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Technical Note

A general framework for face reconstruction using single still image based on 2D-to-3D transformation kernel

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ABSTRACT

Face authentication is a biometric classification method that verifies the identity of a user based on image of their face. Accuracy of the authentication is reduced when the pose, illumination and expression of the training face images are different than the testing image. The methods in this paper are designed to improve the accuracy of a features-based face recognition system when the pose between the input images and training images are different. First, an efficient 2D-to-3D integrated face reconstruction approach is introduced to reconstruct a personalized 3D face model from a single frontal face image with neutral expression and normal illumination. Second, realistic virtual faces with different poses are synthesized based on the personalized 3D face to characterize the face subspace. Finally, face recognition is conducted based on these representative virtual faces. Compared with other related works, this framework has the following advantages: (1) only one single frontal face is required for face recognition, which avoids the burdensome enrollment work; and (2) the synthesized face samples provide the capability to conduct recognition under difficult conditions like complex pose, illumination and expression. From the experimental results, we conclude that the proposed method improves the accuracy of face recognition by varying the pose, illumination and expression.

1. Introduction

Biometric identification [1] system makes use of either physiological characteristics [2–5] (such as a fingerprint, iris pattern, ear, and face) or behavior patterns [6–8] (such as hand-writing, voice, and key-stroke patterns) to identify a person. Because of human inherent protectiveness of his/her eyes, some people are reluctant to use eye identification systems. In face identification [9–11], matching accuracy is reduced when the pose of the query images is different than the database images. If the pose of faces in the training and testing images are the same the accuracy improves. There are a few methods to adjust the pose of faces. One method is by Active Appearance Models (AAMs) [12–14] which makes a structural model of the face that has a face sub-image mapped to it; this mapped model can then be transformed geometrically to create a uniform pose. Second method is cascading tri-linear tensors [15–19], which allows the transformation of a virtual camera to pose the images in a 3D manner. Third method makes a panoramic image of the face [20] by combining images of different angles of a face into a single image. In this framework, the face model is determined from a frontal face image. Human intervention is usually involved. We propose to use generic 3D face model for view synthesis from a single image with known pose. The paper also addresses the problem of view synthesis with the application on face recognition.

Fig. 1 shows the block diagram of the proposed method, which consists of three steps, namely, face feature extraction, mask orientation adjustment and virtual face view synthesis. The first step is to locate three facial landmarks, which are the two outer eye corners and the center of the nose and determines the face orientation of the input face image using the three landmarks and anthropological standard. In the second step, the mask is rotated based on the detected face orientation. The rotated 3D mask is overlaid on the face image. As the mask will not be perfectly matching with the face image, a refinement process has to be performed in the third step. Once the precise 3D face model of that person is obtained, the virtual face with other orientations can be synthesized by rotating the 3D mask.

The rest of this paper is organized as follows. In the next section, we will describe the details of the face detection algorithm. Section 3 introduces a method for features extraction, mask adjustment, mask refinement and virtual face synthesis. We introduce our testing face databases in Section 4. In Section 5, we present our experimental results. Finally, we conclude in Section 6.

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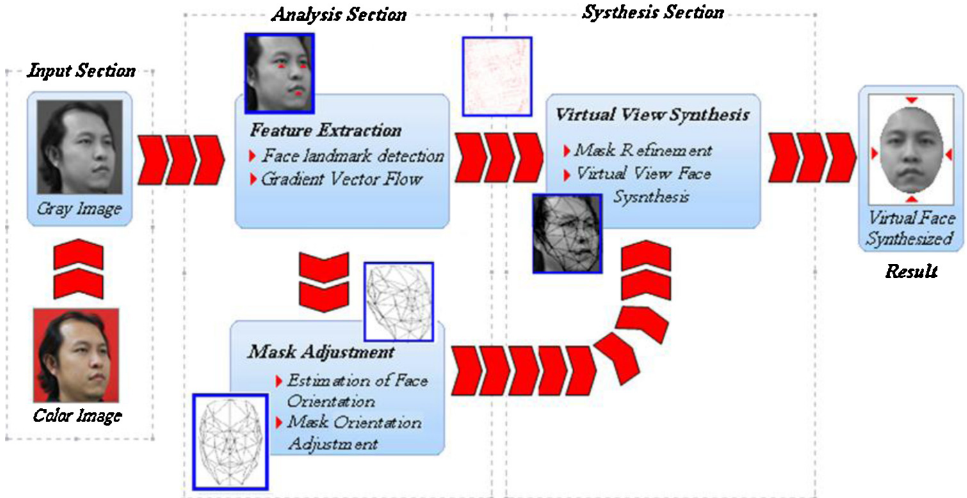

Fig. 1. The block diagram of our proposed method.

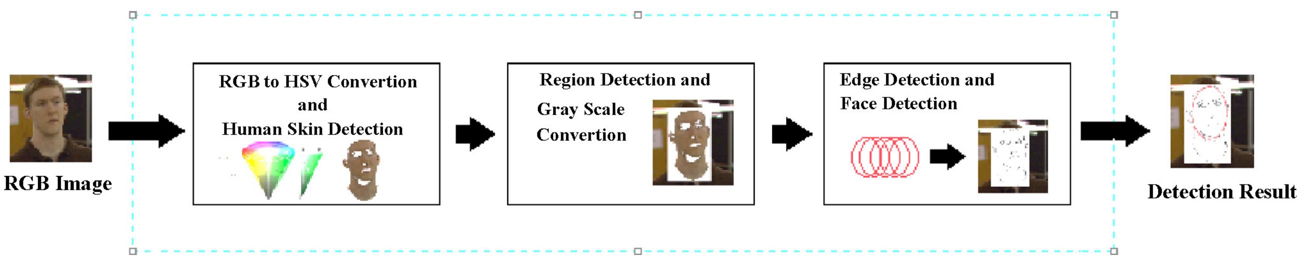

Fig. 2. A color-based face detection algorithms.

2. Face detection

In this section, we describe the fast algorithm of color based face detection. This algorithm will search only the human skin areas, not the entire background. The whole algorithm is shown in Fig. 2.

2.1. Human skin classification and color model conversion

The set of primary colors in the RGB has been used in various applications such as image representation and games. However, the RGB seems to be not very useful in image understanding. This is because, in addition to colors, it must also deal with light and brightness. Thus, it is difficult to use it in classifying human skin. In our approach, we employ the HSV color model to classify the human skin areas. The color parameters are Hue (H), Saturation (S) and Value (V). Hue is a color attribute that represents a pure color, Saturation defines the relative purity or the amount of white light mixed with a hue, and Value refers to the brightness of the image. These are the RGB–HSV conversions given by Travis [21]. To convert from RGB to HSV (assuming normalized RGB values), we have to find the maximum and minimum values from the RGB triplet. Saturation, S, is then given by:

$$S = \frac{\max - \min}{\max}, \tag{1}$$

and Value, V, is:

$$V = \max, \tag{2}$$

The Hue, H, is then calculated as follows. First calculate R', G' and B':

$$R' = \frac{\max\text{-}R}{\max - \min}, \tag{3}$$

$$G' = \frac{\max\text{-}G}{\max - \min}, \tag{4}$$

$$B' = \frac{\max\text{-}B}{\max - \min}, \tag{5}$$

if saturation, S, is 0 (zero), then hue is undefined otherwise:

$$H = \begin{cases} 5 + B' & \text{iif } R = \max \text{ and } G = \min, \\ 1 - G' & \text{if } R = \max \text{ and } G \neq \min, \\ R' + 1 & \text{if } G = \max \text{ and } B = \min, \\ 3 - B' & \text{if } G = \max \text{ and } B \neq \min, \\ 3 + G' & \text{if } R = \max, \\ 5 - R' & \text{otherwise.} \end{cases} \tag{6}$$

Hue, H, is then converted to degrees by multiplying with 60 giving HSV with S and V between 0° and 1° and H between 0° and 360°. The skin segmentation in HS space is shown in Fig. 3.

From [22], we have found that the Hue and Saturation that can be used to identify human skin are in the ranges [180,239] and [0.13, 0.87], respectively. The skin segmentation is defined as:

$$I_{x,y} = \begin{cases} \text{GRAY}_{x,y} & \text{if } \{[H_{x,y} \in [180, 239]] \cap [S_{x,y} \in [0.13, 0.87]]\} \\ \text{white} & \text{otherwise} \end{cases}, \tag{7}$$

where $I_{x,y}$ is denoted by pixel color in the order of x-axis and y-axis directions of input image. The human skin pixels are set to the *GRAY* scale colors. Otherwise, they must be set to the white color. The GRAY scale conversion is computed by:

$$\text{GRAY}_{x,y} = 0.299R_{x,y} + 0.587G_{x,y} + 0.114B_{x,y}. \tag{8}$$

The sample result of this section is shown in Fig. 4.