Making Kabuki Face

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This paper introduces our work on making use of Computer Graphics technology to preserve Japanese ancient art: Kabuki. The purpose of our project is to reconstruct realistic 3D face model of ancient Kabuki player. To achieve this, we design a pipeline: 3D data scanning, texture mapping, mesh deformation and facial animation. After defining corresponding feature points, we can solve texture mapping problem as an optimization or an interpolation problem. Two texture mapping methods, Conjugate Gradient optimization and Radial Basis Function, are presented in this paper. Experimental results show that we can solve texture mapping problem efficiently. Finally, we analyze and compare the results from these two methods.

Keywords: Computer Graphics, Texture Mapping, KABUKI, Face Animation, Radial Basis Function

1. Introduction

Kabuki is a traditional form of Japanese theater. It was founded early in the 17th century, and over next 300 years developed into a sophisticated, highly stylized form of theater. There are abundant culture legacies to describe the long history of this outstanding art, such as beautiful pictures of Kabuki dance and Kabuki makeup, statues of famous Kabuki player, and so on. However, they are all traditional methods and lack of interactivity: One can only view the static pictures or the statues.

The aim of our project is to make use of such legacies to reconstruct and animate Kabuki face in computer by means of Computer Graphics (CG) and Computer Vision (CV) technique. The advantages are obvious. Firstly, by using CG and CV techniques, the traditional media can be converted into digital media, and digital media is more suitable to preserve culture legacies because it will not decay or be etched. Secondly, it is easier to distribute digital media via computer network. Thirdly, through animation techniques, it can provide interactivity for people and make more interesting demonstration of this ancient art.

The rest of this paper is organized as follows. Section 2 introduces the basic flowchart of our project. Section 3 shows the related work. Section 4 describes Texture Mapping work on reconstructing 3D model of Kabuki face and section 5 introduces the future work that need be done.

2. Basic Idea

A lot of CG and CV techniques can be used to reconstruct and animate Kabuki face in computer, but we need to make choice according to the situation of out project. Figure 1 illustrates the basic procedure designed for our project.

Since we want to animate Kabuki face to mimic different Kabuki expressions, a 3D model of Kabuki face is needed. As mentioned in the previous section, what we have in hand is the pictures of Kabuki face and one statue of famous Kabuki player. So we plan to use 3D scanner to get the range data of the statue and adopt a technique in [1] to generate the 3D mesh. To reconstruct the Kabuki face realistically, we need to map Kabuki face to the 3D mesh. This also enables us to generate various kinds of makeup face by using different face textures. The final step is to animate the 3D mesh to mimic various expressions in Kabuki. Many face animation techniques can be adopted to achieve this goal [2, 3, 4, 5].

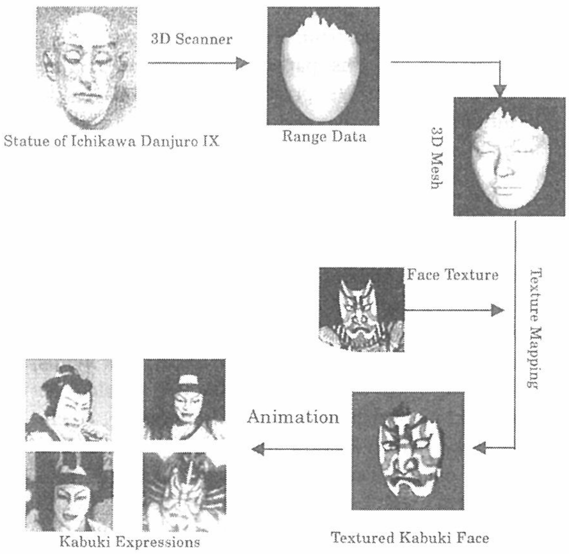


Figure 1 Project flowchart

3. Related Work

Our research can be categorized into Virtual Heritage, which is a relatively new research topic. The research content of Virtual Heritage usually includes color restoration, 3D modeling, style learning, content based retrieval, and so on. The purpose of color restoration is to recover damaged color of ancient pictures and wall paintings. Researchers have presented several methods to restore the color, such as knowledge-based approaches [6, 7] and inpainting method [8]. There are also many researches on 3D Modeling and Content based Retrieval [6, 9].

Our research focuses on reconstructing and animating realistic 3D face model of ancient Kabuki player, so it is highly related to face modeling and facial animation in Computer Graphics. After Parke presented his first research result on face modeling based on two orthogonal views of face [10], face modeling experienced great improvements. Realistic face modeling considers both the recovery of 3D face model and face textures. Automatic feature mapping, Radial Basis Functions are applied to face modeling to improve the efficiency and reality of the face model [4, 11]. Recently, Statistical methods also find their application in Face modeling [12]. Ref [13] proposed a constrained Texture Mapping algorithm to map texture to Face Model. It considered similarity and smooth term altogether and achieved good result.

The difficulty in modeling 3D ancient Kabuki player face is that there are only ancient pictures or some statues to describe face of Kabuki players. Thus, the popular methods in computer vision and Computer Graphics to do face modeling cannot be applied to our case directly, since they usually need photographs of face from different viewpoints or a face database. In this paper, we focus on texture mapping problem. We present two methods to do Texture Mapping and experimental Results show that our methods are very efficient.

4. Mapping Kabuki Makeup to 3D Face Model

We have finished experiments on mapping Kabuki makeup to 3D mesh. It is well known that 2D texture mapping problem in CG can be viewed as a parameterization of arbitrary 3D mesh. In other words, a mapping $M:(x,y,z)\rightarrow(u,v)$ should be computed to finish this task. Fortunately, there already exists such kind of mapping from the nature of range data, because range data is defined on a regular grid, which can be naturally treated as 2D parameterization of 3D mesh. This can be written as following:

$$P = R(x,y) \qquad (1)$$

Where P is the 3D position, R is a vectored valued function and (x,y) is the coordinate of grid points.

However, the (x,y) above represents grid point and is not in texture space. To generate texture coordinate (u,v) for each 3D point, we need another mapping from (x,y) to (u,v). After defining some corresponding feature points, we successfully convert this problem into an optimization or an interpolation problem.

4.1 Optimization Method

Let (R_i, T_i) denote one pair of correspondence feature points, where R_i is the coordinate (x,y) in range grid and T_i is the coordinate in texture space. The objective function of optimization can be written as:

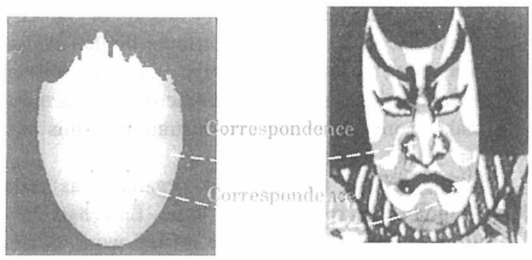
$$O(x_t, y_t) = \sum_i \left(\frac{x_t - T_i^x}{\sqrt{(x_t - T_i^x)^2 + (y_t - T_i^y)^2}} - a_i \right)^2 + \sum_i \left(\frac{y_t - T_i^y}{\sqrt{(x_t - T_i^x)^2 + (y_t - T_i^y)^2}} - b_i \right)^2 \qquad (2)$$

where:

$$a_i = \frac{x_r - R_i^x}{\sqrt{(x_r - R_i^x)^2 + (y_r - R_i^y)^2}}$$

$$b_i = \frac{y_r - R_i^y}{\sqrt{(x_r - R_i^x)^2 + (y_r - R_i^y)^2}}$$

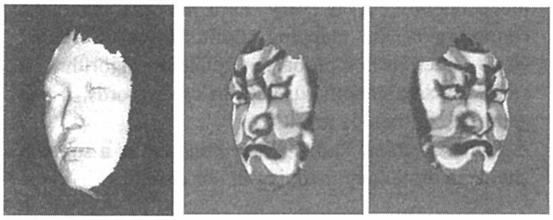
This means to find coordinate (x_t, y_t) in texture space to minimize the objective function $O(x_t, y_t)$ after given grid point (x_r, y_r).



Range Data | Kabuki Face Texture

Figure 2 Defining feature points

Conjugate gradient algorithm can be used to solve this optimization problem [14]. After carefully selecting initial values, the function can be solved quite well. The feature points are manually defined according to the feature of face. Figure 2 shows the defined feature points. Figure 3 shows the experimental results.



Face Mesh Side View of Textured Mesh

Figure 3 Texture mapping results

4.2 Radial Basis Function

After defining the corresponding feature points, the texture mapping problem can also be viewed as a scattered data interpolation problem. There are many scattered interpolation algorithms, such as Shepard interpolation, Radial Basis Function (RBF), Laplace/Poisson interpolation and so on [15]. Since RBF can construct smooth surface and it is suitable to nondense scattered data interpolation. In our case, we don't want user to define too many feature points, so we choose RBF as our interpolation algorithm.

The definition of RBF is the following:

$$y = \sum_i w_i h_i(x) \tag{3}$$

where w_i is weight coefficient and h_i is the kernel function. The kernel function is usually determined by a center c_i and radius r. When distance from center exceeds the radius r, the value of the kernel function will approach to zero very fast. So, the kernel function is Gaussian-like function.

Given known pairs: (x_i, y_i) $i = 0,1,2,\ldots,n-1$, we need to compute coefficients w_i to construct a RBF network so that the following least square function is minimum:

$$g = \sum_i \left(y_i - \sum_j w_j h_j(x_i) \right)^2 \tag{4}$$

In theory of RBF, We rewrite the Eq.(4) into Eq. (5) to guarantee the smooth of interpolated curve or surface:

$$g = \sum_i \left(y_i - \sum_j w_j h_j(x_i) \right)^2 + \lambda \sum_i w_j \tag{5}$$

Taking derivative to w_i, We get:

$$\left(\mathbf{H}^T\mathbf{H} + \lambda\mathbf{I}\right)\mathbf{w} = \mathbf{H}^T\mathbf{y} \tag{6}$$

where $H_{ij} = h_j(x_i)$ and $\mathbf{w}, \mathbf{y}$ are column vectors which contain w_i and y_i respectively.

To select a good parameter λ, we adopt Global-Ridge algorithm introduced in [15] and Generalized cross-validation in [16] as error criteria. Please refer to [15, 16] for details. In our case, we construct two RBF networks for u, v texture coordinates respectively.

Figure 4 illustrates the feature points defined for RBF interpolation. Please notice that we need to define more feature points and the corresponding feature points that determine the area of interpolation are absolutely necessary in RBF interpolation.

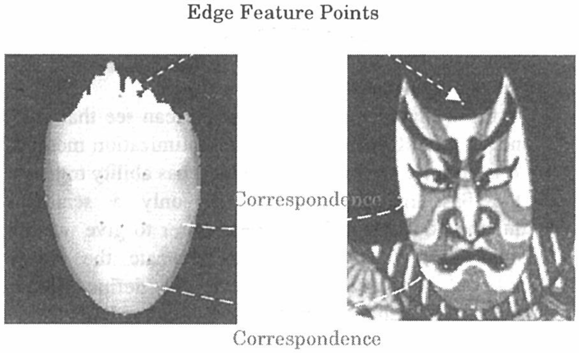


Figure 4 Feature points in RBF

Figure 5 shows the mapping result of same Kabuki Face in optimization algorithm. Figure 6 and 7 gives the result of mapping a make-up of Danjuro Eighth to the 3D Face Model.

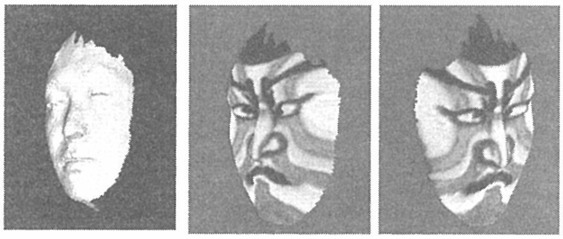


Figure 5 RBF mapping result

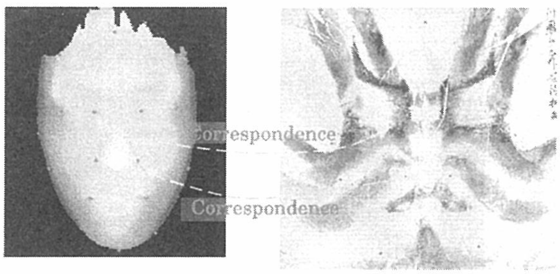


Figure 6 Feature points for make-up of Danjuro eighth

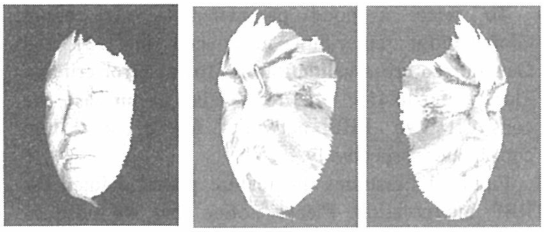


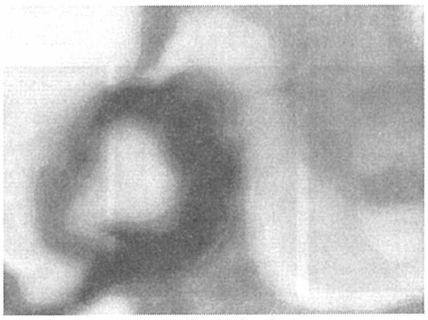
Figure 7 Mapping result of make-up of Danjuro eighth

4.3 Analysis of Result

It is necessary to analyze the results from two methods mentioned above. We will compare the results in two sides: the number of feature points and the continuity of the result.

From Figure 2 and Figure 4, we can see that RBF needs more feature points than Optimization method. It is because Optimization method has ability to guess the best match, but RBF is only a scattered interpolation algorithm, it needs user to give out the controlling feature points to estimate the whole interpolation area. That is why we define feature points at the edge of interpolation area for RBF.

However, RBF can achieve a better quality of mapping, in other words, it can generate continuous result. Figure 8 illustrates this fact. There is obvious incontinuity in the result of Optimization method. RBF can achieve better result.



a. Optimization

b. RBF

Figure 8 Analysis of result

It is not strange that we get this result. Since our optimization method solve every range grid point independently, it is very hard to guarantee the continuity of the mapping result. However, Radial Basis Function is a global interpolation algorithm. It can construct smooth surface. In other words, it can generate continuous result.

Thus, we think Radial Basis Function is a suitable choice to do texture mapping in our case.

5. Future Work

There are still a lot of works ahead to accomplish the flowchart illustrated in Figure 1. We conclude them in the following aspects:

Mesh deforming: Although we can get specific 3D mesh from range data, it is not enough, because we want to reconstruct face of different Kabuki player, and it is impossible to get face range data of every Kabuki player. Thus mesh-deforming technique is necessary to adapt one specific 3D mesh to different Kabuki players. We plan to deform mesh according to the pictures of the face of Kabuki player.

Facial animation: It is used to simulate Kabuki expressions. Parameterized facial model should be constructed from face range data. As to the animation model, physics based muscle model or Pseudo muscle model will be considered, and it is better to make our animation conform to the recent MPEG-4 Face animation standard.

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