Research on Non-frontal Face Detection Method Based on Skin Color and Region Segmentation

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Abstract. The detection of face region can be divided into two kinds: frontal and non-frontal faces. This thesis focuses on the detection of human face region in non-frontal cases. A method of separating face and neck region is presented to extract the non-frontal face in the image. Facial features are usually used in frontal face detection, such as eyes, mouth and etc. With complete facial features, the frontal face can be easier to detected with high accuracy now. However, the research on non-frontal face detection is just beginning. Since the non frontal face image can not provide complete facial features information, it is necessary to develop a new method. Skin color is the most prominent facial feature in the non-frontal cases. It is found that the skin color has better clustering capability in YCbCr color space. According to the skin color characteristics and illumination conditions in the YCbCr color space, the Gaussian model and the Otsu method are used to segment the skin color to extract the non-frontal face region in the images. But the segmented skin color area often contains the neck region. In this paper, the contour line of the chin is fitted by illumination intensity and position information, remove the neck area and get a face region without the neck. Simulation results show the effectiveness of the proposed method for the detection of non-frontal face region.

Keywords: Non-frontal face detection · Gaussian model · Edge detection · Region growing

1 Introduction

Face detection is a kind of computer technology which can detect the position and size of faces in any digital images. Traditional face detection is aimed at frontal faces, while non frontal face is based on side faces. Traditional face detection usually uses facial features to detect face, however facial features may not be captured or only partially captured in non frontal case. Instead of facial features, skin color model will be used in this thesis. As the most prominent feature of human face, skin color is more and more widely used in face detection system. YCbCr is a kind of color space which contains illumination information. Skin color has good clustering in this color space. The distribution of Cb and Cr components of skin color is almost the same in YCbCr color space which is consistent with two-dimensional Gauss distribution. An improved Gaussian skin color model based on Otsu method has better skin color segmentation effect.

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In non-frontal cases, the segmented skin area is made up of the face region and the neck region. Typically, the face region is located above the neck region. Edge detection and eight connected domain method are used to find a suitable fitting curve between the face region and the neck region. A distinct feature in neck region is the shadow of the chin. Fitting the curve of the chin through the brightness changes in the neck area. Region growth is used to remove the are below the chin.

2 Skin Color Segmentation

2.1 YCbCr Color Space

YCbCr is a kind of color space which separating color and brightness. YCbCr can be transformed from the RGB color space [2, 9], where Y represents the brightness information, Cb and Cr on behalf of the color information. The transform matrix is as follows:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 65.481 & 128.553 & 24.996 \\ -37.797 & -374.207 & 112 \\ 112 & -93.786 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

Figure 1 shows the aggregation of skin color in YCbCr color space [3]. The blue dots represent all collected pixels in the image, and the red dots represent the skin color pixels.

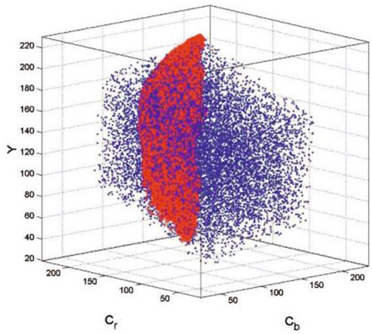

Fig. 1. The aggregation of skin color in YCbCr color space (Color figure online)

2.2 Otsu (Maximum Inter-class Variance Method)

The maximum inter-class variance method was proposed by Otsu [11] in 1978. This is a stable and commonly used algorithm which based on the principle of least squares method. In Gaussian skin color model, the selected segmentation threshold should make the difference between the average gray level of the whole image and the target area largest, the same to the non target area. Otsu can be used to adjust the segmentation threshold adaptively.

The specific algorithm of Otsu is as follows:

Gray level range is [0, L−1], the number of pixels of gray level *i* is n_i, then the total number of pixels is $N = \sum_{i=0}^{L-1} n_i$, the probability of each gray level is $p_i = \frac{n_i}{N}$, and $\sum_{I=0}^{L-1} p_i = 1$. Using threshold T to divide the pixels into c_0 and c_1, pixels in [0, T−1] belong to c_0 and [T, L−1] belong to c_1. Then the probability of regional c_0 and c_1 are:

$$\begin{aligned} p_0 &= \sum_{i=0}^{L-1} p_i \\ p_1 &= \sum_{i=T}^{L-1} p_i = 1 - p_0 \end{aligned} \tag{2}$$

The average gray level of area C1 and C2 are:

$$\begin{aligned} \mu &= \frac{1}{P_0} \sum_{i=0}^{L-1} ip_i = \frac{\mu(T)}{p_0} \\ \mu_1 &= \frac{1}{P_0} \sum_{i=T}^{L-1} ip_i = \frac{\mu - \mu(T)}{1 - p_0} \\ \mu &= \sum_{i=0}^{L-1} ip_i = \sum_{i=0}^{L-1} ip_i + \sum_{i=T}^{L-1} ip_i = p_0\mu_0 + p_1\mu_1 \end{aligned} \tag{3}$$

(μ is the average gray level of whole image)

The total variance of the two regions are:

$$\sigma_B^2 = p_0(\mu_0 - \mu)^2 + p_1(\mu_1 - \mu)^2 = p_0 p_1(\mu_0 - \mu)^2 \tag{4}$$

2.3 Improved Gaussian Skin Color Model

In the YCbCr color space, the distribution of color components Cb and Cr of different skin color tends to be consistent, which is similar to the two-dimensional Gaussian distribution N(M, C) (Fig. 2).

By calculating the probability of each pixel, a skin color similarity face image is formed. Finally, according to the segmentation threshold of Otsu, the skin color segmentation area is obtained. The probability of the pixels is calculated by the Gaussian probability density function:

$$P(Cb, Cr) = \exp\left[-0.5(\mathbf{x} - \mathbf{M})^T \mathbf{C}^{-1} (\mathbf{x} - \mathbf{M})\right] \tag{5}$$

X is the Cr and Cb value of sample pixels in YCbCr color space, $x = [Cb.Cr]^T$, M is the sample mean value of Cr and Cb, M = E(x), C is the variance matrix of skin

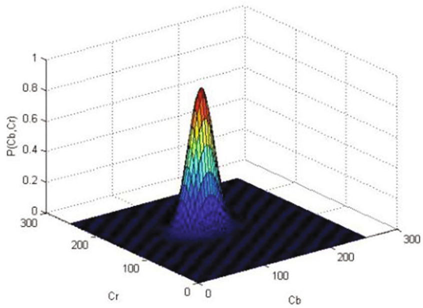

Fig. 2. Two dimensional Gaussian distribution of skin color in YCbCr color space

color similarity model, $C = E((x - M)(x - M)T)$. Through a large number of simulation experiments, it is concluded that the mean M and variance C values are:

$$\mathbf{C} = \begin{bmatrix} 160.130 & 12.1430 \\ 12.1430 & 299.457 \end{bmatrix}$$
$$M = (148.5599, 117.4361) \tag{6}$$

Gaussian skin color model [8] transfer the RGB image into gray image. The gray value of pixels is represented by the possibility which pixels belonging to the skin area. Then, the gray image can be further converted to binary image by threshold. The general method of binarization is to set the fixed threshold value, but the effect is not ideal. In this thesis, we will use Otsu to automatically adjust the threshold of skin segmentation in Gaussian model (Fig. 3).

Fig. 3. Improved Gaussian skin color model skin segmentation

3 Edge Detection and Eight Connected Domain Method

In order to realize the approximate separation of neck and face, the edge detection and eight connected domain method are used to find the suitable segmentation line [10]. Canny operator is used to detect the facial contour after skin color segmentation, and then the eight domain method is used to find the coordinates of all pixels. The eight connected domain method can detect and extract all the closed curve among all the edges in binary image. We choose the eight connected domain as the standard algorithm. As we can see, there will be only one edge curve in the skin color segmentation image. This algorithm can collect all pixels of the skin color contour (Fig. 4).

Fig. 4. Skin color contour extraction

In the experiment, because the position of the camera is fixed, the position of the mouth in the face contour is about 1/3 of the whole contour height. After the approximate segmentation, we can guarantee that the upper part dose not contain the neck, the lower is the part of the chin and neck area (Fig. 5).

Fig. 5. Separation of face region and neck region

4 Chin Fitting

A large number of experiments show that there is a linear relationship between the average brightness of the neck and the chin. Converting the neck part to YCbCr color space to extract the brightness of the pixels [1, 7]. According to the average brightness value of the neck part, dynamically adjust the threshold of the chin shadow to find the edge of the chin (Fig. 6).

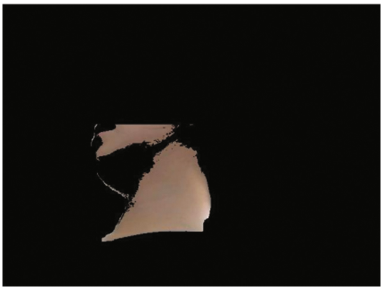

Fig. 6. Neck part chin fitting

5 Region Growing Algorithm for Neck Culling

Region growing is the process of integrating pixels or sub regions into larger regions based on a previously defined. The basic idea is to start with a set of growth points which can be either a single pixel or a small area. Combining the adjacent pixels or regions which are similar to the growth point to form a new growth point. Repeating this process until it cannot grow. The similarity judgment of growing points and adjacent regions can be gray level, texture, color and other image information. We choose gray level to judge the growth point because there will be a binary image of face.

Using eight field method to find the face contour and neck contour. In order to culling the neck area, the center coordinates of the face contour are calculated as the starting point for the region growth (Fig. 7).

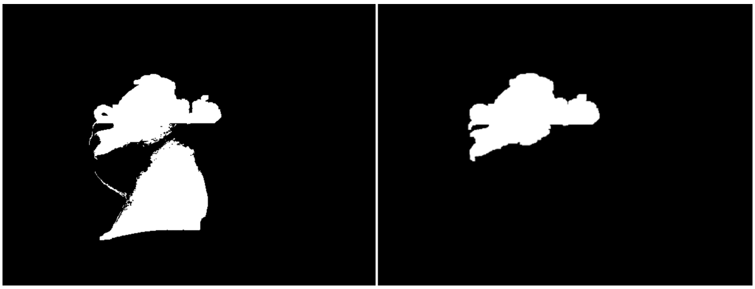

Fig. 7. Regional growth culling neck part

6 Conclusion and Further Work

The experimental results show that this method has a good effect on non-frontal face detection which can fitting the contour of the chin and culling the neck part. However, the experimental results are obtained under ideal illumination conditions. When the position and strength of the light source changed, the separation effect may be poor. Adapting to more complex conditions will be the focus of future research.

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