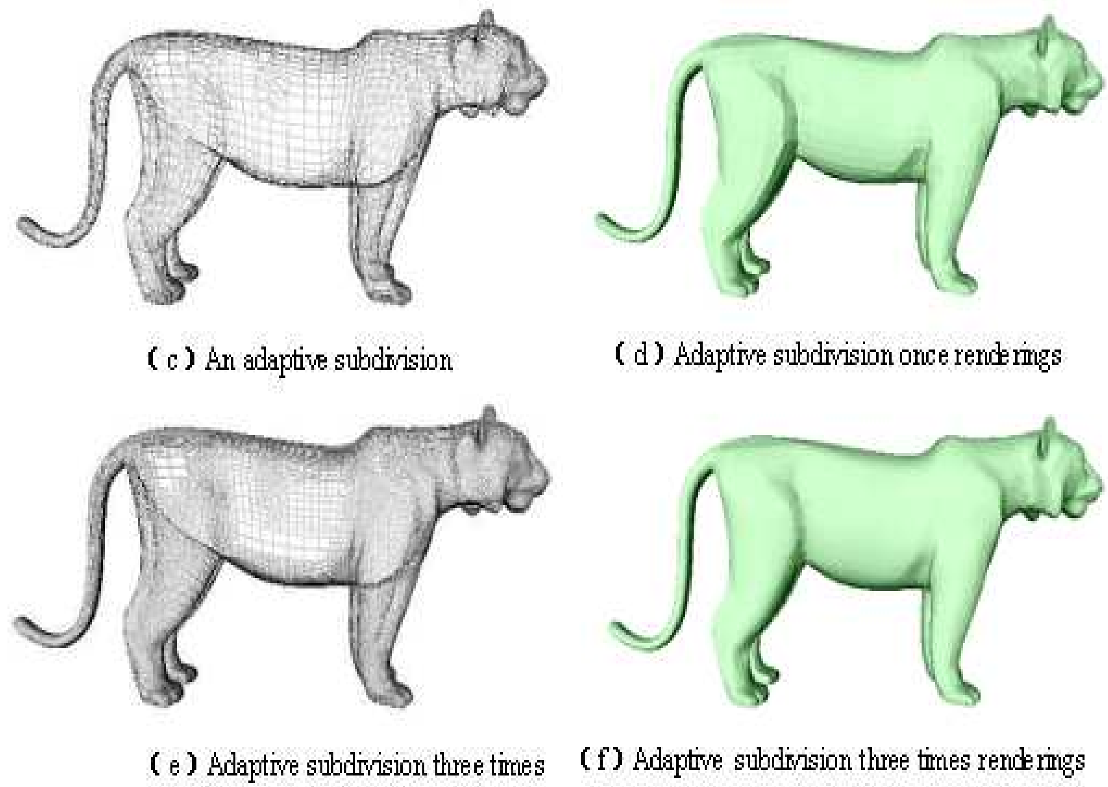

***Figure 3** Leopard Model Adaptive Subdivision Map*

Figure 3 shows experimental results of the Leopard model using the adaptive subdivision algorithm in this article. Figure 3 (c),(e) respectively show the result of the Leopard Model subdivided by this adaptive subdivision algorithm 1 times and 3 times. We can see from the experimental results that the adaptive subdivision algorithm subdivides in the relatively uneven areas and the areas of high curvature, so the threshold standard given in the algorithm can accurately describe some basic features of the leopard model. Such as the front face, ears, neck, buttocks, tail and legs of the leopard model are further subdivided, and these areas are not smooth and have high curvature. These areas need to be subdivided some times. In contrast, the relatively smooth areas of the original model are not subdivided further, such as the stomach and other parts. From the table 1we can see that the number of the initial grids of the leopard model is 2268. After subdivided by this adaptive subdivision algorithm, the amount of data reduces significantly compared with the normal 1-4 Doo-Sabin subdivision. With the increase in the number of subdivision, model data reduction will be more obvious. This makes the processing speed of the adaptive subdivision much faster than the speed of normal subdivision, and the model will be more easily controlled in the subsequent processing. And it can effectively reduce the growth speed of the grids in the subdivision. Therefore, it has great benefit to the application in the graphics transmission and multi-resolution analysis.

***Table 1** Leopard Models Adaptive Segmentation Of Data And Statistics*

Model	Number of initial network	Adaptive Subdivision		ε_T
		Subdivision number	Number of segments	
The Leopard	2268	1	7216	0.05
		3	39654	

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Of course, whatever the adaptive subdivision methods will undermine the overall continuity of subdivision surfaces, which will make some cracks and deterioration. But this is the lack of all theadaptive subdivision algorithms and is inevitable. Because in theadaptive segmentation, according to the given criteria, some patches will not participate in the lower segments, while some patches take partin, what making some patches in different layers, so it is difficult to get high quality adaptive subdivision surface.

5. CONCLUSION

This chapter make a summary on the adaptive research and subdivision surfaces of several commonly used criteria for adaptive subdivision geometry and the strategy to eliminate cracks, and based on feature modeling needs, proposed to mean normal vector and the vertex of the vertex angle between the plane of the intersection, as a judge of the second threshold algorithm based on Adaptive Subdivision. This algorithm can not only use grid with fewer patches that model, but also to maintain the good characteristics of the effect, almost sub-surface quality and uniformity.Experimental results show that the algorithm can effectively reduce the storage space of models, slow the growth of mesh subdivision process. It has great benefits in graphics transmission, multi-resolution analysis and control applications in the grid.

6. ACKNOWLEDGMENTS

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