LOOP’S SUBDIVISION SURFACES SCHEME IN VIRTUAL ENVIRONMENT

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ABSTRACT
Various methods have been suggested for subdivision scheme, but none of these methods are capable to produce a good sharp feature such as darts, creases and corner. Loop’s subdivision scheme is one of the schemes that capable to fulfill this criterion and can generate a good representation of a smooth surface. Loop’s is the popular subdivision surfaces scheme for triangular meshes. This scheme is an approximating vertex insertion scheme. In addition, loop’s is the simplest scheme to produce a subdivision surfaces because this scheme can avoid the computation cost and also can give us smooth surfaces at C2 continues of the limit surface. Therefore, the capabilities of loop’s scheme inspired us to study more on this scheme. In this paper, we will discuss about the usage of Loop’s subdivision surfaces scheme in surface fitting, multiresolution analysis and in the reconstruction application. We also explain about the general construction of Loop’s scheme in a subdivision surfaces.

Keywords: Loops subdivision schemes, subdivision surfaces, surface fitting, multiresolution analysis, reconstruction, virtual environment.

1 INTRODUCTION
Virtual environment can be defined as a virtual world application that lets user experience to navigate and interact with a three-dimensional environment. The major element in virtual environment is interaction, 3D graphic and immersion [1]. There are a lot of techniques that can be used to make a virtual environment looks realistic such as crowd simulation, motion capture, realistic 3D modeling and so on. A technique in 3D modeling which is promising to create a good and smooth surface for 3D object is subdivision surface technique.

A subdivision surface is a technique that generally used in object modeling, animation [2] and games. A subdivision surface involved the process of repeating to refine the control mesh to get a limit surface. The strength of subdivision surfaces is their capability to deal with irregular meshes for defining arbitrary two-manifolds. There are several applications of subdivision surfaces such as surface fitting [3], multiresolution analysis [4] and reconstruction of objects from samples of 3D data. In the surface fitting, the object will looks like as a real because this application will produce the smoothness, arbitrary control mesh connectivity and intuitive shape control properties. The second application of subdivision surfaces is multiresolution analysis which is suitable for real time visualization of large data sets where this technique is capable to separate the models into a hierarchy of meshes and represent it in different level of detail [5]. Lastly, reconstruction of objects from samples of 3D data application is to generate a piecewise smooth surface by balancing a least squares fitting component with a function that measures mesh size [4].

There are a lot of issues in subdivision surfaces that the researchers try to tackle such as issues in fast rendering [6], computation cost, accuracy and efficiency [3] in the representation of smooth shapes. For fast rendering issues, subdivision surfaces can offer a good representation of surface by providing the efficient algorithm [6]. In cost-effective calculation issue, it stresses up on how to solve the mathematical computation in subdivision surfaces by the effective and simple algorithm with less computational cost. Accuracy and efficiency becomes the important issues in order to represent a smooth shape in the subdivision surface fitting.
We can use Loop’s subdivision as an approach to solve this issue. This scheme uses a simple computation and the characteristic map of this scheme doesn’t need to represent an explicit piecewise polynomial [7]. In this paper, we will explain about loop’s subdivision scheme and the general construction of this scheme in virtual environment.

2 RELATED WORK

Loop’s [8][9] subdivision scheme was proposed by Charles Loops in 1987. This scheme can produce the smooth surface from triangular mesh. Bertram [10] and Hagen were presenting a modified Loop subdivision surface for the approximation of scattered data in the plane. They proposed a simple and efficient variant of Loop’s subdivision scheme which can be used for terrain modeling and also suitable for approximating bivariate functions with multi-dimensional ranges such as planar tensor fields and color images. Pulli and Segal [6] have presented an algorithm for subdivision surface triangulation, in which fast, uses minimum memory and is simpler in structure. For that reason, this algorithm can produce a fast rendering because it allow a high rendering performance on graphic hardware that suitable for subdivision surfaces. Loops subdivision surfaces also use in surface fitting, multiresolution analysis and reconstruction of 3D object application. The explanation about the related works of loop’s scheme in this application is exposed as below:

2.1 Surface Fitting

An approach for automatically fitting subdivision surfaces from a dense triangle mesh by extended Loop’s scheme using a piecewise linear approximation to produce a concise and accurate surface was first introduced by Hoope et al. [11]. They used Loop’s scheme to model sharp features such as creases and corners. In previous work, Ling, Wang and Yan [3] have presented an effective approach to do the fitting sharp features with loop subdivision surfaces. They performed a new precise evaluation scheme for the Loop subdivision with sharp features in an optimization framework. To produce a sharp feature, they compute the limit surface by representing in any parameter value (t,u) and allocate the parameterization in the fitting Loop subdivision surface. Kovacs et al [12] has presents a construction for a smooth boundary using an extension of Loop’s scheme and Schaefer’s [13][14] approximation of Catmull Clark surfaces (ACC) to support piecewise smooth surfaces with creases and boundaries with corners.

2.2 Multiresolution Analysis

Other than surface fitting, Loop’s subdivision scheme also has been used in multiresolution. The core idea in multiresolution analysis is to decompose a complex function into a simple low resolution part with a wavelet coefficient [15]. Lounsbery [15] found that the multiresolution analysis can be applied to any uniformly convergent subdivision scheme with subdivision connectivity [16]. Eck et. al [16] introduced a method to carry out the subdivision connectivity restriction by completely arbitrary meshes and then convert to multiresolution form. Mandal et. al. proposed a multiresolution dynamic framework by combining the shape modeling and shape recovery for subdivision surfaces.

2.3 Reconstruction of 3D Object

The other application of subdivision surfaces is reconstruction of 3D object. Hoppe [11] has described a method that automatically produces the reconstruction of concise, accurate and piecewise smooth surfaces from unorganized 3D points. In their studies, there are three phases for reconstruction method. The first one is initial estimation, then mesh optimization and lastly is piecewise smooth surface optimization. Hoppe contributed a new class of piecewise smooth representation based on subdivision in the piecewise smooth surface optimization phase. The next section will explain about a loops scheme and the general construction of this subdivision scheme.

3 A CONSTRUCTION OF LOOP’S SUBDIVISION SCHEME

The previous section discussed the use of Loop’s subdivision surfaces in surface fitting, multiresolution analysis and reconstruction of 3D object applications. As mention before, we identified that loop’s scheme play an importance role in this application in order to make surfaces looks like a real and smooth. Therefore, we concentrate on Loop’s subdivision surfaces scheme in our study. In this section we will explain a general construction of Loop’s subdivision surfaces.

The simplest scheme for subdivision is Loop subdivision and works only on triangular meshes.
The triangle is split into four and more to quartic triangular B-Splines. Interior cases, boundary cases and extraordinary vertices are some of notation that can be handling by this scheme. The general pattern of refinement for Loop scheme is vertex insertion. This scheme is created from C2-continuous on a regular meshes based on the three-directional box spline [18].

In this scheme, the control mesh and all refined meshes consist of triangles and refined by quadrisection only. After that, the position of vertices for the refined mesh is computed as weighted averages. The coordinates of the new vertex \( x_1^k, x_2^k, x_3^k, \ldots x_i^k \) (as shown in the figure 1 above) on the edges of the previous mesh are computed as equation (1):

\[
x_{i+1}^k = \frac{3x_0^k + x_{i-1}^k + 3x_i^k + x_{i+1}^k}{8},
\]

\[\text{for } i = 1 \ldots n\]  

(1)

Where \( i \) is an index. The position of the new vertices is compute from the old vertices by equation (2). Figure 2 illustrated the refinement of the equation 1 and 2:

\[
x_{i+1}^k = (1 - Nw)x_0^k + wx_i^k + \ldots + w x_N^k
\]

(2)

\[\text{for } i = 1 \ldots n\]

Besides that, Warren’s [20] also purpose the equation to get the values for \( w \) as represent in equation (4). This equation is simpler than Loop’s scheme to evaluate the \( w \).

\[
w = \begin{cases} \frac{3}{8N} & \text{for } N > 3 \\ \frac{3}{16} & \text{for } N = 3 \end{cases}
\]

(4)

The rules of extraordinary crease vertices were modified for odd vertices adjacent to produce tangent plane continuous surfaces on the one side of the boundary [18]. To keep C1 continuity, the interior odd vertices adjacent to an extraordinary vertex were modified as the figure 3 for \( n > 7 \). For \( n < 7 \), no modification is needed.

It’s easy to compute a pair of the tangent vectors for Loop’s scheme. The equation (5) is representing to compute tangent for interior vertex.

\[
t_1 = \sum_{i=0}^{k-1} \cos \left( \frac{2\pi}{k} x(v_i, 1) \right)
\]

\[
t_2 = \sum_{i=0}^{k-1} \sin \left( \frac{2\pi}{k} x(v_i, 1) \right)
\]

(5)

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From this equation $t$ is refer to the tangent vector and is used to determine a normal. The normal is produced by the cross product of $t_1$ and $t_2$ and can be written as a weighted sum of vertices $x(v_i), x(v_i, l), i=l, l \neq i$.

The tangent along the surface at the boundary vertex is calculated by using equation (6).

$$t_{along} = x(v_{0,1}) - x(v_{k-1,1})$$

The equation (7) used to get the tangent across the boundary or the crease.

$$f_{2, k = 2, t_{across}} = x(v_{0,1}) + x(v_{1,1}) - 2x(v_0)$$

$$f_{2, k = 3, t_{across}} = x(v_{2,1}) - x(v_0)$$

$$f_{2, k \geq 4, t_{across}} = \sin \theta \left( x(v_{0,1}) + x(v_{k-1,1}) \right) + (2\cos \theta - 2) \sum_{i=1}^{k-2} \sin i \theta x(v_{i,1})$$

$$\theta = \pi / (k - 1)$$

The equation (7) is apply when the tangent plane continuous at the boundary.

Then we need to compute the limit position of control points for a fixed vertex by $\lim_{j \rightarrow \infty} v_j(v)$ where lim is refer to the limit position. Besides that, the mask to calculate the limit value for the interior vertices is shown in equation (8). For the boundary vertices, this is representing in equation (9) [18].

Where $\beta$ is replaced by $X = \frac{1}{3/(8\beta) + n}$

$$p_{\infty}(v_0) = \frac{1}{5} x(v_{0,1}) + \frac{2}{5} x(v_0) + \frac{1}{5} x(v_{1,k-1})$$

The algorithm to construct a Loop’s subdivision scheme is shown below:

```plaintext
Begin
   Read the input from 3d object.
   For each triangle
      First pass:
         Create new vertices at the midpoints of the edges of the triangle.
      Second Pass:
         Refine each triangle into 4 triangles by splitting each edge and connecting new vertices.
      Third Pass:
         Applied a Loop’s mask weather the vertices are average or refined.
   End For
End
```

4 CONCLUSION AND DISCUSSION

A subdivision surface is the technique that is capable of producing the smooth surfaces in the curve and surface modeling research area. Loop’s subdivision scheme is one of the approaches to provide a good smooth surface for 3D object in virtual environment. As a conclusion, we have highlighted the importance and the usage of Loop’s subdivision surfaces scheme in the surface fitting, multiresolution analysis and in the reconstruction application in our current paper.

We can apply this application to construct a good smooth surface for 3D object such as real in a virtual environment. In this paper, we also discussed about the general construction of loop’s scheme in a subdivision surfaces. Loops subdivision scheme cannot handle the verity of data input from 3D object. In spite of this matter, the researchers need to improve this scheme to produce a better representation of surface for 3D object. Therefore, for the future work, we will focus on how to combined Loop subdivision scheme with the butterfly scheme to subdivide the verity of 3D object in virtual environment. As an addition, we also want to improve the computation and the effectiveness of Loop’s subdivision.

REFERENCES


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