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RGB Color Analysis for Face Detection

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1. Introduction

1.1 Background

In our daily life, more and more application techniques based on biometrics recognition such as fingerprints, iris pattern and face recognition are developed to secure access control. Along with the development of those techniques, computer control plays an important role in making the biometrics recognition more economically feasible in such developments. Face recognition has gained an immense interest during the last decades with application taken place in many fields such as financial transactions, monitoring system, credit card verification, ATM access, personal PC access, video surveillance, *etc.* For those applications, face detection and tracking are the key processes of face recognition.

1.2 Related Work

In recent surveys on face detection, there are several researches working to solve this problem. Such as Principal Component Analysis (PCA), Neural Networks (NN), Support Vector Machines (SVM), Hough Transform (HT), Geometrical Template Matching (GTM), color analysis *etc.* based methods are used to achieve this application.

For face recognition PCA can be time consuming and this article will give quantitative data for choosing the best platform for implementing this algorithm. El-Bakry & Zhao concentrate on increasing the speed of PCA during the test phase while its performance is the same as conventional implementation. For face detection, the PCA algorithm is applied to check the presence of a face at each pixel position in the input image. This searching problem is realized using cross correlation in the frequency domain. The cross correlation is preformed between the whole input image and the eigen-values. This new idea increases the speed of the detection process compared to normal implementation of PCA algorithm in the spatial domain (El-Bakry & Zhao, 2006).

NN have been used in the field of image processing, it provides an optimistic result in terms of quality of outcome and ease of implementation. NN proved it to be invaluable in applications where a function based model or parametric approach to information processing are difficult to formulate. The description of NN can be summarized as a

collection of units that are connected in some pattern to allow communication between the units. These units are referred as neurons or nodes generally. Using NN usually require a large number "face" and "non-face" images to train respectively for getting the network model. Lin *et al.* proposed an approach combining feature-based, knowledge-based and machine learning methods for detecting human faces in color images under different illumination condition, scale, rotation, wearing glasses, *etc.* (Lin *et al.*, 2005).

The method using SVM have attracted much attention recently because it is faster and has demonstrated more excellent results than NN. Jee *et al.* proposed real-time face detection method to detect facial region using skin color and edge information simultaneously in order to complement detect of color information. They using SVM to verifying eye and face candidate o fix the face region (Jee *et al.*, 2004).

The HT transform is a powerful tool to detect the specified geometrical among a cluster of data points. Wu *et al.* use a segment-based stereo vision system to detect the three-Dimension (3-D) feature of objects which include eyes, nose, mouth, *etc.* and use a 3D HT transform to determine the plane containing the rims from the detected 3-D data (Wu *et al.*, 2002).

GTM based methods are incorporated to detect gray faces in real time applications. Face detection methods based on the representation used reveals that detection algorithms using holistic representations have the advantage of finding small faces or faces in low quality images, while those using the geometrical facial features provide a good solution for detecting faces in different poses. A combination of holistic and feature-based approaches is a promising approach to face detection as well as face recognition.

Color analysis based methods have been used and proven to be an effective feature in the applications of face detection and tracking. Although different people have different skin color, several studies have that the major difference lays largely between their intensity rather than their chrominance. Hsu *et al.* proposed a face detection algorithm that is able to handle a wide range of variations in static color images, based on a lighting compensation technique and a nonlinear color transformation. They approach models skin color using a parametric ellipse in a two-Dimensional (2-D) transformed color space and extracts facial features by constructing feature maps for the eyes, mouth, and face boundary (Hsu *et al.*, 2002). For more effective estimation of the illuminant color, in Do *et al.* proposed method, the pixels in the sclera region of the eyes are first segmented from face images captured under various illuminations. The estimated color from the sclera approximately corresponds to the illuminant color, as the pixel values for sclera region are assumed to be white under the canonical illuminant. The color values of face images are then transformed using a conversion matrix constructed based on the chromaticity values of the estimated and canonical illuminants. Lastly, use the transformed images to detect skin region in HSV color space (Do *et al.*, 2007). Not only this, other color space also have been used to detect pixels as skin region including RGB (Stokman & Gevers, 2007), HSI, YCbCr (Kumar & Bindu, 2006) and YIQ (Dai & Nakano, 1996). Color information is an efficient tool for identifying facial areas and specific facial features if the skin color model can be properly adapted for different lighting environments. However, such skin color models are not effective where the spectrum of the light source varies significantly. In other words, color appearance is often unstable due to changes in both background and foreground lighting. To solve above

problems, this chapter analyzes the feature of color instead of using the existing color space and color channel analysis based methods.

1.3 Framework of Proposed Color Feature Analysis based Face Detection Method

Fig. 1. Framework of proposed method

1.4 Our RGB Color Analysis Model

We have been developed a color analysis model in RGB color space. We propose a color feature detection algorithm based on color centroids analysis for face detection and tracking. The experiments have been made on video sequences with multiple faces in different positions, scales and poses, or the faces appear or disappear from sequence. This chapter is an extension of our method (Zhang *et al.*, 2008).

1.5 Organization

This chapter is composed by five sections. In Section 2, we introduce how to create the Color Centroids Segmentation (CCS) model from created color triangle in detail. Section 3 describes the thresholding algorithm by analyzing the color centroids region. Use CCS model to detect and track face region will introduced in Section 4. Section 5 presents the thresholding results of our approach and gives the comparative results with other thresholding methods. And we also give some detection results of various situations and compare them with some reference methods. In Section 6, we summarize this paper and propose some future works.

2. Color Centroids Segmentation Model

This section will introduce how to create the CCS model and how to use it for color segmentation. Firstly describes how to transform the three components of 3-D RGB color space to 2-D polar coordinate system for creating color triangle. Then calculates the centroids distribution region of all colors and transforms it to histogram for analysis. Finally, analyzes the histogram and gets multi-threshold to segment the centroids region. After these processes, the colors in one image can be divided to 2~7 colors by 2~7 thresholds and the result is better than traditional thresholding methods.

2.1 Color Triangle Creation

In image processing, RGB, YCbCr, HSV, HSI *etc.* color spaces are widely used. These color spaces use three components to reflect different color. *e.g.* RGB color space consists of *R*, *G* and *B* components. This chapter transforms the 3-D RGB color space (Fig. 2(a)) to 2-D polar system as the color triangle (Fig. 2(b)). The following equation shows how to transform from 3-D color cube to 2-D color triangle.

$$\begin{cases} \begin{bmatrix} \varphi_R \\ r_R \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 90^\circ \\ 0 \end{bmatrix} \\ \begin{bmatrix} \varphi_G \\ r_G \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 210^\circ \\ 0 \end{bmatrix} \\ \begin{bmatrix} \varphi_B \\ r_B \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 330^\circ \\ 0 \end{bmatrix} \end{cases} \quad (1)$$

Here *R*, *G* and *B* are the components value of RGB color space, (φ_R, r_R) , (φ_G, r_G) , (φ_B, r_B) ,

are the coordinate of R , G and B in polar coordinate system. Color triangle is created by following steps:

Fig. 2. Color triangle model

Step1: Create a standard 2-D polar coordinate system;

Step2: Create three color vectors to reflect R , G and B , the range of them are $[0, 255]$ and alternation 120° reciprocally as Fig. 2(b) R , G and B radial show;

Step3: Connect the three apexes.

After above processes, the color triangle can be created as Fig. 2(b). For different R , G and B , the shape of triangle is changeable. For example, Fig. 2(c) show three sets of R , G and B and their corresponding color triangles. From this example, it can be seen that no matter the R , G and B values change the main structure is unmodified.

2.2 Centroids Hexagon

Because the direction of R , G and B vectors are fixed and the value range are $[0, 255]$, different combination of R , G and B represents different color, and the shape of color triangle is different too. The different shape triangles have different centroids and all centroids result in a hexagon region shown as Fig. 3. This hexagon is divided to 7 regions: M (Magenta), R (Red), Y (Yellow), G (Green), C (Cyan), B (Blue) and L (Luminance, achromatic) regions. So we may use seven threshold curves as the separating lines for thresholding.

Observe the relationship between color and its corresponding centroid position of color triangle, we find that if the R , G and B values are close, no matter small or large, it only

reflect the luminance information (weak color information). So the centroids of corresponding color triangles will locate in a circular region (L region). And other six color regions reflect the color feature of R , G and B components.

Fig. 3. Color centroids segmentation model

3. Color Centroids Segmentation Model Based Color Segmentation

3.1 Multiple thresholds Selection

Considering the L region usually is not the goal region and the existing method cannot effectively divide white and black region which are noises, cluster them into one region can effectively to overcome the influence from white, black and other achromatic regions. Here we let r_L as the threshold of L region (radius of L region), φ as the angle, the function of threshold curve is:

$$r(\varphi) = T_L, (0^\circ < \varphi \leq 360^\circ) \quad (2)$$

The other six regions which around the L region as following formulas show:

$$\left\{ \begin{array}{ll} M \text{ Region:} & \varphi_B \leq \varphi \leq \varphi_M, \quad r_M > r_L \\ R \text{ Region:} & \varphi_M \leq \varphi \leq \varphi_R, \quad r_R > r_L \\ Y \text{ Region:} & \varphi_R \leq \varphi \leq \varphi_Y, \quad r_Y > r_L \\ G \text{ Region:} & \varphi_Y \leq \varphi \leq \varphi_G, \quad r_G > r_L \\ C \text{ Region:} & \varphi_G \leq \varphi \leq \varphi_C, \quad r_C > r_L \\ B \text{ Region:} & \varphi_C \leq \varphi \leq \varphi_B, \quad r_B > r_L \end{array} \right. \quad (3)$$

In formula (3) and (4), r_L , φ_M , φ_R , φ_Y , φ_G , φ_C and φ_B are the thresholds, and the initial value of them is 5, 60°, 120°, 180°, 240°, 300° and 360°.

The seven thresholds can divide all colors in one image into seven clusters and the result is shown in Fig. 4(b). But these thresholds cannot always get ideal result for different image scene. So we propose an automatic threshold selection method to get the suitable threshold for different images.

3.2 Automatic Multi-threshold Acquisition

By observing the distribution of color centroids in hexagon as Fig. 4(d), we can see that the centroid distribution of different color is different, only when the $R = G = B$, the centroids are same and it is the origin of hexagon. The color information is stronger; the centroid is more far away from origin. For example, $(R, G, B) = (255, 0, 0)$ is the pure red color and its centroid is the up peak point in Fig. 3. But threshold curve determination in Fig. 4(d) is not easy. For display the distribution feature more clearly, we transform the centroids hexagon distribution in Polar coordinate system to histogram distribution in Cartesian coordinate system as shown in Fig. 4(e). In the Fig. 4(e), horizontal axis is φ ($\varphi \in (0^\circ, 360^\circ]$), vertical axis is r ($r \in [0, 85]$) and other six vertical color-lines are threshold curves ($\varphi_M, \varphi_R, \varphi_Y, \varphi_G, \varphi_C$ and φ_B).

To segment goal region ideally, the thresholds must be calculated accurately. Because the histogram is not smooth, so we use one-Dimension (1-D) iterative median filter to smooth it for analysis. Through many experiments and observation, we define the adjustment range of threshold curves from left 20° to right 20° and find the left and right valleys respectively in this range by histogram analysis method. For r_L , we define the range from 3 to 15 and calculate the average value of each valley bottom (one color region only calculate one minimum value). After this process, Fig. 4(c) can be got.

Fig. 4. Color centroids distribution selection

4. Face Detection and Tracking

4.1 Thresholding

By analyzing the color features introduced above, the thresholding results can be acquired to detect face region in color image.

4.1.1 Color Centroids Segmentation for Thresholding

The CCS can overcome the shortage of existing methods which based on color information, because it can conquer the influences of color and luminance. The proposed method calculates the direction of color and clusters the dark and light region into one cluster which will result in removing some noises. By analyzing many sample color of face region, we find that it always distributes in the range of $50^\circ \sim 150^\circ$ and shown in Fig. 5(a). So we only need to calculate the φ'_M , φ'_R and r_L for time saving. The pre-face region:

$$r(\varphi) = r_{Face}, \quad (\varphi \in [\varphi'_M, \varphi'_R], r \in [r_L, 85]) \quad (4)$$

Fig. 5. Sample face region centroids distribution

Then the method described in Section III is used to select thresholds φ'_M , φ'_R and r_L to get the threshold curves for thresholding. Other thresholds keep invariant as initial values without calculation. By this way, the binary image can be got as Fig. 6(b). From the result we can see that sky, background, white scarf and red cloth region are clustered to black and only the face color similar regions are clustered to white. Through this processing, many noise can be removed, especially the excessive bright, dark and different color regions. But because some color of background and cloth is close to the face region color, it is clustered to pre-face region.

4.1.2 Nonlinear Thresholding for Correction

Despite the CCS thresholding can get better result, but it cannot remove some noises caused by dark color regions. To denoise them, this paper uses the nonlinear thresholding method to correct the binary image acquired by CCS. Considering the gray values of the dark color

is lower, apply the nonlinear transform described as equation (5) to transform gray images to divide it into 2 clusters; finally apply inverse transform to get the binary image. Fig. 6(c) is the binary image by nonlinear thresholding.

$$f_{Binary}(x, y) = \frac{\ln[1+255f_{Original}(x, y)]}{k \ln[1+255]} \quad (5)$$

Where, k is the number of cluster, here $k=2$. From Fig. 6(c), it can be seen that the background of binary image with white color and scarf region has been clustered to same value with the face region by nonlinear thresholding, so it is hard to separate the face. But this binary image can overcome some shortages of CCS, for example the dark color regions. Sometimes, the centroids of some bright regions are also in the goal region, but in fact they are noise regions. So use formula (6) to correct image processed by the CCS based method with "and operation".

$$f_{Final}(x, y) = f_{CCS}(x, y) \cap f_{Nonliner}(x, y) \quad (6)$$

After this, it will get the ideal result. Fig. 6(d) shows the corrected binary image and from this we can see that have been ignoring many noise.

Fig. 6. Proposed thresholding method

4.2 Pre-face Region Decision

Once the ideal binary image is got, median filter is used to denoise and show in Fig. 7(b). The white region is the wait-decision region, it maybe include face, hand, skin region and other close color regions (the white region on Fig. 7(b)). Here all wait-decision regions are analyzed in a selection process and some of them will be accepted by the aspect ratio and size.

Accepted by size:

Calculate the average area S_{Ave} of all wait-decision regions; delete the regions whose area is larger than 50% or smaller than 0.25% average area. If the area of face $S_{Face} \in [0.8S_{Ave}, 1.2S_{Ave}]$, it will be accepted as Fig. 7(c).

Accepted by aspect ratio:

$$C = 4\pi S / L^2$$

(8)

Where C aspect ratio, L is the perimeter of boundary and S is the area of wait-decision region. If $C \in [1, 1.7]$, it will be accepted as Fig. 7d).

Fig. 7. Face region decision

4.3 Face Region Tracking

After face region is fixed, it need use a circle to draw it. Here we pass the following steps to achieve this:

Step1: Use the binary face region as the mask to detect the face region from original image. It shows as Fig. 8(a).

Step2: Calculate the width of the detected face region. Then scan from top and bottom to middle line by line respectively. If the total pixels of line are less than half width, it will be deleted as Fig. 8(b).

Step3: After that, calculate the height of Fig. 8(b) and scan from left and right to middle row by row respectively. If the total pixels of row are less than half height, it will be deleted as Fig. 8(c).

Step4: Because of the eyes and mouth region is usually darker than face skin, divide the face region to 16 sub-blocks as Fig. 8(c). Then maximum entropy method is used to thresholding them respectively, shown in Fig. 8(d).

Step5: Remove noise point by median filter and find all pre-eye and pre-mouth regions in the inscribed circle of face region as Fig. 8(e).

Step6: Fix eyes and mouth region by aspect ratio and occupancy as follows:

Aspect ratio: between 0.2 and 1.7.

Occupancy: between 0.5% and 4% of face region.

Step7: Calculate the area centroids of eyes and mouth respectively as the red point in Fig. 8(e).

Step8: Draw a circumcircle (blue circle in Fig. 8(e)) of triangle which is created by the three centroids. Then use concentric circle multiplied by 1.5 to mark face (green circle in Fig. 8(e)).

Fig. 8. Face tracking process

5. Experimental Results

All the experiments are achieved using Matlab 7.0 on a Celeron M 1.73GHz platform with 2G memory. And all experiment sample images are searched from internet and reference paper.

5.1 The Result of Proposed Method

5.1.1 Thresholding results and comparison

Fig. 9 shows an example with complex background under outdoor situation, (a) is the original image; (b) is the thresholding result by proposed method; (c)~(f) are different results by traditional thresholding methods. Fig. 9(c) is use the histogram analysis method to get the best result by hand, but it hard to select the white, pink, buff *etc* color region; (d) transform the distributing probability of original gray value to frequency domain for thresholding, by this way it cluster all bright region to one class and cannot separate the color information; (e) adopt the traditional maximum entropy method to calculate the suitable entropy for thresholding and (f) is the result of 1-D Otsu method. Compare those thresholding results, but those methods also cannot select the face region; it can be seeing that the proposed method is better than the others.

Fig. 9. Sample image thresholding with different methods

Figure 10(a) is the original image, (b) is the thresholding result by proposed method, (c) is the thresholding result by maximum entropy method, (d) is the thresholding result by histogram analysis method, (e) is the thresholding result by Otsu method, (f)~(i) show the nonlinear thresholding result in every channel of CMKY color space, (j)~(l) show the result of HSV color space, (m)~(o) show RGB color space, (p)~(r) show Lab color space and (s)~(u) show YIQ color space. From the comparison different channel of color space, it only one channel is fit to thresholding, but those channel of color space based method is not good for face detecting. Compare all the thresholding results, the proposed method is better than other thresholding results and color channel based methods.

(d) Histogram analysis method

(e) Otsu method

(f) C channel of CMYK space

(g) M channel of CMYK space

(h) Y channel of CMYK space

(i) K channel of CMYK space

(j) H channel of HSV space

(k) S channel of HSV space

(l) V channel of HSV space

(m) R channel of RGB space

(n) G channel of RGB space

(o) B channel of RGB space

(p) L channel of Lab space

(q) a channel of Lab space

(r) b channel of Lab space

Fig. 10. Compare with thresholding result in different methods and channel of color space

5.1.2 Face detection results

Fig. 11 is two faces image with outdoor situation. The ideal binary image (Fig. 11(c)) can be got by color feature histogram (Fig. 11(b)) analysis for face detection; (a) shows the original image and the accurately tracking result (green circle). From the Fig. 11(c) we can see that the proposed method can cluster the white scarf, pink cloth, sky, building and other dark region to one cluster. Based this ideal binary image, it will help to face detecting. Fig. 12 and Fig. 13 show the indoor image which contains more than one person under the situation. From Fig. 12(b) and Fig. 13(b), we can see that it is easy to segment the goal color region, the Fig. 12(c) and Fig. 13(c) are binary image and green circles of Fig. 12(a) and Fig. 13(a) are detected result. Usually the light-colored clothing regions have an effect on the thresholding result got by using the method based on luminance or histogram analysis. The results show that the proposed method can overcome those influences. But if the clothing region is connected with the face, the region cannot be detected. To overcome this, it need improve the face detection method to determine the pre-face regions.

Fig. 11. Detection with outdoor condition

Fig. 12. Detection with indoor condition

Fig. 13. Detection with sample background

5.2 Comparison with other paper result (Sabeti & Wu, 2007)

Fig. 14 shows a sample image from Sabeti & Wu and (c)~(f) are the results. It is easy to see that Fig. 14(e)(f) are bad thresholding results. (d) is better but include some noise from background. Both (b) and (c) are acceptable results and (b) is better than (c), because (b) lost a small region under left eye. So (c) is the best result in the five methods.

Fig. 14. Thresholding result compare with Sabeti & Wu

6. Conclusions and Future Works

We have presented a novel color thresholding method to segment the color image for temporal face detection and tracking as this chapter introduce. The experimental results demonstrate that the proposed method can detect and track faces under various conditions effectively. The proposed method calculates the color centriods distribution which created by color feature of all colors in one image to conquer the disadvantage of color space and gray based methods. After the ideal binary image got, the face can be marked correctly by the proposed tracking method. All experimental results show an excellent performance of the proposed method for different environments such as the change of room, lighting, complex background and color.

In the future, we need to complete the following items to improve the performance of our method further: 1, overcome the change of pose and view point; 2, use motion analysis for effective prediction; 3, integrate the detection and tracking information to make a face model for real-time recognition.

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