Robust 3D Face Recognition by Using Shape Filtering

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Due to that 3D facial shape is invariant to illumination and makeup, it is believed that 3D face recognition has the potential for more accuracy. Moreover, with the development of 3D scan technology, the acquisition of 3D shape become more accurate and less intrusive, which allows for 3D facial recognition with low cost by measuring geometry on the face. However, since expression deformations bring difficulty to classifier for differentiating interpersonal disparities, expression is the greatest challenge to real world application.

In this paper, we are interested in the issue of robust 3D face recognition under expression variation. Our aim is to do this without overly constraining the conditions in which facial data is acquired. Most often, this means that the amount of scan data used for enrollment is only one and the test data used for authentication can take various expressions. Motivated by multi-scale deformation[1], in this paper, we describe a novel framework for accurate recognition under varying expression, based on manifold shape filtering techniques. The main contribution is a frequency division approach for expression challenge. Facial shape is firstly transformed into geometry image based on mesh parametrization. Then mid-frequency band of shape, which contains most of the discriminative personal information, is used for recognition.

Classical framework of geometry image analysis presented by Kakadiaris et al. [2] and Passalis et al. [3] is shown in Fig.1. Deformable face model is firstly fitted to preprocessing scan data. After that, deformation and normal map are assigned to the model's planar parametrization mesh to obtain their geometry images. Then three channels (X, Y, and Z) of them are analyzed using a wavelet transform and the coefficients are stored for individual features. In our approach, a shape filter is applied to the deformed face model. The filter is constructed by spectral method, which outputs shape signal of mid-frequency band. After that, it is also assigned to the model's parametrization mesh in order to acquire shape-filtered geometry image called normal variation image.

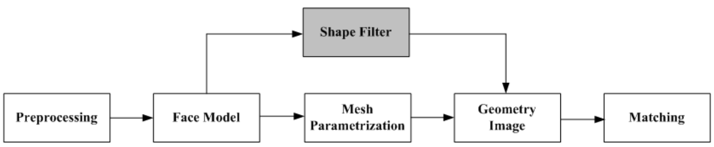

Figure 1: Overview of our proposed shape filtering method

Our main assumption is that each individual face consists of three parts (See Fig. 2). Low-frequency band mainly corresponds to expression changes. Mid-frequency band contains most of the discriminative personal-specific deformation information. High-frequency band represents noise. The fundamental idea behind our method is to apply shape filter to obtain mid-frequency information, and then convert it into a 2D parametrization space that retains the geometry information.

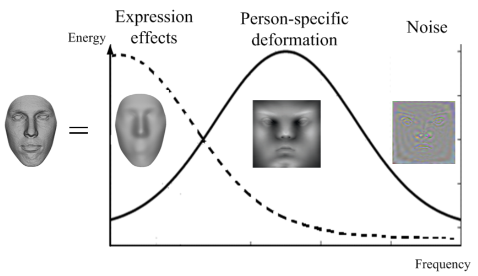

Figure 2: The generative model used for our 3D face recognition

Each individual facial shape X can be represented by $X = \mathscr{B} \oplus \mathscr{D} \oplus \mathscr{N}$ according to its frequency-domain. Noise $\mathscr{N}$ is firstly removed by smoothing algorithm. $\mathscr{B}$ is a smooth base surface. It can be computed based on MHT with the m leading eigenvectors. The geometric detail information $\mathscr{D}$ is a vector function that associates a displacement vector $\mathbf{h}_i$ with each point $\mathbf{b}_i$ on the base surface. According to Botsch's work[1], it is also called multi-scale deformation. Hence, the per-vertex displacement vector can be written as:

$$\mathbf{h}_i = \mathbf{x}_i - \mathbf{b}_i, \mathbf{h}_i \in \mathbb{R}^3 \tag{1}$$

The straightforward representation for the geometric details is a displacement vector. On the other side, two normal directions for facial shape X and its base surface $\mathscr{B}$ can be calculated. If we denote them using $\mathbf{n}_{\mathbf{x_i}}$ and $\mathbf{n}_{\mathbf{b_i}}$, the variation of normal direction can be written as:

$$\Delta = \mathbf{n}_{\mathbf{x_i}} - \mathbf{n}_{\mathbf{b_i}} \tag{2}$$

In this paper, we just focus on the normal variation. It is the output of the system after applying spectral filter to facial shape. Then it is assigned to the vertices of planar mesh. After regular sample on this grid, we can get 2D image containing geometry information. Fig. 3 shows us two types of geometry images. They are obtained by assigning different attributions to mesh vertices, namely normal image and normal variation image.

The performance on different subsets without filtering stage (normal image) is measured and compared to performance on these sets using shape filter (normal variation image). Note that cosine similarity measure is used during matching step.

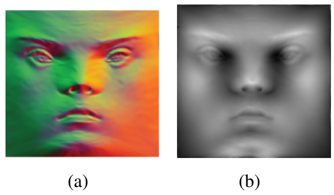

Figure 3: Geometry images of different attributions. (a) normal image (b) normal variation image.

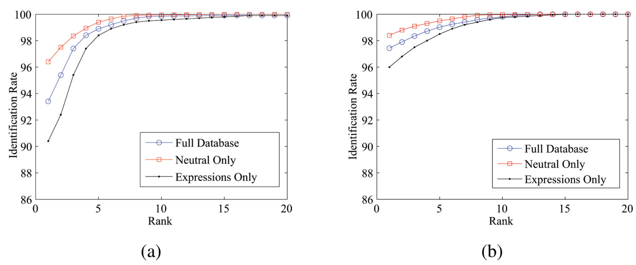

Figure 4: Performance comparison. (a) shows the results without shape filter. (b) is the results using shape filter

[1] M. Botsch. and O. Sorkine. On linear variational surface deformation methods. *IEEE Transactions on Visualization and Computer Graphics.*, 14(1):213–230, 2008.

[2] I. Kakadiaris, G. Passalis, G. Toderici, N. Murtuza, Y. Lu, and T. Theoharis. Three-dimensional face recognition in the presence of facial expressions: An annotated deformable model approach. *TPAMI*, 29(4):640–649, 2007.

[3] G. Passalis, I. Kakadiaris, and T. Theoharis. Intraclass retrieval of nonrigid 3d objects: Application to face recognition. *TPAMI*, 29(2): 218–229, 2007.