文化財の3次元物体モデリングとビジュアライゼーションプロジェクト

古めかしい歌舞伎演劇者の顔面の3Dモデルの構築

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概要 本研究では、三百年前の歌舞伎演劇者の顔面のモデルを構築し、そのモデルに隈取をマッピングしたコンピューターグラフィクスのテクニックである。顔面のモデルの構築の困難は歌舞伎演劇者の絵の不足である。この制限を越えるため、本研究で、歌舞伎の古絵から推測された3D幾何学に基づいて、MPEG-4アニメーション標準と互換性がある顔面のモデルを変形させる。変形とテクスチャマッピングのアルゴリズムは、RBF（Radial Basis Function）を利用する。同時に滑らかさと精度を得るために、パラメタの調整に基づく多層のRBFの方法を提示する。提案した方法は、変形とテクスチャマッピングの問題をよく解決できる。

Three-dimensional object modeling and visualization of cultural heritages project

Construction of 3D Face Models of Ancient Kabuki Players

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Abstract: We will present our research work on applying Computer Graphics technique to reconstruct 3D face model of ancient Kabuki players who were three hundreds years ago and map special Kabuki face make-up style to the 3D face to demonstrate this ancient Japanese art. In the Kabuki face modeling work, we face the difficulty of the lack of input. Only some paintings of ancient Kabuki players are available. Because of the limitation of input, we deform face model which is compatible with MPEG-4 face animation standard according to ancient drawings to get the 3DD geometry, and then a texture mapping algorithm is used to map Kabuki make-up onto the reconstructed 3D face model. The deformation and texture mapping algorithm are based on radial basis function network. To achieve the smoothness and precision simultaneously, we present a multilevel radial basis function method based on the adjustment of radiuses. Our multilevel RBF method can solve the deformation and texture mapping problem quite well.

1. Introduction

Kabuki is a traditional form of Japanese theater. It was founded early in the 17th century, and over the 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 player which is called UKIYOE in Japan and Kabuki make-up pictures (called Kumadori). However, they are all traditional media and lack of interactivity:

Figure 1 Examples of UKIYOE

One can only view the static pictures. The aim of our research is to make use of such legacies to reconstruct and animate 3D Kabuki face model in computer by means of Computer Graphics techniques. It is a new way to preserve the culture heritage, and we believe that it also provides an interesting way for people to know about Kabuki art.

There are already abundant research works on face modeling. They can be roughly categorized according to their input, such as multiple photographs [1, 2, 3], range data [4, 5], video [6] and face model database [8].

Face modeling based on two orthogonal or multiple photographs try to make use of the correspondence of different photographs to compute the precise 3D shape and high quality face texture. Parke [1] presents putting a skin grid on the face and compute 3D coordinate of each grid point from two orthogonal photographs. Many methods are introduced to automate Parke's method. Face detection technique is used to detect feature points on a face [2], and deformation techniques, such as direct free form deformation and radial basis function, are also applied to adapt a generic facial model according to the detected feature points.

Besides the 3D shape, researchers also stress the importance of creating high quality face texture. Basically, it's a blending of multiple views. According to [3], face texture extraction can be divided into view-independent blending and view-dependant blending, and it considers self-occlusion, smoothness, positional certainty and view similarity. Face modeling from video provides not only the way to construct the 3D shape of a face but also the way to generate high quality texture map. Furthermore, they provide a way to capture the motion of face to create high quality animations [6].

Range data is another important source for face modeling. Lee et al [4] proposed a method to adapt a physics-based face model with animation structure to a specific range data. Blanz et al [8] presented to construct a face database and reconstruct the 3D face model by the linear combination of the face models in the database. All face models in this database are embedded into a vector space and PCA is used to find the principle eigenvectors to compress the data. Their method can deal with face reconstruction from single photograph or multiple photographs by statistical gradient optimization.

Unfortunately, we can not find such kind of input mentioned above from the culture legacies of Kabuki. Firstly, the ancient players were from several hundred years ago, it is impossible to get their photographs. We can only get drawings of their face. Secondly, Kabuki player often use a special make-up style (see details in Section 4), we must provide way to map make-up to the 3D face model. That means we can't get the 3D shape and texture at same time. To deal with the reconstruction problem, we design a procedure to deform the 3D face model compatible with MPEG4 face animation standard according to the UKIYOE to get the 3D geometry information, then a texture mapping algorithm is used to map the our special texture to the reconstructed 3D face model. Since our face model is compatible with MPEG4 standard, we can obtain the animatable structure automatically after deformation, and many subsequent applications can benefit from this, such as Virtual Environments, web applications, and so on [14, 15]. Radial basis function (RBF) is the base of our deformation and texture mapping algorithm, and we present a multilevel approach to enhance the precision of original RBF network to make it suitable to both deformation and texture mapping.

The remainder of this paper is organized as follows. Section 2 will describe the principle of multilevel RBF method. In section 3, we will introduce how to reconstruct 3D face model from ancient drawings. Kabuki make-up mapping is described in section 4, and we conclude and discuss future work in section 5.

2. Multilevel Radial Basis Function

RBF has been widely used in scattered interpolation, deformation and so on, and we will show that it is also suitable for texture mapping. In the theory of RBF, a regulation term is usually used to guarantee the smoothness of the constructed surface [12]. However, this also leads to the imprecision at data points. To solve this problem, we present a Multilevel RBF approach to achieve the precision and smoothness at the same time. Lee et al presented a multilevel B-Splines method to do scattered data interpolation [11], they built multilevel method by increasing the density of knots. However, our method is based on radius of RBF.

2.1 Radial Basis Function

The definition of RBF network 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_i. 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 so that the following least square function is minimum:

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

Taking derivative to w_i, We get:

$$\left(\mathbf{H}^T\mathbf{H} + \lambda\mathbf{I}\right)\mathbf{w} = \mathbf{H}^T\mathbf{y} \tag{5}$$

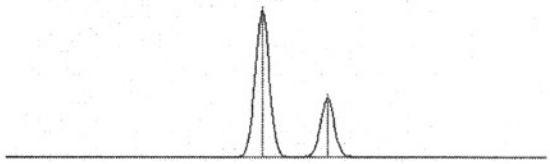
where $H_{ij} = h_j(x_i)$ and $\mathbf{w}, \mathbf{y}$ are column vectors which contain w_i and y_i respectively. To select a good parameter λ, we adopt the global-Ridge algorithm and the generalized cross-validation as error criteria [12].

2.2 Multilevel RBF method

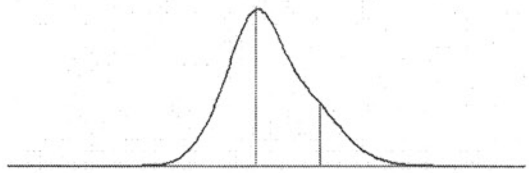
Center c and radius r of kernel function are the parameters to control the behavior of the RBF network. In most applications, the center is obvious. So, the radius r is the parameter that we can resort to control the RBF network. We will analyze the influence of the radius to the RBF network first, and then explain why we choose the multilevel approach.

As illustrated in figure 2, there is a straight line and two points on it will be moved to new positions. A small radius is selected first, and the result from RBF (Figure 2.a) shows that the middle regions between these two points are not affected. We need to point out that this is not suitable to interpolation application, and we can not use small radius to do texture mapping.

In figure 2.b, we choose a large radius instead. Notice that the radius is large enough to let two points to influence each other. At this time, the middle region is influenced and interpolation is much better than the previous case. However, there are still approximation errors at the data points. That means the resulting curve can not pass the data points precisely.



(a) Small radius



(b) Large radius

Figure 2. Influence of Radius

According to the above discussion, we are able to design a multilevel RBF approach. First, large radiuses are selected to get the approximation and compute the approximation errors remained at the data points, and then reduce the length of radius gradually to approximate the error to get the precise result at the data points. The multilevel RBF can be written as:

$$y = \sum_j \sum_i w_{ij} h_{ij}(x), \qquad r_{ij_1} > r_{ij_2},\ if\ j_1 > j_2 \tag{6}$$

We omit the regulation term in Eq. (6) for the purpose of clarity. Figure 3 shows the result of this approach for the problem above. Now the interpolated curve is better.

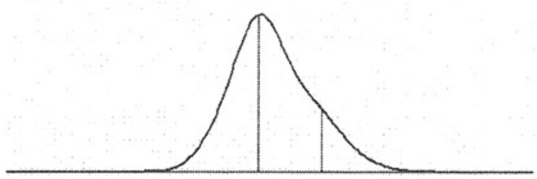


Figure 3. Interpolation with Multilevel RBF

Figure 4 illustrates some results in 2D case.

Green points represent the feature points and dash lines stand for the correspondence. Notice the irregular correspondence in feature points. With that correspondence, RBF can be used to find point in right two figures corresponding to the red point in leftmost figure. The red points in right two figures are the result from multilevel RBF method and original RBF method.

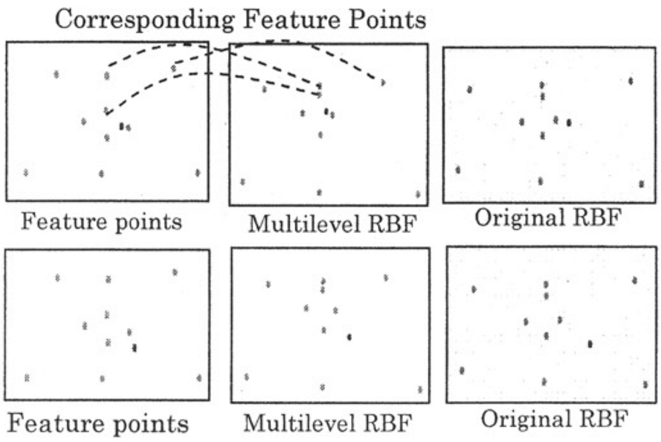


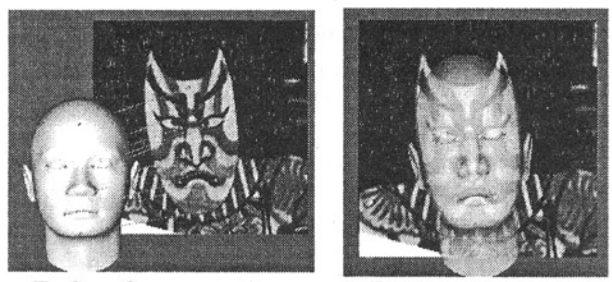
Figure 4. Comparison in 2D Case

It is obvious that our multilevel RBF approach can preserve relationships between feature points better than the original RBF network in an irregular case. In the first row of figure 4, multilevel RBF comes up with a correct result which is still inside the region of surrounding feature points, while original one level RBF generates a result outside of surrounding region. In second row, multilevel RBF also comes up with a better result. This feature of multilevel RBF builds a good fundament for both deformation and texture mapping.

3. Reconstruct 3D Face Model from UKIYOE

The reconstruction procedure in this paper is actually a registration and deformation procedure. Registration and deformation can acquire the 3D face model which is very similar to the face of Kabuki player and this 3D face model can match the UKIYOE very precisely. After we get a precise match between face model and UKIYOE, the face model is projected on the picture to calculate the texture coordinates, and symmetry constraints are used to reconstruct the face model from side view pictures. Since our standard face model is compatible with MPEG-4 face animation standard, there are already feature points information in it, and each feature points is associated with influence region [15]. Thus, it is easy to get the parameters for RBF network.

After user input UKIYOE and face model, our system starts with registering face model to UKIYOE. The purpose of registration is to get a rough match between UKIYOE and 3D face model, and the parameters of translation, rotation and scale will be estimated at same time. There are already many research papers on this topic [9]. Since we let user to select feature points manually, the feature points in our case can't be too many. We choose traditional optimization algorithm, conjugate gradient, to solve this problem. Figure 5 illustrates the result. We also enable user to adjust the transformation manually.



Define feature points Registration result

Figure 5 Guess Transformation

Multilevel RBF is used to deform the 3D face model to match the outline, eyes, nose and mouth of face. Since our face model contains MPEG4 feature points and their influence region, it is easy for us to choose the radiuses according to the influence region of MPEG4 feature points. User can also specify arbitrary feature points in the region when the original MPEG4 feature points are not enough to control the shape of 3D face model. Figure 6 illustrates the deformation result, and final result after texture mapping is showed in figure 7.

With the symmetry constraints in the face model, we can also reconstruct 3D face model from the side view pictures (Figure 8). The feature points defined in MPEG-4 face animation standard facilitate the identification of symmetry constraints, for example, the feature point 4.3 should be symmetric to the feature point 4.4. Ref. [14] lists a lot of constraints between MPEG-4 feature points. They are also the constraints we consider in the reconstruction.

Figure 6 Deformation Result

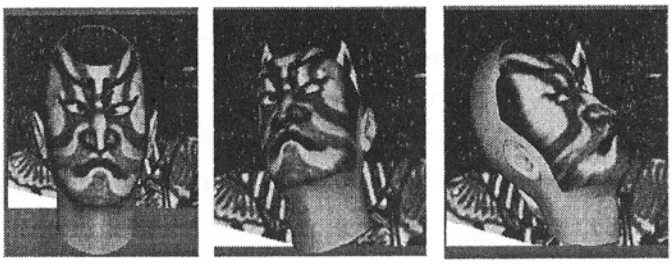


Figure 7. Reconstruction Result

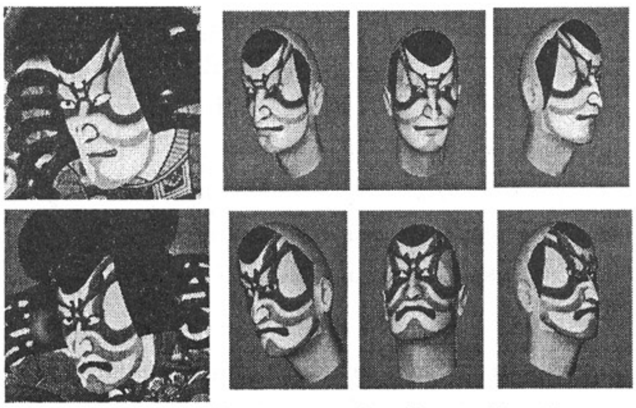


Figure 8. Reconstruction from side-view

4. Kumadori Mapping

Kumadori is the name of the special face make-up style in Kabuki, which is usually viewed as the most distinctive feature associated with Kabuki. Kumadori uses bold lines to highlight the eyes, cheekbone and jaw line which helps to emphasize the emotional responsiveness of the character, and its color implies the personality of the character. Figure 9 illustrates some examples of Kumadori.

After defining the corresponding feature points on face model and 2D Texture image, texture mapping can be solved as an optimization problem or a scattered data interpolation problem [10, 16]. Ref. [16] also adopts RBF to solve texture mapping problem, and they point out that RBF network with

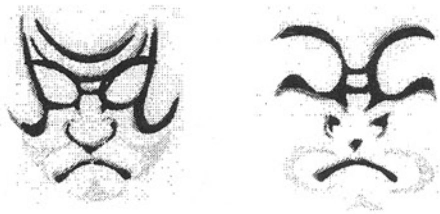


Figure 9.. Kumadori examples

regulation term is suitable to texture mapping. However, our mapping problem is more difficult since we need to preserve the cure shape in Kumadori, and the correspondence is not obvious in our case. Furthermore, our multilevel RBF can enhance the precision of RBF network, which is very important to texture mapping problem. Another reason for us to adopt RBF is that we can base our system on same algorithm, which brings us more clear software architecture. Figure 10 illustrates the result.

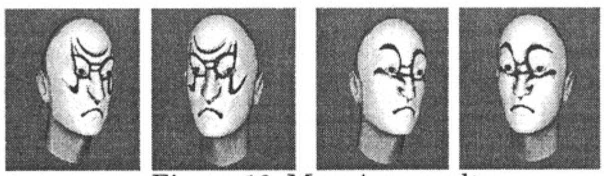


Figure 10. Mapping results

There are some kumadori acquired from the ancient famous Kabuki player, which is treated as a treasure of Japanese culture. Figure 14 shows the procedure of how to acquire the kumadori and one kumadori acquired from Danjuro eighth who is a famous player about three hundred years ago. Mapping such kind of kumadori to the 3D face model is of special meaning to people.

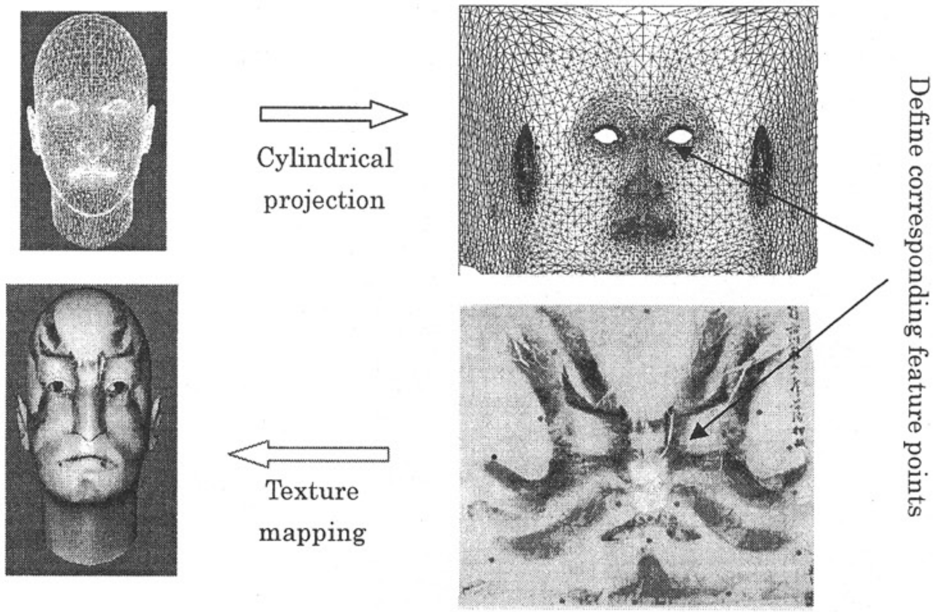


Figure 11. Mapping ancient Kumadori

Since this ancient kumadori is acquired by putting a paper on the face of the player, it is quite similar to cylindrical projection. So, we decide to project the deformed 3D face model to a cylindrical plane. This step can also be viewed as a 2D Parameterization of 3D Face model. Figure 11 illustrates the projection result. The red triangles are of face part of the face model. Please notice the irregular deformation at the mouth part. In Kumadori picture of figure 15, the mouth is very close to the nose. It is caused by the acquisition method of this Kumadori. The result shows that our multilevel RBF approach can handle this quite well.

5. Conclusion

A 3D reconstruction method from the ancient drawings of Kabuki player has been described. It is based on multilevel radial basis function algorithm. The reason we present a multilevel RBF method is to achieve the smoothness and precision simultaneously, which is very important in texture mapping. Experimental results prove the effectivity of our method.

There is a new research hotspot on investigating how to apply the CG techniques to the field of cultural heritage. Our face modeling system can be classified into that research, which provides a new way to interact with cultural heritage. The reconstruction result is not precise 3D reconstruction of original face comparing to other reconstruction methods, but it provides interesting results and the other applications can be based on the reconstruction results of our method.

Many problems are still remained to be solved. The hair of kabuki player will be added to improve the visual effect, and the animation techniques will be applied to mimic the expressions in Kabuki. We also plan to find ways to realistically render the Japanese traditional costume used in Kabuki.

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