Fast-Automatic 3D Face Generation Using a Single Video Camera

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1 Introduction

Reconstructing a 3D face model only with a single camera without attaching landmarks and pattern projecting on a face is still a challenging task in computer vision and computer graphics. FaceGen [2011] is able to reconstruct 3D shape and texture from 2D single image based on 3D morphable model. Since the users have to determine of the facial feature points manually, the method does not work automatically. Moreover, it requires a couple of minutes to generate a 3D face model. Thus, the computational cost is not enough cheap for practical usage.

Choi et al. [2010] proposed a hybrid approach that combines Structure-from-Motion (SfM) and generic-model deformation to estimate face geometry efficiently. This method can automatically reconstruct a 3D face model from multi-view images. They compute a 3D face model along with the modification of generic face, thus, the reconstructed face does not reflect individual shape especially the shape of nose and unevenness of the cheeks.

In this paper, we propose a fast-automatic 3D face reconstruction method based on Structure-from-Motion and Deformable Face Model (DFM). Considering both 2D frontal face image constraint, 3D geometric constraint, and likelihood constraint, we are able to reconstruct subject's face model accurately, robustly, and automatically. Using our method, it is possible to create a 3D face model in 5.8 [sec] by only shaking own head freely in front of a single video camera.

2 System Overview

Figure 1 shows the overview of our proposal method which is composed of 6 steps as follows.

(a) Image Sequence Acquisition: We capture an image sequence in which a subject rotates the head in front of a camera freely and gradually. Note that, unlike Choi's method which allows only horizontal movement, ours does not constrain the subject how to rotate own head. Therefore we can obtain information of the subject's face observed from multi-view directions.

(b) Feature Detection: We detect 87 feature points from the frontal face image in the sequence used for 2D constraint. We also detect 28 feature points from all frames in the sequence used for 3D constraint based on the method proposed by Irie et al. [2011].

(c) Factorization: We estimate 3D position of 28 feature points transition acquired from an image sequence using SfM algorithm.

(d) Deformable Face Model: The generic 3D face model cannot represent individual facial parts geometry. Therefore, we construct the "Deformable Face Model(DFM)" by calculating Principal Components(PCs $\mathbf{p}$) for vertices of each face model in the database which includes 1153 male/female, young/elderly 3D face models. The DFM is able to generate a variety of 3D facial geometry by controlling each magnitude of Principal Component.

(e) Optimal Deformation: We formulate the cost function $E(\mathbf{p})$ as equation (1) for 3D facial shape estimation. This function is defined as a summation of the 2D-fitness term, the 3D-fitness term, and the likelihood term (the details are stated in supplemental materials).

$$E(\mathbf{p}) = \alpha E_{2Dfitness}(\mathbf{p}) + \beta E_{3Dfitness}(\mathbf{p}) - \gamma E_{likelihood}(\mathbf{p}) \qquad (1)$$

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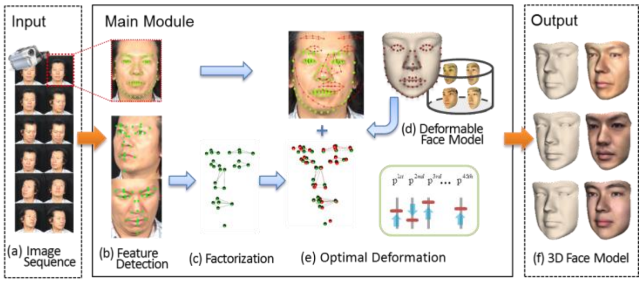

Figure 1: *Overview of Our Method*

The 2D-fitness term represents the sum of the Euclid distance between the vertex of the frontal facial feature point and its corresponding vertex of the DFM. This constraint controls the shape of the face contour and organs appropriately.

The 3D-fitness term represents the sum of the Euclid distance between the vertex of the estimated point by SfM and its corresponding vertex of the DFM. This constraint reflects depth characteristics such as height of nose.

The likelihood term computes the face likelihood of currently estimated $\mathbf{p}$ based on the method proposed by Maejima et al. [2008]. This constraint maintains a human-like face structure not to generate an unnatural face.

And the coefficients α, β, γ decide contributions for each term. We solve the optimal PCs $\mathbf{p}$ from this function by BFGS minimization method.

(f) 3D Face Generation: We can acquire a final 3D face model by deforming the DFM based on estimated optimal $\mathbf{p}$, and mapping the texture of frontal face image to the deformed DFM.

3 Experimental Result and Conclusion

For our experiments, we used an Intel Xeon E3-1245(3.30GHz) machine and an image sequence which are acquired with a single consumer video camera which can record with 29.97 fps and resolution of 600*600 pixels. Experimental results show that our method can generate a 3D face model with 2.1 [mm] estimation error in 5.8 [sec] after capturing an image sequence.

In consequence, we can fast-automatic generate a 3D face model, and succeed to represent more plausible facial geometry even compared with our previous poster [Hara et al. 2011] by re-formulating the cost function (the comparison results are shown in supplemental materials). As a future work, it is necessary to extend our database by collecting more various types of face models in order to generate 3D faces with variation of ethnicity.

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