Generation of Person-Specific 3D Model Based on Single Photograph

Fenglan Huang, Ting Sun, Fanliang Bu*
People's Public Security University of China
Beijing, China
e-mail: bufanliangbfl@163.com

***Abstract*—At present, a person-specific 3D model generation technology has been an active research topic for scientists in the field of computer vision and computer graphics. The paper proposes a 3D modeling method based on single photograph, by analysis of individual difference like geometric features which present the shape and locations of facial components. An extension of the basic Active Appearance Model is proposed to localize some facial feature points in the frontal image and all these feature points are aligned to fit the generic 3D face model to a specialized one to reflect the given person's face, being both more robust and faster. Then an optimized texture mapping of cylindrical projection and model adjustment technologies are presented, to synthesize personal virtual face realistically. This method rectifies these previous defects, such as the difficulty in gaining access to acquiring the accurate data of a 3D face model, slowly manual location methods, incomplete facial information mining. The approach gives a significant improvement in both the reliability and the overall accuracy of 3D modeling.**

Keywords-generic face model; active appearance model; texture mapping; model adjustment

I. INTRODUCTION

With the development of computer graphics technology, 3D face model is widely used in face recognition, expression synthesis, virtual reality, facial animation and other areas [1]. However, it is difficult to find identical faces in the world, so the research on how to generate the person-specific 3D model has a very high practical value. At present, domestic and international studies on techniques for 3D modeling are various, which typically include as follow:

Modeling technology based on 3D scanning data: Using 3D scanning instrument to capture accurate information of the facial structures, modeling according to the 3D information obtained from the specific face, and using surface interpolation, image mosaic, and other optimization technology transformation converted to 3D face surfaces. However, this method requires precise face data and relatively expensive equipment. It is difficult to meet the general needs so that it is not popular.

Modeling technology based on 3D morphable model: Depending on two facial images, we find the correspondence and generate a smooth transition between the images [2]. This method resolves the geometrical features of face images at different angles, which can eliminate ambiguity and help to establish a high accuracy of 3D face model. However, The morphable model requires a large number of face samples, the computational complexity is high and the modeling effect could be improved.

Modeling technology based on standard face model: Adopting face model which represents common facial features and correct the gap between person-specific 3D face model and the generic face model [3]. The current technical problems exist although this method calculates simply. For example, when the great difference between a specified generation of face model and a generic face model, it is uneasy to obtain an idealized 3D face model.

In combination of the above modeling methods, this paper proposes a new face modeling method ---generation of person-specific 3D model based on single photograph. This method uses an extension of the basic Active Appearance Model to calibrate the feature points, changing the conventional slow manual calibration operations. And by deforming the standard face model to generate 3D face model with personalized features, it reduces the computational complexity; texture mapping of cylindrical projection is chose for adding texture to mesh model, while the generated models are partial and whole shape adjustments and multi-angle transform, improving the model's flexibility compared with the existing methods, enhancing the factuality of the synthetic face.

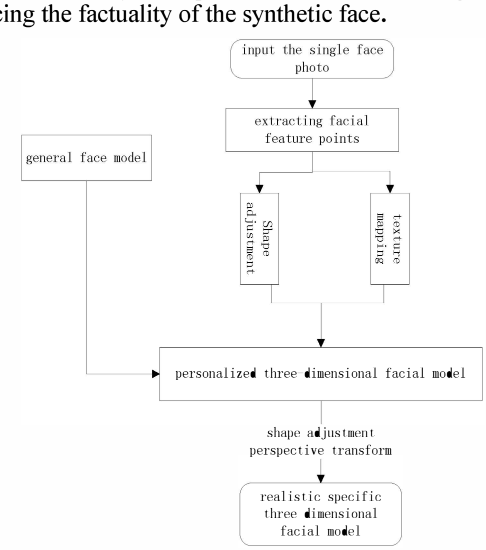

Figure 1. The generation flowchart of person- specific 3D model

II. BASIC IDEAS

A person-specific 3D model generation technology has wide application, which is able to meet certain face model need [4].This method only needs a single photograph and a generic face model without collecting a large number of training image samples. Also we fit the generic 3D face model to a specialized one to reflect the given person's face, adjust model to achieve personalized matching, finally add the texture information and model adjustment. Fig. 1 outlines the overview of our system.

The main content of this article are:

A. Selection of Generic Face Model

Although there are a lot of differences in faces, many similarities still exist. Common is the starting point of constituting general model. In general, we are talking about the universal human face which is capable of replying to a public face features. This paper chooses geometric surface generating generic model, which captures the facial surface and location data from different perspectives, with certain popularity [5]. Generic face model is shown in Fig. 2.

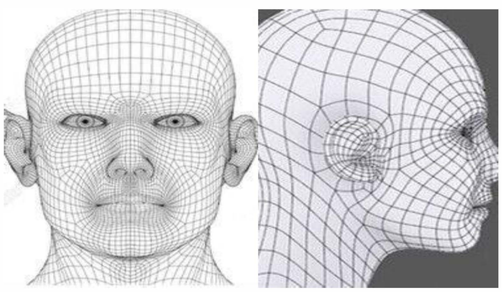

Figure 2. Generic face model

B. The Definition and Extraction of Facial Feature Points

Locating facial features is an important stage in many facial image interpretation tasks .Landmarks matching or not, directly affects the availability of face image and 3D reconstruction results. The selection of facial feature points is external contour and internal points of face components such as the nose, eyes, mouth [6]. We define 23 feature points based on the International Civil Aviation Organization calibration, and then extend to 69 precise points. At the same time, blending the advantage of the Active Shape Model and Active Appearance Model, we take the inverse algorithm fitting way to extract facial feature points accurately. Fig. 3 below shows the mesh of Active Appearance Model.

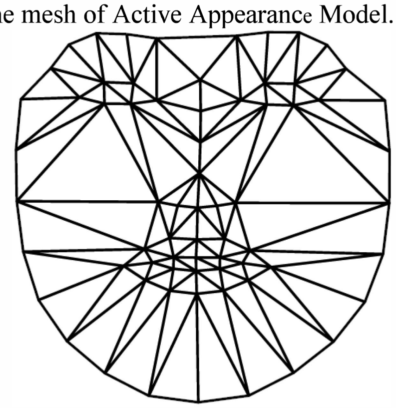

Figure 3. Active appearance model

C. 3D Model Generation

Modification of the generic face model is the process of using the facial feature information which is extracted from 3D model to deform standard face model. When you get the 3D facial feature information, We calculate differential displacement between them, moving and getting new landmarks . the new model becomes basis of facial model generation, later adjusting and modifying.

D. Adding Texture and Model Adjustments

3D model still exist some defects after the synthesis and adding texture can achieve surface detail description, rendering a realistic face model. Through some kind of relationship in texture mapping, 3D model's key points can be linked with the 2D space of the specific person, eventually the 2D texture patterns display on 3D model. This paper optimizes texture mapping based on the cylindrical model [7], selecting cylindrical surface as middle surface, and matching face projection in two-dimensional space and specific face region. After texture mapping, we get added texture model. Fig. 4 shows the results before and after added texture to the 3D grid.

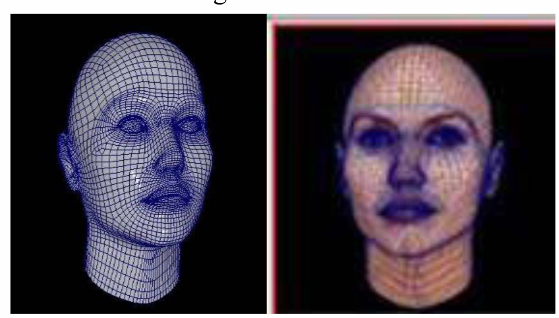

Figure 4. not add texture to the grid Mesh and texture

In addition, the variety of expressions, human faces, posture and lighting contribute to the differences between the generated specific face and the real face. In order to synthesize realistic model, this paper achieves 3D model deformation partly and wholly by histogram transformation, gray scale transformation and linear interpolation. Compared with the previous method, the method realizes a multi-angle observation and adding model adjustment makes the 3D modeling truly.

III. ALGORITHM DESCRIPTION

Active Appearance Model improves the limitations of the ASM model only depending on shape information constraints and gives a better match to the texture [8]. Added texture model allows AAM more accurate in the location of facial feature, however the texture increases mutual restraint with shapes, resulting in poor AAM fitting effect. This paper proposes an extension of the basic AAM, which consists of an AAM internal contour and an ASM external contour. When optimizing the model, we show the reverse algorithm to enhance the robustness of model. Specific algorithms are as follow: first collect a series of face sample images and with manual annotated landmarks for key facial features, after normalization and change, it forms face collection.

$$s = (x_1, y_1, x_2, y_2 \ldots x_v, y_v)^T \tag{1}$$

The shape model:

$$x = \bar{x} + Us \tag{2}$$

where $\bar{x}$ is the mean shape, s is the shape parameter, U is a matrix composed of shape feature vector transform. Facial feature points are extracted to form the feature vector that represents the face geometry To remove the effects of other components, we apply principal component analysis (PCA) to obtain the feature vector of shape space.

When creating the texture models, we need a correct alignment of the shapes between sample face and average faces, that is to say, standardizing the texture data of face image in gray-scale values after normalization and it can be obtained:

$$g = \bar{g} + Vt \tag{3}$$

where $\bar{g}$ is the mean texture, t is the parameter of gray images, V is a matrix composed of the feature vectors of face image texture space.

After passing through the synthesis of shape and texture model, we can get the eventual image, expressed by the following vector:

$$A = \begin{pmatrix} \Lambda s \\ t \end{pmatrix} \tag{4}$$

where Λ is diagonal weight matrix. In addition, the reverse algorithm is selected to fit the existing Active Appearance Model: Calculate the gradient of surface images and enter the initial value of the face image; repeated calculation, distorting the image and updating the parameter. The extension of basic Active Appearance Model could remove rotation and translation, which makes the location of facial feature more accurate. Fig. 5 below shows a face with correctly positioned landmarks.

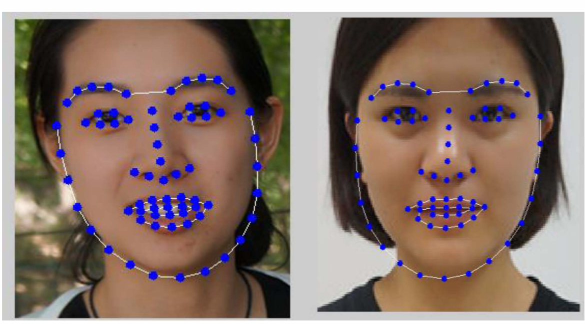

Figure 5. Labeled face

This cylindrical projection is a common method of two-step texture mapping. This method selects the cylindrical surfaces as an intermediate surface and the two-dimensional texture space is mapped to a simple cylindrical surface, using image interpolation technology to optimize texture synthesis. Concrete walks as follows: (a) map the face texture to the cylindrical surface; (b) package 3D facial model in cylindrical surface, map texture to the model surface to achieve texture synthesis purpose. Set the radius to R, high to h of the cylindrical surface, the texture coordinates and cylindrical coordinates are mapping as shown in Fig. 6.

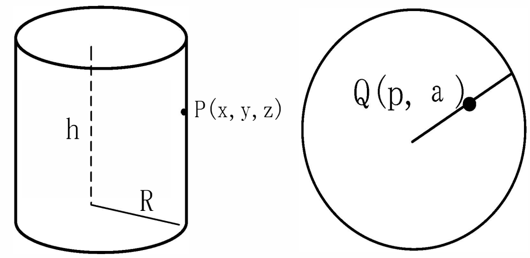

Figure 6. $S: (p,\alpha) \rightarrow (x,y,z)$

Geometric relation of cylinder projection:

$$x = p\cos a \sin b$$
$$y = p \sin a \sin b$$
$$z = p \tag{5}$$

Among them: $0 \le a \le 2\pi$ $\le b \le \pi$

Defines a mapping function, the function operates to achieve linear transform and inverse transform:

$$(x', y') = F(x, y, z) \tag{6}$$

The texture of the middle cylindrical surface is mapped to the 3D face model.

$$(x', y', z') \rightarrow (x, y, z) \tag{7}$$

Texture mapping method based on cylindrical projection is clear and simple, but there are still defects that 2D surface texture could not be completely mapped to the middle surface. This paper adds a linear interpolation method, processing the seam of image and improving the effect of texture mapping.

IV. Experimental Analysis

In this paper, we use the face photographs, which should eliminate the effects of illumination, tilt angle and background. The experiment begins with the image preprocessing to get the frontal face of the non-destructive, high-resolution photos [9]. The image shows in Fig. 7 below after preprocessing.

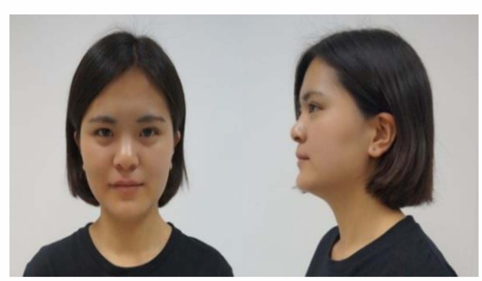

Figure 7. Face images (front and side)

Fig. 8 shows the specific-person facial modeling results which base on a single photograph with a 30 degrees angle of left, front, 30 degrees angle of right.

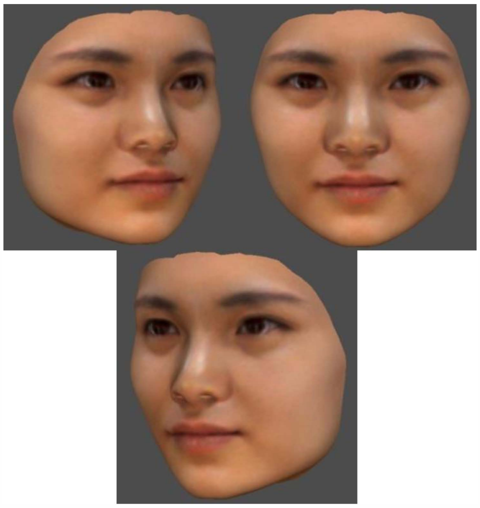

Figure 8. 3D model

Fig. 9 shows a person-specific 3D face which base on the local modification of the 3D facial images with the nose drop, front and chin width adjustment.

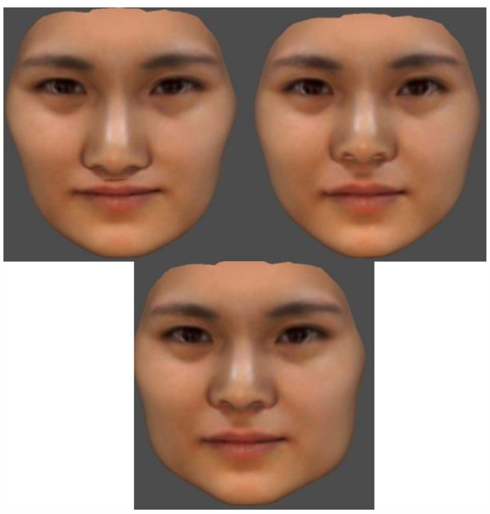

Figure 9. Model adjustments

In this paper, generating person-specific 3D model uses an extension of the basic Active Appearance Model. However, "3DS" file is created to load 3D face in the past. Fig. 10 shows the difference between two methods. By comparing the results, Models produced by our method are suited to specific individuals for applications.

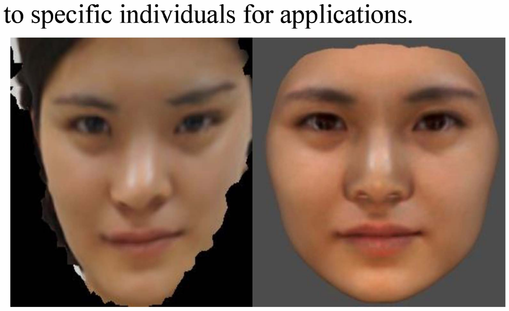

Figure 10. Comparisons of the models

Experiments show that the face image after image preprocessing, uses an extension of the basic Active Appearance Model, modifies generic face model, and combines with the optimization method of texture mapping based on cylindrical surface so that we get realistic synthesis of the specific-person 3D model.

V. CONCLUSION

This paper proposes a method for generating person-specific 3D model based on single photograph. The experimental results show that this method can rapidly synthesize realistic facial models and has practical value. Based on the generic face model, an extension of the basic Active Appearance Model, and extract the depth information to match the model in order to generate a person-specific 3D model. It achieves a specific facial texture mapping, adding the function of the model adjustment, providing an important reference to the Asian modeling. It also establishes a better foundation for face recognition, facial expression synthesis, and techniques such as facial aging [10].

ACKNOWLEDGMENT

The author would like to take this opportunity to thank my professor for the tremendous support and guidance provided us throughout the research.

This work is supported by the National Key Research and Development Plan(Grant No.2016YFC0801005)

REFERENCES

[1] Du Ping, Xu Dawei, Liu Chongqing. Research of Personal 3D Face Model and Its Application Shanghai Jiaotong University,2003. (37): 435-439

[2] Dawn, Yao Li xiu etc. 3D Facial Caricaturing Based on Sparse Morphable Model Journal of Electronics, 2010.（8）1798-1802

[3] Yan Jie. Modification from General Face Model to Specific Face Model [J]. Computer Engineering and Science,1997 ,19 (2) :21 - 24.

[4] Lu Hong, Liao long Long. Application-Oriented Construction of Personalized 3D Face Model. Computer Systems & Applications, 2014.(3)132-137

[5] Parke, F. I., & Waters, K. (1996). Computerfacial animation. Natick, MA:A.K. Peters Ltd.

[6] Lin Wei Xun Facial features localization [J], China Image and Graphics,2003.(8)849-859

[7] Qian Wei yan, Hu Xiaotong. Surface Texture Reconstruction for 3D Object Based on CylindricalBack-Projection Algorithm. Journal of Tianjin university of science and technology, 2009.(3)58-62.

[8] Cootes TF, Taylor CJ, Cooper DH, Graham J. Active shape models-their training and application. Computer Vision andImage Understanding, 1995, 61(1): 38-59.

[9] Yongsuk Jang Kim, Sun-Tae Chung, Boogyun Kim, and Seongwon Cho,“3D Face Modeling based on 3D Dense Morphable Face Shape Model”, World Academy of Science, Engineering and Technology 37 2008.

[10] Huang and L.A. Tang, “3D Face Modeling and ItsApplications,”Int'l J. Pattern Recognition and ArtificialIntelligence, vol. 10, no. 5, pp. 491-519, 1996.