Improved Research for 3D Mesh Segmentation Based on Watershed Algorithm

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Abstract. Most of the 3D mesh segmentation method now is based on the curvature model. This unified error method leads to poor segmentation results. In order to solve the problem of “the unified error”, in this paper, we used the watershed algorithm. We used region growing algorithm to improve the segmentation of watershed algorithm and apply the ROI conception to achieve interest segmentation. In this method, without considering the smoothness of the split edge, the 3D mesh model can achieve their desired segmentation effect.

Introduction

With the development of virtual reality technology, three-dimensional model is gradually used in various fields. The development of 3D model technology and 3D model of automatic generation, it makes the model more accurate. This caused great challenge on the performance of the computer. Model simplification is becoming more and more important. Three-dimensional mesh segmentation technology is an important application of model simplification technology. It is proposed as early as the beginning of 90s of last century and be improved with the development of information technology. In this paper, we will improve the 3D model segmentation technique based on watershed algorithm and ROI and regional growth algorithm to achieve three-dimensional model of the segmentation.

ROI Concept, Watershed Algorithm and Regional Growth Algorithm

ROI Concept

In a practical application of the 3D mesh model, the user may only be interested in some areas of the mesh model and want a higher resolution of the area, while other areas may be as long as the visual requirements are met. But, most of the simplification algorithms simplify the whole model in uniform way, and rarely take into account the difference between interest domain and non-interest domain. This may result in a lot of non-interest domain and the details of the rich segment are not fully simplified, affecting the final simplification effect.

ROI coding technology is a JPEG2000 standard technology [2]. ROI coding technology is the main idea for the user's interest in the region of the image by low-pressure or loss less compression, while other regions using a higher compression method to achieve high-quality, low space occupancy mode. In the process of
simplifying the segmentation of the 3D mesh model, it is often necessary to reduce the area with high resolution requirement and simplify the model with lower resolution so as to not occupy the space of the model rendering, higher model quality. Therefore, it is necessary to introduce the ROI idea into the model segmentation.

**Watershed Algorithm**

The watershed algorithm was first proposed by Serro and applied to image processing. Vincent firstly extended this algorithm to the segmentation of 3D model mesh surfaces. Watershed algorithm is simulated flooding process of implementation: Assuming that the 3D mesh model is a 3D terrain map, the standard to measure the level of the ground point of the function definition with the proper height. Find out all the local minimum point in topographic map. From the beginning of the minimum point of immersion, the water gradually flooded the model basin. When the rising water from two different regions came together, built a dam at the intersection. This constitutes a watershed segmentation model.

**Regional Growth Algorithm**

Region generation algorithm is a kind of technology which can find out the similar triangle meshes, and merges them into a new region. Specifically, we need to find a seed point from one region, a similar point in the neighborhood, and judge them if the growth condition is satisfied. If so, merge the region connected with the seed point and then repeated the previous step, until does not meet the conditions of the seed points are included only to stop, so that an area is formed.

**Improvement of 3D Mesh Model Segmentation Algorithm for Watershed**

Watershed segmentation algorithm can fast realize the model, for example, Koschan [3] proposed a fast watershed algorithm. In the process of realization, it is very easy to set up a water-dividing line between every two adjacent minimum points, which leads to the phenomenon of over-segmentation, which affects the simplified quality of the model. This paper will introduce a regional growth algorithm to improve such problems.

We combine the regional growth algorithm and the watershed algorithm; segment the mesh model in this way. By means of topographical interpretation, when adjacent curvatures of two adjacent minimum points are less than a given threshold T, the dams are not built between the two reservoirs; they will merge into one region. When is greater than the given threshold T, casting a watershed. Use the method of regional growth has to select a good seed, the appropriate growth criteria and termination conditions. These three factors directly affect the effect of regional growth and the simplified quality of the model.

**Regional Growth of Seeds**

Triangular mesh model is a linear surface, it is composed of dots, edge, a combination of piecewise surface, therefore, we can use the vertex, or a triangle as the growth of the seed. In this paper, we use the vertex as a seed.

The process of the growing seed can be expressed as follows: Figure 1 (a), the vertex \( V_1 \) is a regional seed growing seed vertex, then all triangles with vertex \( V_1 \) is a part of the growth area. Then judge any vertex \( V_i \) and the adjacent vertex \( V_1 \) whether or not satisfies the growth conditions. If satisfied, then it will be \( V_i \) for the vertex, continue to grow. The the new region merged with \( V_1 \) region.
The initial seed selection determines the shape of the region growth. The method adopted in this paper is to select the vertex with the maximum of the vertex curvature as the initial seed without segmentation. This method can make all the details of the region (edges, wrinkles, etc.) are in accordance with the vertex of the local feature degree size has entered the extended region, in order to reduce these areas, appear in the split edge. The traditional method of the curvature of the vertex is computed by the binary derivative. It can only be considered approximate valuation of constant curvature to get somewhere. We use the method proposed by Liu Yang Jia [1], and use the vertex feature degree as an approximate estimate of the curvature of the point. This approximation reflects the unevenness of the location of the grid model. The vertex local feature degree is defined as follows:

\[
U_{v_0} = \sum_{i=1}^{m} (1 - n_{v_0} \cdot n_{t_i})
\]

\(U_{v_0}\) is the local characteristic degree of the mesh model at vertex \(V_0\). \(N_{v_0}\) is the unit normal vector of vertex \(V_0\). \(N_{t_i}\) is the unit normal vector of the triangular patches \(T_i\) associated with the vertex \(V_0\). The normal of the vertex unit normal and the associated triangles belong to the same side of the model. \(M\) is the total number of triangular facets of vertex \(v_0\). The unit normal vector \(n_{t_i}\) of the \(i\) associated triangle is given by:

\[
n_{t_i} = \frac{(v_i - v_0) \cdot (v_{(i + 1) \mod m} - v_0)}{\| (v_i - v_0) \cdot (v_{(i + 1) \mod m} - v_0) \|}
\]

The unit normal vector \(V_0\) of the vertex \(v_{v_0}\) is calculated as follows:

\[
n_{v_0} = \sum_{i=1}^{m} \frac{n_{t_i}}{\sum_{i=1}^{m} n_{t_i}}
\]

It can be obtained from the above three formulas to calculate the value of the local features \(U_{v_0}\) of the vertex \(V_0\).

**Growth Criteria**

The growth criterion was defined as the local characteristic degree of the fixed point, and the characteristic degree was used as the criterion of regional growth. Growth of the region to meet the conditions to determine, otherwise the termination of growth. If the local characteristic degree of the vertex \(V_i\) and the vertex \(V_i\) satisfies the growth of a certain threshold, the adjacent triangles of \(V_i\) can be extended into the region. The growth criteria are defined as:
Where $R_i$ and $R_l$ denote the local characteristic degrees of $R_i$ and $R_l$ respectively, $R_{thod}$ is the growth threshold, and its size is chosen according to the actual situation. For the region called smoothed, the value is smaller and more complex.

**ROI-Based Watershed 3D Mesh Model Segmentation Algorithm**

$S = \{s_1, s_2, \ldots, s_n\}$ is a set of points that are uniquely marked. The minimum value of the vertex characteristic degree is $V_{min}$. The maximum is $V_{max}$. The determined threshold is $R_{thod}$. The detailed fusion algorithm is described as follows:

The water flow first reaches the minimum point $SV_{mi}$ of the vertex characteristic degree in the set $S$. We mark such points as $SM_i$ ($i = 1, 2, \ldots, n$). $N$ is the number of points with the feature value $SV_{min}$. We use $SM_i$ as the seed point for regional growth, after growing through the region, the point $SM_i$ corresponding to the region.

Where: $CB$ water basin; each point $v$ in $CB_T (Mi)$ is grown as a seed point, and the growth rule is the same as the above method until there is no point position satisfying the growing condition. Assuming a total of $N$ seed points for regional growth, $V_{min}$ corresponding to the basin is:

$$CB_r (h_{min}) = U_{i=1}^{N} CB_T (SM_i)$$

According to the above formula, we can get $SV_n$ corresponding to the basin. Will increase the current degree of character value 1, recorded as $SV$, then $SV=SV_{min}+1$. Repeat the above steps until $SV = SV_{max}$. We calculated all the basin, and use the edge of the basin as a watershed. When all special mark points are divided, calculate the common minimum vertex characteristic value $V_{min}$, and repeat the above steps until the whole model is divided.

**Experimental Results and Analysis**

Experimental environment: CPU Intel (R) Core (TM) i7-4790, memory 8G, code-writing environment for the Windows 7 system VS2015 and OpenGL. Some experimental results of the algorithm are shown in the following figure:

![Figure 2. Horse’s model before, the unified error segmentation method and the improved watershed algorithm segmentation comparison chart.](image)

The three pictures in Figure 2 are shown: the original model, the unified error segmentation method model and the improved watershed algorithm segmentation method model. It is clearly known that the second picture’s split area is general; there is no specific detail of the horse (eyes, mouth, ears, etc.). In the last image, the three colors are divided: red, high-resolution areas that are special markers, green, more details of the region, blue, low-resolution area. From the experimental results, it can be seen that the user-marked area can be segmented in the segmentation domain of the model, and the complicated parts of the non-interest domain can be segmented and the 3D mesh segmentation is realized.
Conclusions

In this paper, we are proposed an ROI-based 3D mesh model segmentation algorithm. This algorithm improves the watershed algorithm by introducing the region growing algorithm. At the same time, the user interest domain is taken as the first condition of region segmentation. Using the local feature threshold as the criterion of regional growth criterion. The grid model is segmented. However, in this algorithm, the problem of segmentation boundary is not taken into account, and the boundary of the segmentation is not uniform. In the future research and study on the details of the boundary segmentation and segmentation to do to improve, and finally achieve the satisfactory segmentation results.

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References


