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3D Model Retrieval Method Based on Sample Prediction

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Abstract. This paper presents a novel method for 3D model retrieval combining the content-based retrieval and the text-based retrieval. Algorithm merges the content-based retrieval and the text-based retrieval through the sample library. The user only need to enter a keyword and the algorithm will search the 3D models with a keyword in the database. It will automatically select the sample for the user to retrieve the 3D models without any keyword. Experimental results demonstrated the efficiency and performance of the proposal algorithm.

Keyword: sample library, 3D model retrieval, content-based retrieval

1. Introduction

With the development of the 3D modeling methods and graphics hardware technology, the number of 3D model is increasing rapidly. The key question of 3D model retrieval is how to find required models quickly, completely and accurately.

The original three-dimensional model retrieval method is based on the text retrieval of three-dimensional model. This search method usually needs one or more keywords describing contents of a 3D model and then we can get the required models through the keyword search technology, which is a simple and easy method to use. However, the characteristics of a 3D model are rich in content and low in abstraction, which therefore are difficult to be fully described with a few key words in many cases. With the increasing number of 3D models, it is almost impossible to make the artificial keywords for each three-dimensional model. The content-based retrieval came into being.

The 3D mode retrieval based on content uses the features of a 3D model including the shape, appearance, skeleton and other basic visual feature. By extracting and matching the characteristics of 3D models, we can identify the similarity among them. The biggest advantage of content-based retrieval is that the approach has objectivity. However, the current retrieval system based on content requires the user to provide a sample or hand-drawn sample, which will lead to the inconvenience to the user. And when a sample or hand-painted sample the user provides is inaccurate, the search efficiency will reduce greatly..

In this paper, we integrated the advantages of the two retrieval methods, combining the two methods by sample database.

2. The Three-dimensional Model Search Algorithm based on Sample Database

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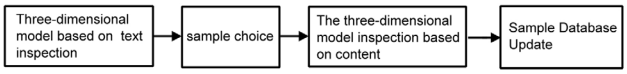
In this section, a noel algorithm is proposed to retrieve 3D models from model database. Our approach falls into the boundary-based category. The following shows the diagram for this approach.



After the user enters the keyword, firstly retrieve models with keywords. Next, a sample is selected from the sample library according to the keyword entered by the user and then models without any keywords are retrieved based on the content. Finally update the sample database according to users' choice.

2.1. The 3D Model Retrieval based on the Text

Model files in the database are traversed and the filename of every model is taken out which is the keyword of the model.

Match the query keyword entered by user to the keyword of every model, and then put the successful model in the result model library.

2.2. Sample Selection

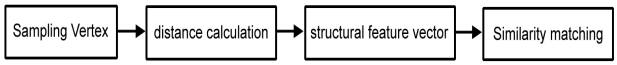
a) Look through all the samples in the sample database and take out the keywords of each sample.

b) Match the query keyword entered by users to the keywords of the sample.

c) If there is any successful matched model, then use the model as a sample for retrieval based on the content. If there is no matched model, the algorithm will select the first model from the result model library of 2.1 as the sample of content-based retrieval.

2.3. The Three-dimensional Model Retrieval based on Content

This paper presents a 3D retrieval algorithm based on the centric distance distribution in this experiment. Basic idea of this algorithm is as follows:



Sampling vertices: we use halton sequence [1] to sample 1024 points in accordance with the principle of equal area [2].

First, for each triangle, we compute its area:

$$\triangle ABC = \sqrt{S^*(S-a)^*(S-b)^*(S-c)}$$

$$S = (a+b+c)/2$$

a, b, c is the length of each edge of a triangle,

Store the area of each triangle in a cumulative array along with the order computed, and then the dimension of this array is the number of model triangular facets.

Generate 1024 random numbers ranking from 0 to the total cumulative area according to the principle of halton.

Randomly select an integer m and choose an integer t less than m. and then the 1024 random numbers are generated by the following rules:

M is expressed as a polynomial t:

$$m = \sum_{i=0}^{n} a_n t^n$$

Use the coefficient series to obtain the random number :

$$m_{Random} = \sum_{i=0}^{n} a_n t^{-(n+1)}$$

Order m=m+1 and repeat ① until the 1024random number is obtained.

Perform a binary search on the array of cumulative areas until we find the reference number of the triangle facets corresponding to the index number, so, you can find a triangular patch is proportional to the probability of its area.

For each selected triangle with vertices (A, B, C), we construct a point on its surface by generating two random numbers, r_1 and r_2, between 0 and 1, and evaluating the following equation:

$$P = \left(1-\sqrt{r_1}\right)A + \sqrt{r_1}\left(1-\sqrt{r_2}\right)B + \sqrt{r_1}r_2 C \text{ 。}$$

This algorithm is taken to ensure that the final series of vertices in accordance with the principle of equal area are distributed in the model surface evenly. According to Princeton University, we randomly select 1024 vertices.

Distance calculation: calculated the distances from any point of 1024 sampling points to the center of the model.

The center of a model is calculated as follows:

$$P = \frac{1}{n}\sum_{i=1}^{n} P_i$$

P means the center-of-mass coordinate; n means the number of model vertices.

Calculate the distance from each sampling point to P :

$d_i = \sqrt{(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2}$ $P\left(x_i, y_i, z_i\right)$ is the coordinate of the ith vertex and $p(x,y,z)$ is the centric coordinate of the model..

Construct the feature vector of the model as follows:

If there is

$$d_{\max} = \max\{d_i\}$$

$$d_{\min} = \min\{d_i\}$$

Divide $\left[d_{\min}, d_{\max}\right]$ into some subintervals, and the interval of each interval is d:

$$d = \frac{d_{\max} - d_{\min}}{10}$$

Calculate the percentage according to the distances in each subinterval as the feature vector of the model.

3. The similarity measure:

Set the feature vector of any two models can be expressed as:

$$X = \left(x_1, x_2, \ldots, x_n\right), \quad Y = \left(y_1, y_2, \ldots, y_n\right)$$

Using distance [3] of Minkowski to measure the similarity between two models:

$$D(X,Y) = \left(\sum_{i=1}^{n} |x_i - y_i|^r\right)^{\frac{1}{r}} \qquad r = 1, 2, \ldots, \infty$$

3.1. Update of Sample Database

Sample library is set before retrieval. Two problems will appear in the process of the sample library prediction.

Firstly, the forecasting sample is not the user's expectation. To solve the problem, the system is completed on the first search, and we provide the second search interface for users, through which user can select a sample from the result model library to retrieve for the second according their need.

Secondly, the sample database is not complete; the sample database does not contain the samples of all types of 3D model. As for this problem, when selecting the sample, if there is not any sample in the sample library, the proposed algorithm will choose the model in the result model library as the sample for content-based retrieval.

After the user selects a model from the result model library, our approach will put this model into the sample library to update and supplement the sample library.

4. Experiment

According to the proposed algorithm, we use java language to develop a 3D model retrieval system in Windows platform. When a user enters a keyword for retrieval, the system will retrieve the models that match to the keyword, and then automatically select the sample for the user to retrieve the similar models to the sample The standard test database [4 provided by shape analysis group of Princeton University, containing 907 models, is used.

Calculate separately the recall ratio and precision for each part, Table 1 is created. The definition formula [5] for searching the recall ratio r and checking precision ratio s is as follows:

$$r = \frac{R_d}{R_d + R_m}$$

$$s = \frac{R_d}{R_d + R_f}$$

Among them, Rm = being not searched and it is related, Rd = searching and it is related, Rf = searched but it is relevant.

search key	average recall ratio	average checking accuracy rate
human body	73.2%	80.0%
house	75.8%	75.0%
carriage wheel	84.6%	85.0%
flower	71.0%	70.0%

Table 1: The recall ratio and checking accuracy rate in experiment

The experimental results show that the combination of text-based and content-based retrieval not only provides the users with the convenience, but the retrieval efficiency also increases significantly.

5. Conclusion

This paper presents a novel algorithm for 3D model retrieval based on the sample prediction. Pre-setting sample in the sample database, the user only need to enter a keyword, the algorithm will automatically select the sample from the sample database. Comparing with existing algorithms, the experimental results show that the recall ratio and checking accuracy rate of our algorithm are improved significantly.

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