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A Calibration Template Method Based on Statistical Distribution

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Abstract

For improving automation calibration precision of multiple view texture collection in texture reconstruction, in this paper a new kind of calibration template using statistical distribution of surface texture is proposed. Firstly, there is a normalization processing be made according to statistical distribution of texture feature, such as species of color, quantity of geometric pattern and bump texture, etc. for the division of viewpoint. Then, the camera views of calibration template are assigned by using the normalization data with the calibration algorithm. Finally, the algorithm analysis is made by viewpoint division of four cases and the accuracy of our method can improve more than 10 percent. The experimental results show that, the proposed new calibration template method can better improve precision of 2D-3D registration and texture accuracy of reconstruction model than the uniform calibration template, while no obviously increasing the amount of calculation.

Keywords: *three-dimensional texture reconstruction, camera calibration, statistical distribution, perspective projection*

1. Introduction

Texture is an important feature to distinguish objects, so surface texture reconstruction is an important part in the research of graphics. There is the research of surface reconstruction in SIGGRAPH 2014, such as without mesh real time surface reconstruction [1], the continuous projection reconstruction [2], and the real sense floating surface reconstruction [3], *etc.* Artec spider scanner is a color scanner that suitable for middle and small objects, but the scanning effect depends on its operator. Texture effects of scanning mode are restricted by scanners, operators and other factors, and have larger difference with texture effects of real objects, so it is necessary to do further texture mapping.

Traditional texture mapping is realized by 2D texture that makes coverage for geometric model with some algorithm. It improves the sense of reality and simulates texture details of object surface, but it cannot satisfy 3D texture reconstruction of object surface and has limits in application [4]. For texture reconstruction of real object, multiple angle texture image sequences based on real shoot adding surface texture to real geometric model of object, that names 3D real object texture reconstruction, which emerges as a new technology, and receives extensive attention and becomes a research hotspot in recent years [5-6].

The literature [7] points out two main steps to obtain texture of real objects: (1) registration that refers to the fitting between camera image and 3D information in the same coordinate system; (2) texture calculation that refers to the representation and optimization of perspective projection from 2D texture to 3D texture. There are two main methods of registration techniques as point feature method [8] and line feature method [9-10]. The literature [11] has concretely studied two techniques: 3D-2D feature point matching and silhouette line matching, and designed calibration template to improve the

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precision and speed of registration for the key problem of camera calibration [12]. According to the literature [13], aiming at texture mapping problem of 3D model of cultural relics, it puts forward an interactive method for optimization from the mathematical point of camera calibration.

However, the calibration method in texture acquisition still has limits. It uses a single acquisition and calibration method and doesn't have a surface texture acquisition strategy for the process of digitization protection of different cultural relics. This paper studies that considering the specific texture distribution of cultural relics' surface and according to the two texture features: color and geometric pattern, to make a quantization for texture distribution data. On this basis, this paper puts forward the non-uniform texture acquisition and calibration method.

2. The Calibration Algorithm of Statistical Distribution

2.1. Statistical Distribution Method

The surface texture of the real model is not uniform distribution, so the distribution of two or more important texture features are considered, and a reasonable allocation of the viewpoint is given, so as to save resources and improve the accuracy of the acquisition. The most typical evenly distributed object is person model such as the Tang Tricolor, Terra Cotta Warriors, and do on. It commonly has abundant texture information in the front, while relatively has simplex texture in the back. In order to reflect the accuracy in the process of acquisition, we should set more shooting viewpoints in the front, and reduce shooting viewpoints in the back. Multi view texture acquisition environment is shown in Figure 1.

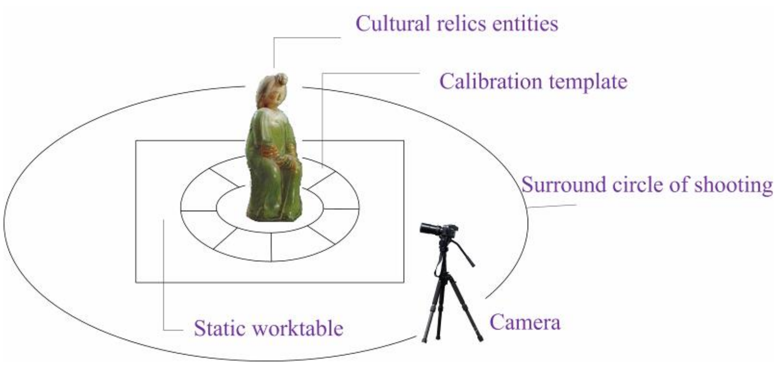

Figure 1. Environment of Texture Acquisition

Based on the above considerations, a statistical distribution calibration template is proposed by this paper, utilizing the heterogeneity to make a quantization for texture feature. To set the number of surface color of collected object as TN1, the types of geometric pattern as TN2, other number of texture features as TN3, TN4, *etc.* And the number of initial viewpoints of calibration template as $n=4$. According to $\mathrm{TN1}_{n_i}$, $\mathrm{TN2}_{n_i}$, $\mathrm{TN3}_{n_i}$, $\mathrm{TN4}_{n_i}$, $\cdots$ of each viewpoint, the normalized parameters TN_{n_i} of texture is calculated as:

$$\mathrm{TN}_{n_i}=\frac{\mathrm{TN1}_{n_i}}{\mathrm{TN1}}+\frac{\mathrm{TN2}_{n_i}}{\mathrm{TN2}}+\frac{\mathrm{TN3}_{n_i}}{\mathrm{TN3}}+\frac{\mathrm{TN4}_{n_i}}{\mathrm{TN4}}\cdots \tag{1}$$

The initial value: TN1, TN2, TN3,$\cdots$, $n=4$, and the algorithm flow chart is shown in Figure 2.

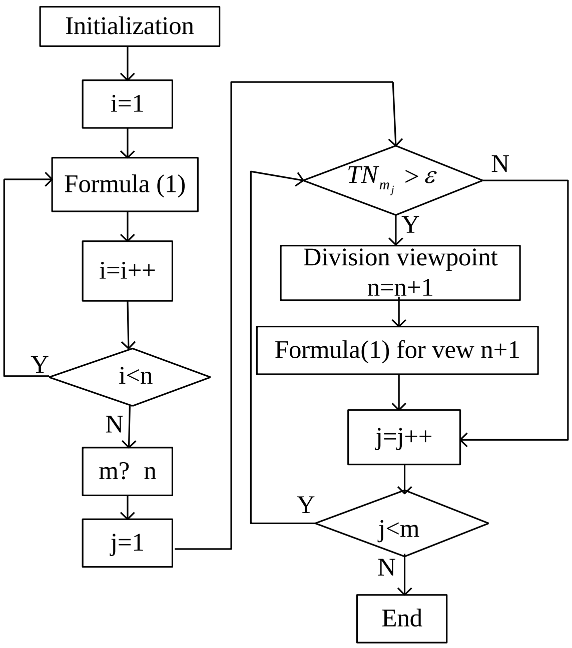

Figure 2. Algorithm Flow Chart of Statistical Distribution Calibration

In which n is get by making a looping execution for the above contents until $TN_{m_j} \le \varepsilon$ and n is certainly no longer changing. 'n' is the number of viewpoints of the final calibration template obtained by camera. Generally speaking, due to more texture information in the front of figure, the calculated normalized parameter of texture is bigger and has more viewpoint distribution; the back of figure is on the contrary.

2.2. Algorithm Analysis

Here, we set n=3, 6, 7, and 8 as examples for analyzing and comparing differences between the method proposed by this paper and the uniform calibration, as shown in Figure 3. The analysis includes two aspects: accuracy and time complexity. In Figure 3, the upper side of lateral axis expresses the back surface with less texture information; the lower side shows the front surface with more texture information. Uniformity calibration separately uses n/2 viewpoints to make an acquisition for the back surface and the front surface. The method proposed by this paper respectively adopts 1, 2, 3, 3 viewpoints to make an acquisition for the back surface, and adopts 2, 4, 4, 5 viewpoints to make an acquisition for the front surface. Viewpoint 1, 5 are in the boundary line of the front and back, according to each of the 0.5 points for each view. When doing virtual display, the information in the front can decide the effect in a greater degree, so the accuracy of this method can improve more than 10 percent. For time complexity, this method increases the algorithm calculation of Formula (1), because n is a limited value, so this part has little effect for computation costs.

To sum up, the algorithm of statistical distribution calibration based on texture distribution feature can improve the precision of texture acquisition without obviously increasing the time complexity.

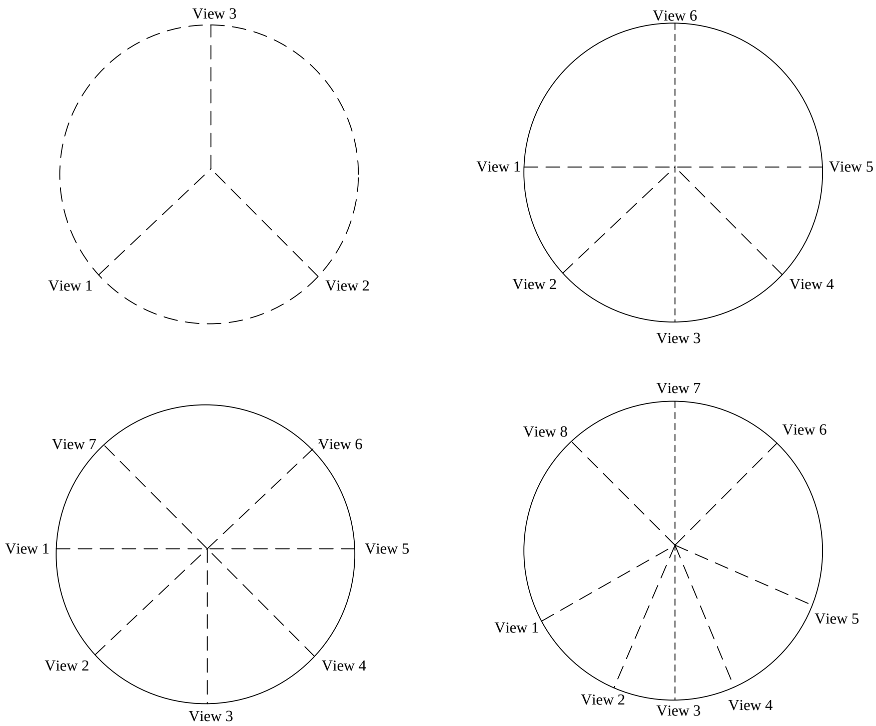

Figure 3. The Viewpoint Division for Different Views

4. Experiments

Texture data acquisition should comply with the following constraints: (1) uniform light; (2) invariant condition of light; (3) unchanged camera parameters, and keeping the distance of objects unchanged; (4) the same post-processing. The experimental geometry model is obtained by 3D scanner named Artec spider, the texture photographs is taken under the condition of the fixed internal references by a camera with 13000000 pixel and F2.4 aperture. The calculation of perspective mapping is finished by Matlab7.0, finally the texture mapping is completed by Open GL.

4.1. Experimental Data

According to the method proposed in this paper, to make texture data acquisition, shown in Figure 4.

For bear, TN1 is set as 8, TN2 is set as 4. For kneel terracotta warrior, TN1 is set as 2, TN2 is set as 5, TN3 is set as 3.The distinguishing property of color texture information for bear model is stronger, comparatively speaking to geometry information. The distinguishing property of geometry texture information for kneel terracotta warrior model is stronger, comparatively speaking to color information. The viewpoints of two models are shown in Figure 5, based on algorithm flow of statistical distribution calibration.

Figure 4. Texture Data Acquisition Based on Statistical Distribution of Texture

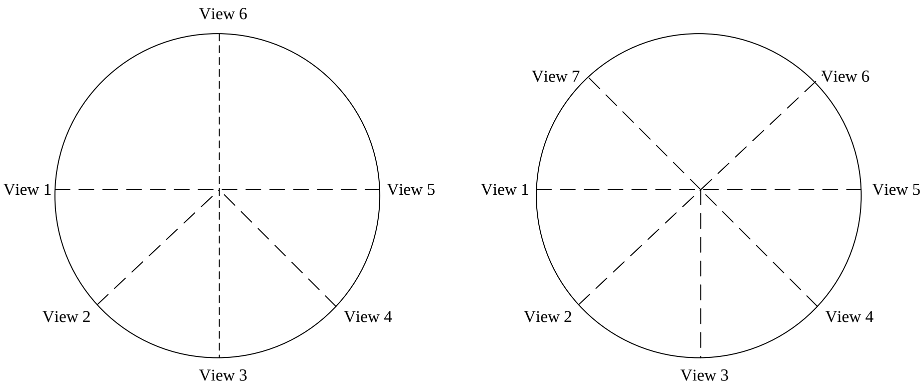

Figure 5. The Viewpoints for Two Models

4.2. Experiments Results

Based on the above data, realize texture mapping of real photo based on the method proposed in this paper for the real object. Its experimental results compared with texture reconstruction results of scanners and texture reconstruction results of uniform calibration algorithm are shown in Figure 6.

Figure 6. Reconstruction Comparison of Three Kinds of Texture

Figure 7. Effects of Statistical Distribution Reconstruction with Each Angle and Unwrap Map 1

Figure 8. Effects of Statistical Distribution Reconstruction with Each Angle and Unwrap Map 2

Four bear images of Figure 6, separately is the surface reconstruction model of original mode, scanner, uniform texture and non-uniform texture. Figure 7, shows that this proposed method has more detailed reconstruction effects based on improving scanner texture, especially in the leg joint of model, and has no obvious computing costs, compared with uniform calibration algorithm. Light model of uniform texture is not better regulated, temporarily not be considered. And Figure 8, is Effects of statistical distribution reconstruction with each angle for kneel terracotta warrior model.

Table 1. Accuracy Comparison for Statistical Distribution of Bear

Viewpoint number n	Traditional method		Statistical distribution method		Accuracy increase (%)
	Positive view points 1	Back view points 1	Positive view points 2	Back view points 2	
6	3.0	3.0	4.0	2.0	17
8	4.0	4.0	5.0	3.0	13
10	5.0	5.0	6.5	3.5	15
12	6.0	6.0	8.0	4.0	17

Table 2. Accuracy Comparison for Statistical Distribution of Kneel Terracotta Warrior

Viewpoint number n	Traditional method		Statistical distribution method		Accuracy increase (%)
	Positive view points 1	Back view points 1	Positive view points 2	Back view points 2	
5	2.5	2.5	3.0	2.0	10
7	3.5	3.5	4.0	3.0	7
9	4.5	4.5	5.5	3.5	11
11	5.5	5.5	7.0	4.0	14

5. Conclusion and Future Work

We have introduced a novel calibration template method which applies the features of statistical distribution of surface textures. We showed how to divide the viewpoint by Formula (1) and the calibration algorithm of statistical distribution. Through analysis of the algorithm and texture acquisition experiments for two models in reconstruction, the advantage of the algorithm in multi view data acquisition is proved more than 10 percent for surface texture reconstruction. In multi view texture, there is discontinuous problem between images. In the future, we want to find more rules for discontinuous characteristic in the joints of multiple angle texture images

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