3D Facial Geometry Reconstruction using Patch Database

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Figure 1: *Results of our facial 3d shape reconstruction method from a a single frontal image which is taken same light source with database.*

Keywords: texture synthesis, 3D reconstruction, shape from X

Concepts: •**Computing methodologies** → **Computer graphics;**

1 Introduction

3D facial shape reconstruction in the wild environments is an important research task in the field of CG and CV. This is because it can be applied to a lot of products, such as 3DCG video games and face recognition. One of the most popular 3D facial shape reconstruction techniques is 3D Model-based approach. This approach approximates a facial shape by using 3D face model, which is calculated by principal component analysis. [Blanz and Vetter 1999] performed a 3D facial reconstruction by fitting points from facial feature points of an input of single facial image to vertex of template 3D facial model named 3D Morphable Model. This method can reconstruct a facial shape from a variety of images which include different lighting and face orientation, as long as facial feature points can be detected. However, representation quality of the result depends on the number of 3D model resolution.

Another reconstruction method is Shape from Shading(SfS) approach. SfS is the method which analyzes shading information from images to recover the high resolution geometry in the form of surface normals. [Kemelmacher-Shlizerman and Basri 2011] proposed a method which applies SfS to the facial image under unknown complex lighting. This method can reconstruct more detailed 3D facial shape than 3D Model-based approach, since this method uses information of each single pixel. However, this method is unable to reconstruct facial images which is far from average face such as different facial expression. This is because the average face albedo is used to solve SfS problems. In addition, it is difficult to reconstruct high quality facial shape from blurred or low resolution input images.

In this paper, we present a novel 3D facial shape reconstruction technique, which is using a completely different approach from two types of previous work. The core idea is to extend 3D geometry of 2D texture synthesis technique. Our approach uses patch-based method to estimate a 3D facial shape, because patch unit texture synthesis has been widely used in the field of image processing[Mohammed et al. 2009]. In our approach, we make a new assumption about a close relationship between facial shape and appearance of each face, to estimate a 3D facial shape by using patch database. Based on the idea, we perform a 3D facial shape reconstruction by taking a correspondence between input image and patch database (including appearance and geometry information). Here we use a surface normal information rather than the depth information directly as geometry data. The experimental study we performed this time is under the known lighting environment. In this case, it is proved that our method allows us to perform a high quality 3D facial shape reconstruction compared to latest works. The following are the novelties of our new approach.

- Needless of feature points and any specific approximation to solve SfS.
- Performing a robust facial shape reconstruction method against images which includes noisy information on facial image.

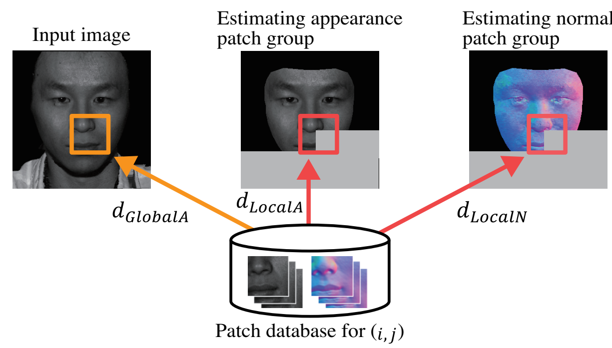

Figure 2: *Overview of optimum patch selection. We construct a database using* 16 *adult men image which size is* 300*[pixel]* ×300*[pixel]. Further, patch image size is* 10*[pixel]* ×10*[pixel], overlap range is* 9*[pixel].*

2 Our Approach

We present a new 3D facial shape reconstruction technique using a patch database. First, a patch database which is including ap-

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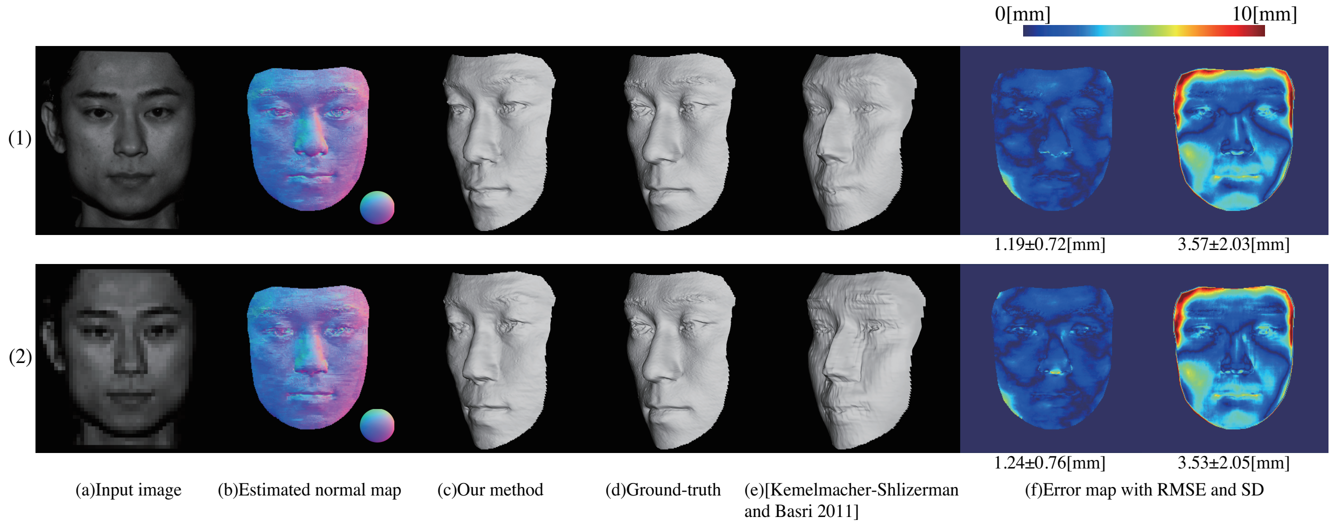

Figure 3: *Results of facial shape reconstruction and comparison with previous method. (1) Reconstructs from same resolution image with database which size is* 300*[pixel]* $\times 300$*[pixel]. (2) Reconstructs from low resolution image which size is* 50*[pixel]* $\times 50$*[pixel]. (f) Left error map consists of (c) and (d), right error map consists of (d) and (e). We describe results of other types of input images in supplemental.*

pearance and surface normal information is constructed by cutting a persons facial image in an overlapping way. These images are taken under the same measurement environment. Then, facial position, scale and rotation are normalized by fitting both inner corners of eyes at the same point between all images. Finally, appearance and surface normal patch database which considers its position correspondence between all patch data are created.

Next, we estimate an input facial image surface normal using patch database. Fig.2 shows the overview of our normal estimation method. In our method, an original evaluation function Eq.(1) is used to select optimum normal patch for input image.

$$E = \alpha d_{GlobalA} + \beta(d_{LocalA} + d_{LocalN}) \tag{1}$$

In Eq.(1), $d_{GlobalA}$ is the appearance general similarity between input image and the appearance patch from patch database. d_{LocalA} and d_{LocalN} are the continuity between each estimating patch group images and each patches from patch database. α and β are weight factor range from 0 to 1. Procedures of finding optimum patch processes are shown below. (i, j) are coordinates of the image space.

1. Normalize input facial image by fitting both inner corners of eyes at the same point between input facial image and patch database.
2. Finding optimum patch data at (i, j) from patch database at the same position by using Eq.(1).
3. Repeating same process in the surrounding patch database.

By following this process, optimum patch which has a general similarity and continuity between each patch is selected. This process is performed in all positions along the raster scan. After all selection, a normal map image of the input image is created. Finally, facial surface depth $(x, y, E(Z(x, y)))$ is calculated from estimated facial normal map (n_x, n_y, n_z) on every vertex, by using a quadratic minimization function [Basri et al. 2007].

$$\begin{aligned} E(Z(x,y)) = &\left(Z(x+1,y) - Z(x,y) + \frac{n_x}{n_z}\right)^2 \\ &+ \left(Z(x,y+1) - Z(x,y) + \frac{n_y}{n_z}\right)^2 \end{aligned} \tag{2}$$

3 Result and Conclusion

Results of 3D facial reconstruction is shown in Fig.1 and Fig.3, and an accuracy evaluation is shown in Fig.3. In this Paper, we use a root mean squared error(RMSE) and standard deviation(SD) as an accuracy evaluation. It is shown that our method can exceed reconstruction accuracy of all results from Fig.3. As shown in Fig.3, grid-like noise appears in SfS method when an input image was low resolution, because this method reconstructs a facial shape from each pixel information. On the other hand, our method can stably reconstruct facial shape, because patch-based method is a robust against the image which includes noisy information. In addition, our method achieves high quality 3D facial reconstruction including personality features at main facial parts, because our method do not need any specific approximation, such as average face albedo which is needed to solve SfS.

In this paper, we presented a novel 3D facial shape reconstruction technique, and performed an experimental study under the known lighting environment. A direction for Future work is to apply the images which have different lighting environment and expression. In addition, we are aiming to establish the usefulness in 3DCG scene such as video game and movie.

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