Face Detection Method Based on Color Barycenter Hexagon Model

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***Abstract*—Human face detection plays an important role in many application areas such as video surveillance, human computer interface, face recognition and face image database management. In the human face detection applications, face region usually form an inconsequential part of the images. Consequently, preliminary segmentation of images into regions that contain "non-face" objects and regions that may contain "face" candidates can greatly accelerate the process of human face detection. Most existing face detection methods [1]-[4] process the image under some assumptions, which make them applicable only under some specifically conditions. Existing techniques for face detection in color images are plagued by poor performance in the presence of variation in illumination, scale variation, variation in skin light, complex backgrounds *etc.* In this research work, we have made a color barycenter hexagon (CBH) model to thresholding the full color image at the presence of varying lighting conditions, for varied skin colors as well as with complex backgrounds and offer idea binary image for face detection. The experimental results show the successful detected face over a wide range of facial variations in color, position, scale, varying lighting conditions, orientation and expression in images from several photo collections and database.**

***Index Terms*—Face detection, Thresholding segmentation, and Color barycenter hexagon (CBH) model.**

I. Introduction

Nowadays, many applications are developed to secure access control and financial transactions are based on biometrics recognition such as fingerprints, iris pattern and face recognition. Along with the development of those technologies, computer controller plays an important role to making the biometrics recognition more economically feasible in such developments.

One of the most common and intuitionistic biometrics recognition is face recognition. In the recent years, the face recognition become popular research direction more and more, and has many applications such as mug shot matching, credit card verification, ATM access, personal PC access, video surveillance *etc.* [5] for status identification.

The first step of automated face recognition is the face detection, an efficiently algorithm of face detection is propitious to the follows recognition. For recent surveys on face detection, [6]-[10] can be referred to. These approaches use some techniques such as principal component analysis, neural networks, machine learning, support vector machines (SVM), Hough transform, geometrical template matching, color analysis *etc.*

The neural network based [11][12] methods require a large number of face and non-face images to training respectively to get the network model [8]. SVM is a linear classifier and can classify goal region in hyper plane. Geometrical facial templates and Hough transform were incorporated to detect gray faces in real time applications [13]. Categorizing 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 transform methods [14]-[19], are useful cues for face detection. However the color based approaches face difficulties in robustly detecting skin colors [20][21] in the presence of complex background and different lighting conditions [22][23].

We proposed a face detection algorithm based on CBH model and it is able to handle a wide range of variations in static color images, various skin tones and with complicated background can be detected effetely.

II. CBH Model

A. Model construction

Usually the image' color can be described in different color space; usually we use RGB, YCbCr, HSV and HSI color space *etc.* In practice, we choice one suitably color space and use 3 channels to reflect it, so the color information must use 3D coordinate to describe. In RGB color space, use 3D coordinate to describe the color characteristic is easy, but use 2D coordinate reflect it and find the relation of colors is not easy. To solve this problem, the color triangle of Fig. 1 is proposed, it use three vectors from origin and alternation 120° reciprocally in one plan, every vector's rang is same as the gray value from 0 to 255. Passing this way, RGB values can be reflected in 2D space. For describe this, we choice polar coordinate system and the formulas describe it:

$$\begin{cases} R: r(\varphi_R) = r_R,\ (\varphi_R = 90^{\circ}\ and\ 0 \le r_R \le 255) \\ G: r(\varphi_G) = r_G,\ (\varphi_G = 210^{\circ}\ and\ 0 \le r_G \le 255) \\ B: r(\varphi_B) = r_B,\ (\varphi_B = 330^{\circ}\ and\ 0 \le r_B \le 255) \end{cases} \quad (1)$$

Connect the three peak of RGB vectors, it can compose a triangle, observing the triangle of Fig. 1, we find that when only change the values of RGB respectively, it can create different shape's triangle and color. The barycenter's position of every triangle can be reflected the characteristic

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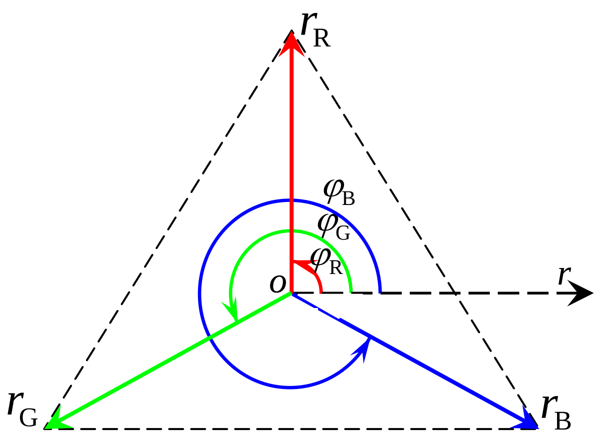


Fig.1 Color Triangle

of correspond color. Based on those analyses, it can be find that the aggregate of all barycenter show as hexagon, so the model of Fig. 2 is created. In this color barycenter model, passing segmentation the region of barycenters, the RGB color space's color can be clustering to 7 regions: RGB (Red, Green and Blue), CMY (Cyan, Magenta and Yellow) and W (luminance) regions. In practice application, the proposed model can clusting the image to 2 ~ 7 color regions.

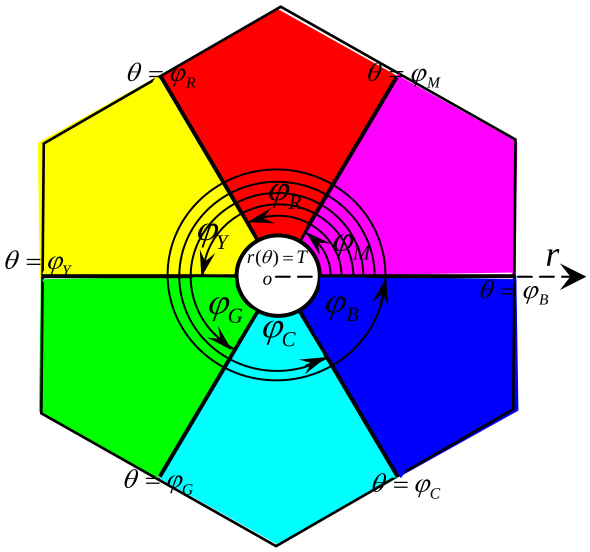


Fig. 2 Color Barycenter Hexagon Model

To use this method, it needs 7 thresholds to calculate the threshold carves and then use those carves to clustering. The following section will introduce the thresholds' range and how to get them.

B. Threshold selection

Section A introduces how to create the CBH model and the strongpoint; this section will introduce how to get the thresholds and how to use the model.

From Fig. 2 we can see it divided 7 parts, the center part of this model is a circular region, if the RGB values are close, no matter dark or light; it has little color information and only reflects the luminance. So the barycenters of those colors' triangle will in this circular region. Usually those regions are not the goal region and belong to noise, so let T as the threshold, the curve's function is:

$$r(\theta) = T, (0 \le T \le 85) \quad (2)$$

If the color has weak color information it will in this region, so threshold T cans thresholding the none-color (weak color) region. Around this circular region it has 6 color blocks can reflect 6 clusters. The follows formulas show the 6 regions:

$$\begin{cases} M: r(\theta) = r_M, (\varphi_B \le \theta \le \varphi_M, T < r_M) \\ R: r(\theta) = r_R, (\varphi_M \le \theta \le \varphi_R, T < r_R) \\ Y: r(\theta) = r_Y, (\varphi_R \le \theta \le \varphi_Y, T < r_Y) \\ G: r(\theta) = r_G, (\varphi_Y \le \theta \le \varphi_G, T < r_G) \\ C: r(\theta) = r_C, (\varphi_G \le \theta \le \varphi_C, T < r_C) \\ B: r(\theta) = r_B, (\varphi_C \le \theta \le \varphi_B, T < r_B) \end{cases} \quad (3)$$

in formula (2) and (3), T, 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°.

Based on those threshold curves, the key point is how to get the thresholds. For different images and goals, the threshold is different; this paper is using this model for face detection. So it only needs three thresholds to detect skin region, then do farther process.

Despite the face skin in different image is different, but usually the color is nearly, it only has the different of luminance. To get the thresholds, we select 50 face regions by hand, then calculate the barycenter of those colors' triangles and print on the CBH model show in Fig. 3. After observing those barycenters distributing, the values can be decided.

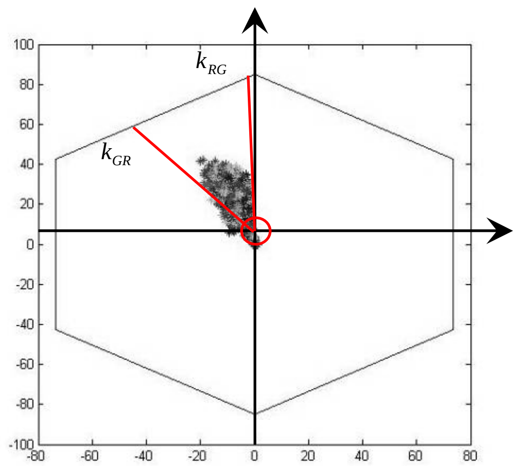


Fig. 3 Threshold Selection

III. Face Detection Based on CBH Model

A. Thresholding

1. Nonlinear thresholding

Considering the frequency of gray values can more exactly reflect it's distributing, so do the nonlinear transform with original image, then quantize to 2 clusters; lastly do inverse transform to get the binary image. The Fig. 4(a)(b) is the original image and binary image, the formula is as follows:

$$f_{binary}(x, y) = \frac{\ln[1 + 255 f_{original}(x, y)]}{k \ln[1 + 255]} \quad (4)$$

k is the number of cluster, here let k=2.

From Fig. 4(b) it can be seeing that though the nonlinear thresholding, the binary image's background with white color has been clustering to same value as the face region, so it hard to separate the face region with background. This method only fit to separate the image which foreground and background have obvious different.

2. CBH model thresholding

Use the CBH model can solve the shortage above, because the judgment rule is calculating the direction of color not the brightness, so it can let the darkly and lightly region comes to one cluster and ignore some noise.

Using the thresholds selection way as section 2, it only need select 3 thresholds to get the threshold curves for thresholding. Passing mass experiments and calculate the face region's barycenter distributing in CBH model, the thresholds can be fixed. For face detection, it only needs passing the thresholds of T, φ_M and φ_R to calculate the threshold curves, other thresholds keep the initial value and without calculate. By this way, the binary image can be got as Fig. 4(c). From the result we can see that the white background region and white collapsible are clustering to black and only the goal region clustering to white. By this way it can ignore many noise regions; especially the excessive bright or dark region and different color region, Fig. 5(b)(c) reflect the effect again.

3. CBH model correct

Some times, the bright region also can reflects some color and it's barycenter in the goal region, but in fact it is noise. For example, the hair region in Fig. 4(c), so it need use some way to denoise. Passing research, we find that for denoise the noise region and hold the goal region, it can use the binary image which thresholding by nonlinear thresholding to correct the binary image which thresholding by CBH model by "and operation" as follows:

$$f_{Final}(x,y) = f_{Nonliner}(x,y) \wedge f_{CBH}(x,y) \qquad (5)$$

Fig. 4(d) is the corrected result.

B. Face detection

After get the idea binary image, the face detection is easy to achieve. In this paper, we use region grow method to get the face. Find the seed for region grow is the first step, passing median filter and open/close operation, the dispersedly noise can be denoised.

Before calculate the seed, we need judgment which region include face. For judgment the region use the corresponding region at gray image then search the eyes [8][24] to judgment if the region include face.

After fixed the regions, let the midpoints of eyes as the seeds for grow, then the face can be detected as Fig. 4(e).

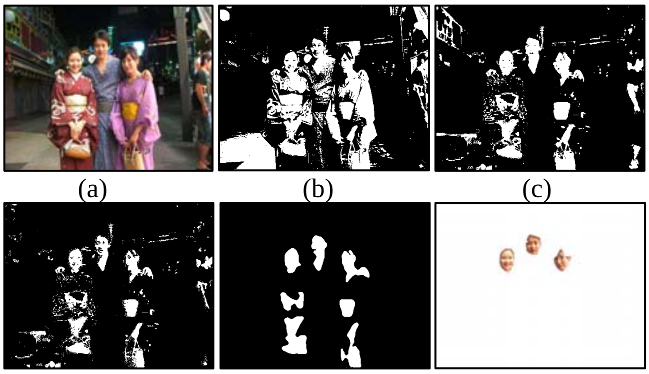
(a) (b) (c) (d) (e)

(a) Original image (b) Nonlinear thresholding (c) CBH model thresholding (d) Corrected CBH thresholding (e) Detected face

Fig. 4 Thresholding Result and Detected Face

IV. RESULT AND ANALYZE

The Fig. 5 compares the 3 thresholding result in complex background with 3 people. Fig. 5(b) is by nonlinear thresholding and the effect is good for vision, but not fit to detection the face; Fig. 5(c) is the result of CBH model and Fig. 5(d) is corrected CBH method. For detection the face, we do the median filter and open/close operation then get Fig. 5(e) and passing some judgment Fig. 5(f) is got. Fig. 6 and Fig. 7 are the sample images and the results. Passing observe the images, is hard thresholding it by existing method, the cupboard of background of Fig. 7 has the same as face region's color direction, so it hard thresholding. But by proposed method can ignore the noise of brightly and outlying color. Fig. 8 is one group detected face result and the result effect is good for do ROI compress and face recognize.



(a) (b) (c)
(d) (e) (f)

(a) Original image (b) Nonlinear thresholding in RGB color space (c) CBH model thresholding (d) Corrected CBH thresholding (e) Filtering and open/close operation (f) Detected face region

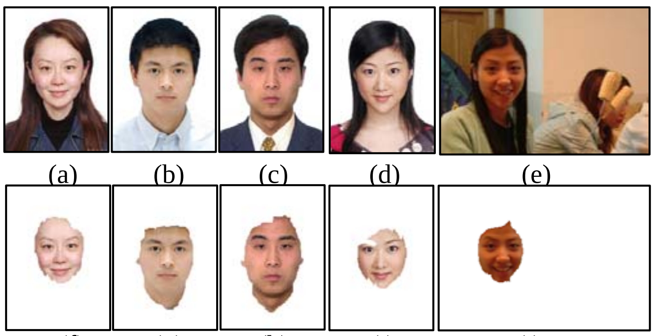
Fig. 5 Sample Image1

(a) Original image (b) Proposed method (c) Detected face

Fig. 6 Sample Image2

(a) Original image (b) Proposed method (c) Detected face

Fig. 7 Sample Image3



(a) (b) (c) (d) (e)
(f) (g) (h) (i) (j)

(a)~(e) Original images (f)~(j) Detected face

Fig. 8 Other Sample Images

V. Conclusion and Future Work

Through result image with the proposed method, it can detect faces under varied conditions effective. Our detection algorithm takes the color image and applies CBH model to detect the valid skin regions. Then use the binary image which quantized by nonlinear thresholding to correct the binary image which thresholding by CBH model. Then use the eyes detection in the region of corrected CBH model to judgment if the face exist and use region grow method to detect the whole goal face region.

In some instance the proposed method can not get idea result, for example if the image include some regions and those region have closely color and shape of face, so is hard to distinguish it. So to conquer this kinks problem, it need combine other method to get effective result.

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