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Face Detection and Extraction Based on Ellipse Clustering Method in YCbCr Space

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ABSTRACT

In this paper a method for detecting and extracting the face from the image in YCbCr spaceis proposed. The face region is obtained from the complex original image by using the difference method and the face color information is taken from the reduced face region throughthe Ellipse clustering method. The experimental results showed that the proposed method can efficiently detect and extract the face from the original image under the general light intensity except for low luminance.

Key words: face location, YCbCr space, difference method, face extraction, ellipse clusteringmethod

1. INTRODUCTION

In the biometric recognition technologies face recognition has developed rapidly, it is regarded as an important field. Face detection impacts on the effect and the final results of face recognition system. There are many methods for face recognition, but most experimental results are based on the face database such as ORL Face Database, Yale Face Database, JAFFE, etc. These kinds of face image databases are generally without the complex background. Thus the experiments using these databases have some limitations in the real complex environment[1-4].

Face detection refers to the process of ascertaining the face location, the size and so on in the original image. The quality of face detection can affect especially the other processes such as face recognition. There are mainly 4 methods for face detection Knowledge Based Methods, Feature Invariant Approaches, Template Matching Methods, and Appearance Based Methods[5].

The shape, size, veins and color of face could be changed according to the people, time and light, which make the face detection be a complex subject. The skin color is relatively stable for face rotation, face expression, and the parts occluded by glass, a cap, and a scarf, which is independent on the specific feature of face. Thus the skin color is an effective factor for face detection. There are many methods for face detection such as the neural networks, wavelet transformation, mosaic diagram method and so on. These methods are based on the statistics or the structure analysis of facial feature and need many analytical procedures with many training samples and are noise-sensitive[6-9].

This paper proposes a face detection method based on the skin color, which ascertains the face region in YCbCr space using difference method, and extracts the skin color information by the ellipse clustering method in the acquired faceregion.

As it is not necessary to train by a large quantity of samples and don't require the intensive computations, its implementation are easy and speedy, it

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has a promising application prospect on the face detection in the practical systems.

2. ELLIPSE CLUSTERING METHOD IN YCBCR SPACE

Rein-Lien Hsu and Anil K.Jain had selected the 853571 pixels of skin color among 137 images from the image library of Heinrich Hertz Institute and projected them in the YCbCr space and the 2D projection in the Cb-Cr subspace. They got the results shown in the Fig. 1. The red part is the region of the gathered skin color.

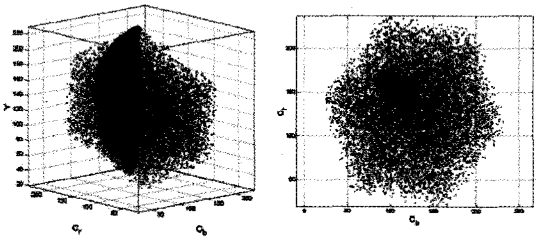


Fig. 1 Projection of skin color in color space (a) Skin color in YCbCr space. (b) Skin color in Cb-Cr space[8].

The mode is mainly about making the skin color information be nice clustering characters in color space of some color by the color encoding transformation. Thus the face location and detection can be simplified and the YCbCr space that can separate the luminance of the color. No luminance consideration but only the hue consideration should be taken to lessen the light impact on the image. Then the skin color region separated by the nonlinearly skin color segmentation in the Cb-Cr space is close to ellipse denoted as the equation (1)[10].

$$\frac{(x-ec_x)^2}{a^2}+\frac{(y-ec_y)^2}{b^2}=1 \qquad (1)$$

where $\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} C_b - cx \\ C_r - cy \end{bmatrix}$,

the constants are cx = 109.38, cy = 152.02, θ =2.53,ec_x = 1.60 ec_y= 2.41, a = 25.39, b = 14.03. The skin color region in the image can be detected by the equation (1).

3. DIFFERENCE METHOD IN YCBCR SPACE

3.1 YCbCr Color Space

The space modes for the image gathering devices are RGB, HSV, YCbCr color space and so on. HSV respectively represent Hue, Saturation, and Value, YCbCr respectively represent Y = Luminance, Cb = blueness, Cr = redness. These color spaces have good characteristic capability of separating the luminance from color[11].

HSV and YCbCr color spaces are more adopted in most of the color separation methods as it can well decrease the disturbance of light during the processing of separating the skin color from other colors. In RGB space when the color changes by light, the corresponding values of R, G and B change simultaneously. However, if the same color value is transformed into YCbCr space, the color doesn't change but only the luminance changes. As shown in Fig. 2, when the color becomes dark under the effect of light, the RGB values are changed gradually from RGB (210,210,210) to RGB (170,170,170). In the corresponding YCbCr color space only the luminance value of Y is changed from 210 to 170, but the other color values, Cb and

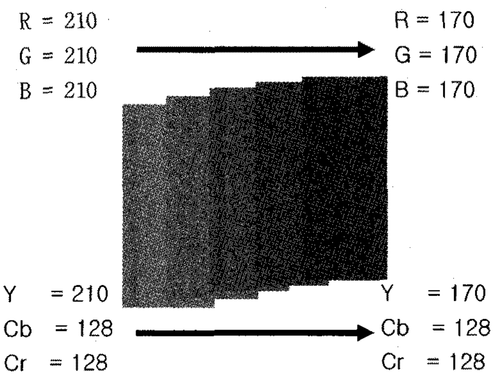


Fig. 2. The color values of RGB and YCbCr affected by light.

Cr keep the same values as 128. Thus the isolated threshold value can be given to the luminanceY when the difference method is used in YCbCr space.

On subtracting between color A (R, G, B) and color A'(R', G', B') in the same location of two images, the threshold in RGB space are set as R-R'< 3, G-G'< 3 and B-B'<3 at threshold value = 3, and the two dots can be determined as the same color.

In the case of Y-Y'<7, Cb-Cb'<3 and Cr-Cr'<3in YCbCr space, the two dots can be determined as the same color. For instance, as shown in Fig. 3, if dot A (255,255,255) is changed into A' (251,251,251) under the effect of light, then the difference between dot A (255, 255, 255) and dot A' (251,251,251) is obtained in RGB space. If the difference |A-A'|, the results of R-R', G-G',B-B' are greater than the given threshold value of 3, then it is determined as the different colors. However, if the color value of the corresponding two dots are A (255,128,128) and A' (251,128,128) in YCbCr space and the difference between Y and Y' = 255-251 < threshold value 7, then it is determined as the same color.

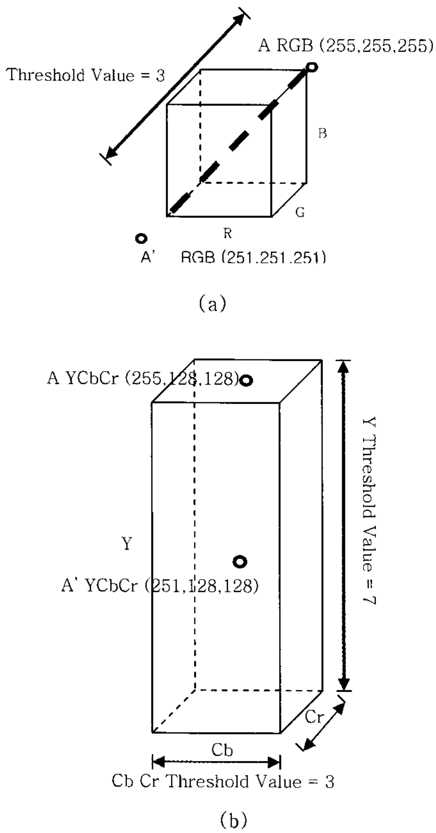


Fig. 3. The threshold values in the difference method (a) The two dots with different colors at the threshold value 3 in RGB space. (b) The two dots with the same color at the luminance threshold value of 7 and the color threshold value of 3 in YCbCr space.

Dot A and dot A' are determined as the same color in the YCbCr just because a broader threshold value can be adopted independently to the luminance Y. That's also the reason why YCbCr space has a character of eliminating effect of light. Becausethe luminance and color can be divided, different threshold value can be given to luminance and color value.

Although the character of luminance and color separation exists in the HSV color space, it has a complex transformational relation with RGBspace and is not favorable for the calculation. The transformation relation of RGB system and the YCbCr color system is as the equation (4).

$$\begin{bmatrix} y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.229 & 0.587 & 0.114 \\ -0.1687 & -0.3313 & 0.5 \\ 0.5 & -0.4187 & -0.0813 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} \tag{2}$$

The difference method is adopted to the YCbCr space to eliminate the impact of light because of its advantages of luminance separation. The ellipse clustering method in the following section is also adopted to the YCbCr space, thus the transformation for colors space isn't required and we can save the computation time.

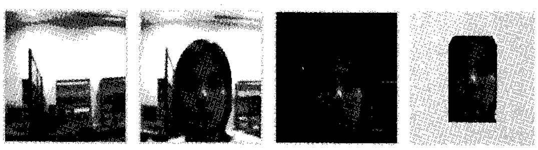
3.2 The Realization of Difference Method in YCbCr

The plan for presetting the background is to store a background without human's face image and then make subtracting between the face image shot by the camera and the background to identify the general body location and finally to test the face location. The image processing consists of mainly 5 steps as the follows.

(1) Project the background Fig. 4.(a) and test image of Fig. 4.(b) into the YCbCr color space.
(2) Make subtraction between the background Fig. 4.(a) and the image of Fig. 4. (b).
(3) Extract the margin of the binary image on the basis of the difference. If the skin color is determined, the skin color region can be detected more easily. As is shown in Fig. 4, the skin color region based on realization is detected. Thus the coming processing can be implemented more exactly.
(4) Ascertain the correct face location by the vertical projection first and then horizontal projection.
(5) Mark the face in the rectangle frame using the projection result, as shown in Fig. 4 (d).

The key point of horizontal is to find the location of the head top through the non-zero pixels and the head feature. Suppose the *f(x,y)* binary image with a size of N×M and non-zero pixel of *T*, and the number of non-zero pixel dots in the *i*th column is px[i], the number of none-zero pixel dot in the section from right to left in the *j*th row is py[j], and the equations are as (3).

$$\begin{cases} px[i]=\sum_{j=0}^{M-1} f(i,j)/T & i=0,1,\cdots,N-1 \\ py[j]=\sum_{i=left}^{right-1} f(i,j)/T & j=0,1,\cdots,N-1 \end{cases} \quad (3)$$



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

Fig. 4. The gathered general face region using difference method in YCbCr space (a) Background image. (b) Test image. (c) Face color region. (d) Face region.

As shown in Fig 4. (d), most of the background image is removed and the face region is extracted. This faceregion image is used in the ellipse clustering method for getting the skin color information and the related computations are considerably reduced because of no background image.

4. FACE EXTRACTION USING ELLIPSE CLUSTERING METHOD IN YCBCR SPACE

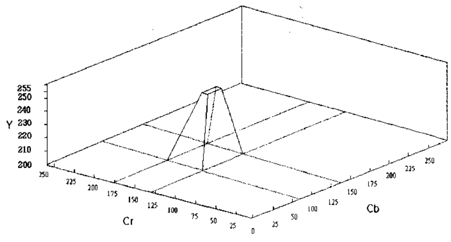
If there is the color region similar to or the same color as the skin color in the background image, it's mean that it can be projected into the red region of Fig. 1. (b), thus it makes the detection and extraction of face information more difficult and complex.

4.1 Skin Color and Its Statistics in YCbCr Space

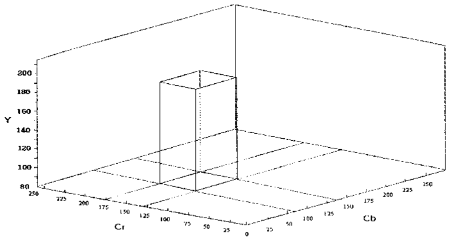
Taking account of the influence of light, the luminance is divided into three regions of 0~80, 80~200, and 200~255, and the ranges of skin color CbCr values in the environment are changed under the influence of light:

(1) When the luminance is in the range of 80~200, the range of skin color value are $77 \le Cb \le 127$ and $133 \le Cr \le 173$
(2) When the luminance is in the range of 0~80, the range bounds of skin color value are changed gradually from $77 \le Cb \le 127$, $133 \le Cr \le 173$ to $120 \le Cb \le 132$, $128 \le Cr \le 135$. These ranges form a stereoscopic inverted trapezia as Fig. 5 (c).
(3) When the luminance is in the range of 200~255, the ranges of skin color are changed gradually from $77 \le Cb \le 127, 133 \le Cr \le 173$ to $116 \le Cb \le 131$, $127 \le Cr \le 148$, and form a stereoscopic trapezia as Fig. 5 (a).

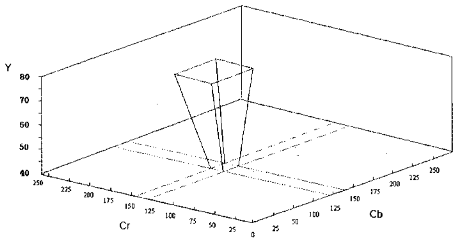
When the luminance is less than 40, the image becomes ash black and isn't able to use for face extraction. However, the eyebrows, eyeballs, hair,



(a)



(b)



(c)

Fig. 5. color regions in the different luminanceSkin values region (a) The range of 200 ~255. (b) The range of 80~200. (c) The range of 40~80.

and so on are always in these regions. Thus these regions can be determined as non-skin color region.

YCbCr space only with skin color is divided into three spaces as in Fig. 6. Thus the face color information can be finally extracted through different non-linear segmentation in these three spaces.

First of all the difference method is applied to Fig. 4.(b) and then the ellipse clustering method is applied to Fig. 4.(d), this sequence leads to get better data for the second method. The image extracted from the original image with complex background by using ellipse clustering method-makes a wrong judgment because the extracted image includes some useless image data. If we project Fig. 4.(d) in YCbCr space, the impact occurred from complex background on the whole face detection process can be completely eliminated. This means that the red regions in Fig. 1. (a) and (b) don't include complex background and color information similar tothe skin color, by which the most information in YCbCr space is all the color information of human body.

At the moment we can just concentrate on the lowest luminance region such as hair, eyeballs, eyebrows and the highest luminance region like the white parts of eyes, and then we can well separate the skin color information and other information by using the ellipse clustering method. The color information in face region and finally the skin color-can be extracted only by amending the constant of the equation (3).

4.2 Procedure for Extracting Face Color Information

The procedure to get the face color information from the original image is as follows.

[Step 1] Apply the difference method to the original image for getting the face region and eliminate human body by projection method

[Step 2] Apply the ellipse clustering method to the faceregion and separate the skin color and the other color information in Cb-Cr space.

(1) In the luminance value range of 80~200, amend the coefficient of equation(3) as follows: a=28.39, b=16.03, cx=124.38, cy=152.02, radian Θ is kept the same.

(2) In the luminance value range of 40~80, expand the major and minor axis of ellipse equation (3) by 1.2 times

(3) Judge the pixel unit that the luminance 40 below as non-skin color region (namely these are eyebrows, eyeballs and hair, eyes excluding white parts)

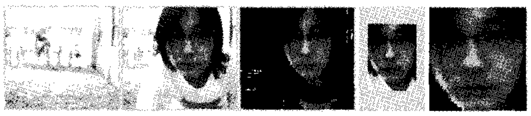
(4) In the luminance value range of 200~255, expand the major and minor axis of ellipse equation(3) by 1.3 times

[Step 3] Project the color information of the skin region onto the new image.

5. EXPERIMENTAL RESULTS AND CONSIDERATIONS

The image processing was programmed in Matlab7.0 in which two images were used in complex background with the human body as a "to-be-identified object" or without it in the size of 512×512 at the same location. The 200 images were respectively taken in the laboratory rom and outside office building in the campus. All the experiments were performed at Windows XP PC.

Several groups of experimental processes were performed under the various intensity of light. Fig. 6 is the case of the abundant light source and Fig. 7 is the case of a stable light intensity of background with a transformative distance between the head and camera from far distance to near distance or to very near distance. Fig. 8 is the case of multi-tiered transformation of light source of background. Fig. 9 is the case of insufficient light source. From Fig. 6 to Fig. 9 respectively, (a) is



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

Fig. 6. The case of the abundant light source.

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

Fig. 7. The case of a stable light intensity of background from the different distances.

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

Fig. 8. The case of multi-tiered transformation of light source of background.

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

Fig. 9. The case of insufficient light source.

the background image, (b) is the to-be-detected face image, (c) is the skin color determination of human body region detected by the difference method, (d) is the face region lined out by projection method, and (e) is the face color information extracted by the ellipse clustering method for a dim light source.

The effect of Fig. 9 (d) and (e) are not obvious and Fig. 9 (f) is the image extracted the skin color region. Fig. 9 (c) is the obtained human body by the difference method. As shown in Fig. 9, the most special case that the face region color almost can't be detected generally occurs when the environment is extremely dark or extremely bright. However, the obtained human body region is almost without any noise by difference method in this case. Thus the face region can be detected by the projection method[12].

The experimental results prove that the white light is helpful for increasing the identity rate because the face color information can be easily identified through white color. Table 1 is the comparison of the three detection methods under the different light intensities.

In Haar Wavelet method the training samples should be adopted and only the face region can be detected. While using Wavelet neural networks method, training samples should also be adopted, by which the face color information can be extract-

Table 1. The Comparison of Correctness Rate(%) in Three Methods

Light Intensity	Proposed Method	Haar Cascade	Wavelet Neural Networks
High Luminance	88	78	76
Normal Luminance	84	75	82
Low Luminance	65	83	70

ed more easily, but light compensation is necessary, However, this method is easily affected by light [13].

The exact face location can be detected efficiently by using Haar cascademethod. However, the wrong determination will arise when the small part that is similar to the skin color exists in the background. The reason why the proposedmethod has a wrong determination is that the same color information as the human body information exists behind the human body, the correctness rate of detection is slightly higher than Haar cascade and Wavelet neural networks method under enough light.

The partial skin color of face region changes by the effect of light under high light intensity, for which face location can be detected but can't be correctly detected by Haar cascade method and Wavelet Neural Networks. However, the proposedmethod can be adopted to correctly detect the face location because the hair is black and it is obviously different from the background with high light intensity.

In the low light intensity the detection rate of Haar cascade method rises, because the surrounding background color is obviously different from the skin color. If there isn't any small part that is similar to the skin color, the correctness rate could be 83%. Because the light intensity is too low to use the difference method and only the face location can be detected and the skin color can't be detected in the proposedmethod and Wavelet Neural Networks, the rate falls.

The experimental results indicate that the proposed method has a pretty good applicability in the environment of high light intensity and general light intensity.

6. CONCLUSION

Themethod for efficiently detecting and extracting the face from the image in YCbCr space has been addressed. First of all the complex background image is eliminated by the difference method, and the skin color information efficiently extracts by ellipse clustering method. As the light effects are alleviated in YCbCr space, the proposed method has a pretty goodapplicability in the environment of high light intensity and general light intensity. The difference method makes up the disadvantages of the ellipse clustering method that eliminates non-skin color information of human body. Thus the face information is effectively detected and extracted. The experimental results showed that the proposed method is better than the existed methods in the face detection except for low luminance. This method can be used in the real-time face detection and recognition system.

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