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The Skin Color Segmentation Algorithm Based on the Cr*A*B Color Space

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Abstract

*Skin color segmentation plays an important role in the biological feature recognition system. In order to improve the system adaptability to the complex environment, a new model of Cr*a*b by combing the YCbCr with Lab model is proposed. Firstly, establish the three-dimensional coordinate system based on the Cr, a, b axes, the two-two coordinates form the directional vectors by using the origin as the starting point. Then calculate the angles between the three vectors. Finally, realize the purpose of skin color segmentation by reducing the dimensions of angle data. Experimental results show that this algorithm can improve the over sensitive of YCbCr model to red and yellow, the defect of the skin color weak clustering in the Lab model is also overcame. Even if for the image with complex background environment, the percent of average accurate detection is about 87.7%. The proposed algorithm can get the high skin color segmentation rate and has good practicability.*

Keywords*: Skin color segmentation; Cr*a*b model; Skin color space; Hand gesture*

1. Introduction

With the development of human-computer interaction technology, biological characteristics based on the human body are widely used. Some expert systems use the hand gesture and facial expression to obtain the systematic interaction. For example, the international aviation organization requires each member country to join the biometric information in the travel document, which has the double recognition technology of face recognition and fingerprint recognition. In some countries, the identification card reserves the storage space for the fingerprint, blood and other personal characteristic data. In these systems, the research of skin color is one of the most active fields. In recently years, with the popularity of video image acquisition equipment, skin color segmentation technique has become active. At present, the typical applications of the skin color segmentation include the face recognition, hand gesture recognition, human body detection, medical diagnosis, cosmetic analysis, and so on[1-6].

The aim of skin color segmentation is to obtain the features of body for further recognition[7]. The skin color segmentation algorithms are basically divided into two categories: based on statistical model and physics model[8]. The statistical model is based on analysis of skin pixel values distribution for a training set of images[9]. Which does not involve the imaging principle, so it is also called static skin color model. The physics model uses the interaction between the skin and light, it uses the skin color reflection model and spectral characteristics to analyze image, so it is also called dynamic skin model. Many research findings had shown that the skin color has some inherent characteristics without considering the influence of environmental factors. Some researchers had carried out some work

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according to these characteristics and made some substantial progress. However, these characteristics applications are only limited in a certain light and specific background conditions, which is not ideal in the complex environment.

In order to improve the system adaptability to complex environment, in this paper, a new model of Cr*a*b by combing the YCbCr with Lab model is proposed to imply the skin color segmentation by selecting the appropriate threshold.

2. Common Color Space and its Distribution

It is important to select a proper color space for skin color detection. The skin color space mainly including the RGB, HSV, YCbCr, Lab space are usually used for skin color detection[10,11].

2.1. RGB space

Three axes of three-dimensional space in the RGB chromatic coordinates are respectively corresponding to three primary colors of red, green and blue. In the Figure1, the origin is corresponding to the black, the farthest peak from the origin is corresponding to the white, the other colors fall in the color cube consisted of three primary colors of red, green and blue [3,12].

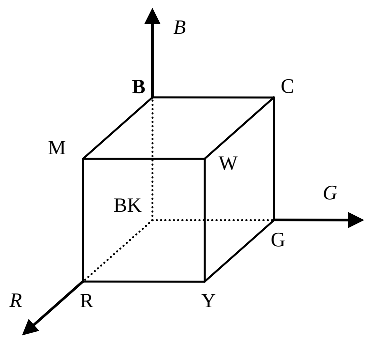

Figure 1. Rgb Color Model

In the Figure1, every letter is set according to the following rules(R-red, G-green, B-Blue, W-white, Y-yellow, BK-black, M-magenta, C-cyan).

The normalization calculation formula of RGB color space model is:

$$\begin{cases} r = \dfrac{R}{R+G+B} \\ g = \dfrac{G}{R+G+B} \\ b = \dfrac{B}{R+G+B} \end{cases} \tag{1}$$

2.2. HSV Space

The HSV (hue-saturation-value) color model is oriented to the user, which is fit for the subjective feeling color model and belongs to the nonlinear color system. It is widely used for skin detection and has been found to outperform RGB model in many researches[13]. It is corresponding to the conical subset of the cylindrical coordinate system, its model is shown in Figure 2[4].

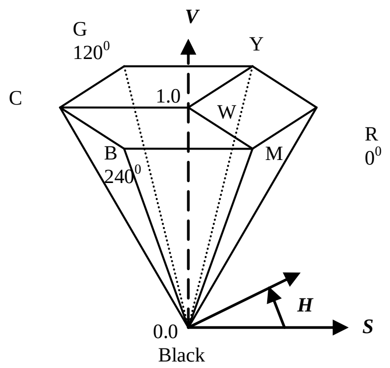

Figure 2. HSV Color Model

The color parameters in the HSV model are hue(H), saturation(S) and value(V), the three components are orthogonal. The H parameter indicates the color information, that is the spectral color position, this parameter uses a perspective to represent the 120^0 intervals of red, green and blue respectively. S is a proportion value, its range is [0 1], it represents the ratio between the purity of the selected color and the maximum purity of color. When S=0, it only express the gray. V is the brightness, its range is [0 1].

The range of RGB is [0 255], The transform formula from RGB to HSV is[3]:

$$\begin{cases} V = \dfrac{1}{3}(R+G+B) \\ S = 1 - 3\dfrac{Min\{R,G,B\}}{R+G+B} \\ TempH = \arccos\left\{\dfrac{(R-G)+(R-B)}{2\sqrt{(R-B)^2+(R-B)(G-B)}}\right\} \end{cases} \quad (2)$$

If $B \le G$, $H=Temph$, or else $H=2\pi\text{-}Temph$. The HSV color model is intuitive, if we want to get some other colors, we can specify the color point of H, and let V=S=1, and then gradually add into the white (it can reduce the S and keep the V invariant) or black (it can reduce the V and keep S invariant).

2.3. YCbCr Space

YCbCr color space is a common color model, where Y is the brightness, Cb represents the blue component of the light source, Cr represents the red component of the light source. The range of RGB is [0 255], The transform formula from RGB to YCbCr is:

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.1687 & -0.3313 & 0.5 \\ 0.5 & -0.4187 & -0.0813 \end{pmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix} \quad (3)$$

$$\begin{cases} R = Y + 1.402(Cr - 0.5) \\ G = y - 0.34414(Cb - 0.5) - 0.71414(Cr - 0.5) \\ B = Y + 1.772(Cb - 0.5) \end{cases} \quad (4)$$

2.4. Lab Space

Lab is a kind of color model. It includes all the spectrum colors that the human can see, so it is the widest color gamut of color space. Besides, each group color value corresponds to a kind of color independent of device. This color space quantized by mathematical theory makes the color of different devices compare, simulate and match.
Lab color model is converted by RGB, which includes the luminance and two color axes (a, b). a channel represents the transition of red green, b channel represents the transition of blue yellow. The positive values of these two channels represent the red and yellow, the negative values represent the green and blue.

For an image, each pixel has a corresponding Lab value. An image is corresponding to the L channel, a channel and b channel. In the Lab space, brightness and color are separated, L channel has no color, a channel and b channel only have color. This is different from the RGB color space, in the RGB color space, R channel, G channel and B channel include the lightness and color.

The value of L belongs to [0 100] (black-white), the value of a belongs to [+127 -128] (red-green), the value of b belongs to [+127 -128] (yellow-blue). The positive value is warm color, while the negative value is cool color.
The transform formula from RGB to Lab is:

$$\begin{pmatrix} L \\ a \\ b \end{pmatrix} = \begin{pmatrix} 0.2126 & 0.7152 & 0.0722 \\ 0.3264 & -0.5 & 0.1736 \\ 0.1217 & 0.3783 & -0.5 \end{pmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} \qquad (5)$$

3. Improved Algorithm

In the HSV, YCbCr and Lab space, chrominance and luminance are separate. The advantages of HSV space are: (1) conform the human eye to the color feeling. When we use the RGB color model to change the attributes of color, such as changing the tone, it must change the R, G, B three coordinates simultaneously, while it only need change the H coordinate when we use the HSV color model. That is to say, the three coordinates in HSV color model are independent. (2) the composition of HSV color model is an uniform color space, which uses the linear scale, the feeling distance of color is proportional to the Euclidean distance of points in the HSV color sense model coordinates.

The disadvantages of HSV space: color components of H, S, V are obtained by the nonlinear transformation by R, G, B, the computational complexity is high, the algorithm complexity is increased, besides, there are some singular points.

The advantages of YCbCr space: (1) in the YcbCr space, Y represents the luminance information, while the Cb and Cr are free of luminance, which can effectively separate the Y. (2) Y, Cb and Cr can be obtained through linear transformation of the R,G, B, which has the high computational efficiency. (3) the clustering characteristic of skin color is good .

The disadvantages of YCbCr space: excessively sensitive to red and yellow. It is not easy to separate red and yellow areas of the background in the process of skin color segmentation.

The advantages of Lab space: (1)its color space is larger than RGB space, this means that the color information described by RGB can be well reflected in the Lab space. (2)this model describes the visual perception of human through the digital way, which is independent to device, so it makes up the deficiency relying on the color characteristics of the equipment in the RGB model. (3) the color layers are clear.

The disadvantages of Lab space: the color samples are enormous, clustering characteristic of color points in the space is weak, which will lead to separate out the reddish in the skin color segmentation.

Based on the above analysis, the Cr*a*b model is proposed as a combination of color space by combining the advantages of YCbCr with Lab color space. Cr represents the red component of light source, a represents the red green channel, b represents the blue yellow channel. The RGB value range is [0 255], The transform formula from RGB to Cr*a*b is:

$$\begin{pmatrix} Cr \\ a \\ b \end{pmatrix} = \begin{pmatrix} 0.5 & -0.4187 & -0.0813 \\ 0.3264 & -0.5 & 0.1736 \\ 0.1217 & 0.3783 & -0.5 \end{pmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 128 \\ 128 \\ 128 \end{bmatrix} \tag{6}$$

The size of image is $m \times n$, $N = m \times n$, establish three-dimensional coordinate system based on the Cr, a, b axes, the Cr*a*b Color Model is shown in Figure 3.

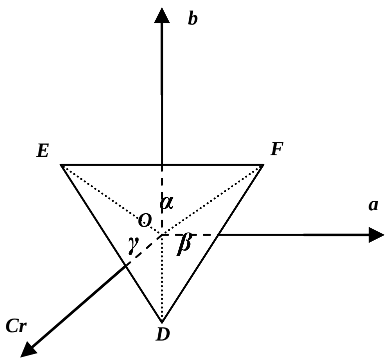

Figure 3. Cr*A*B Color Model

In the formulas (7), (8) and (9), $S(k)$ is the angle product, $\overrightarrow{OD}(k)$, $\overrightarrow{OE}(k)$, $\overrightarrow{OF}(k)$ are the vectors based on the coordinate origin as the starting point, α, β, γ are the two-two angles between the $\overrightarrow{OD}(k)$, $\overrightarrow{OE}(k)$ and $\overrightarrow{OF}(k)$.

$$\begin{cases} \overrightarrow{OD}(k) = \left(Cr(i,j)\ ,\ a(i,j)\right) \\ \overrightarrow{OE}(k) = \left(Cr(i,j), b(i,j)\right) \quad k \in [1,N], 1 \le i \le m, 1 \le j \le n \\ \overrightarrow{OF}(k) = \left(a(i,j), b(i,j)\right) \end{cases} \tag{7}$$

$$\begin{cases} \alpha(k) = \arccos\left(\dfrac{\overrightarrow{OD}(k) \times \overrightarrow{OE}(k)}{\left|\overrightarrow{OD}(k)\right|\left|\overrightarrow{OE}(k)\right|}\right) \\ \beta(k) = \arccos\left(\dfrac{\overrightarrow{OD}(k) \times \overrightarrow{OF}(k)}{\left|\overrightarrow{OD}(k)\right|\left|\overrightarrow{OF}(k)\right|}\right) \\ \gamma(k) = \arccos\left(\dfrac{\overrightarrow{OF}(k) \times \overrightarrow{OE}(k)}{\left|\overrightarrow{OF}(k)\right|\left|\overrightarrow{OE}(k)\right|}\right) \end{cases} \tag{8}$$

$$\begin{cases} d(k) = \dfrac{(\alpha + \beta + \gamma)}{2} \\ S(k) = d(k)\left\{[d(k) - \alpha(k)][d(k) - \beta(k)][d(k) - \gamma(k)]\right\} \end{cases} \tag{9}$$

The angle product of the different colors distributes in different numerical space, skin color region angle product $S(k)$ is in a particular threshold range [τ_1 τ_2], select the appropriate threshold which has obtained from many experiments, it can correctly separate the color region from the background.

The algorithm has certain tolerance to partial red or yellow of the skin color, which not only improves the over sensitivity to red and yellow in primary color space, but also improves the clustering characteristic of the skin color region.

4. Experiments and Results

Select two images of the same person with the same gesture in different background, one is the image with large contrast between the skin color and background, the other is the image with background of red, yellow and their gradient color. We do some contrast experiments using the YCbCr, HSV, Lab and Cr*a*b color model. The experimental results are shown in Figure4. In the Figure4, original image (A) is a gesture image with simple background, original image (B) is the gesture image with complex background.

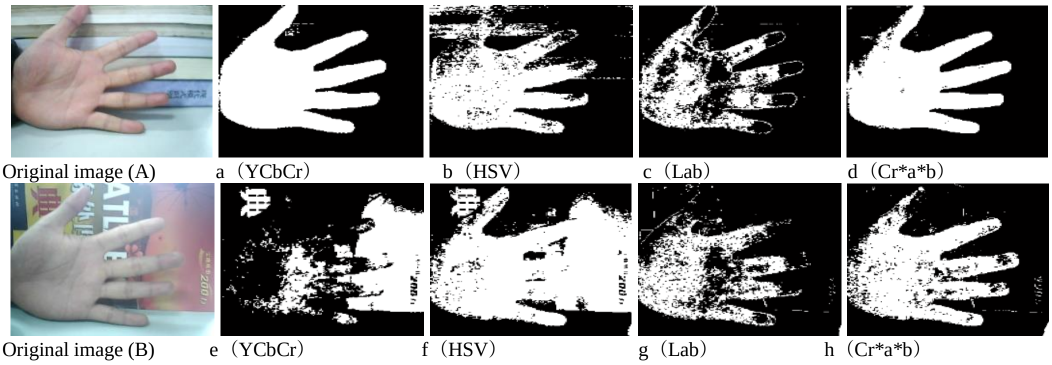

Figure 4. Contrast Experiments Using Different Models

From the Figure 4, it can be seen that: (1)for the image with simple background, YCbCr model and the proposed algorithm can accurately segment the skin regions. HSV model can effectively detect skin color, while it can mistakenly believe the non-skin color region as the skin color region. Lab model is easy to miss the partial red area of hand, such as finger and palm. (2)for the image with complex background, YCbCr model is easy to seriously disturbed by red, it will mistakenly believe red and yellow in red region as skin color region, it may even miss the rest parts of hand. HSV model can correctly detect the skin color, while it will mistakenly identify all red and part of yellow as skin color area. For the Lab model, it may miss the finger and partial red region of palm. For the proposed model, it can effectively separate the background and the skin color region, although there are some missed detections in the hand, it can still get the complete and accurate color region by the morphological filtering.

Define the correct detection numbers of skin color = color point numbers-(the error detection numbers + missed numbers). When the error numbers or missed numbers are arbitrary slants big, the correct detection rate will decrease rapidly. We use the introduced four color model to separately process 100 gesture images with size of 240×320, the related experimental data are shown in Table 1. In the Table 1,"simple" indicates there has no color background similar to the skin color, "complex" indicates there has color background similar to the skin color.

Table 1. The Experimental Results

Color space	Original image numbers	Average color points numbers	Average error detection numbers	Average missed detection numbers	Average correct detection numbers	Percent of average correct detection
YCbCr	50 (simple)	29334	746	253	28335	96.59
	50(complex)	27676	8853	5760	13063	47.20
HSV	50 (simple)	29334	4390	2947	21997	74.98
	50(complex)	27676	13262	2275	12139	43.89
Lab	50 (simple)	29334	527	6454	22353	76.20
	50(complex)	27676	661	7627	19388	70.05
Cr*a*b	50 (simple)	29334	462	737	28135	95.91
	50(complex)	27676	1232	2174	24270	87.69

From the Table 1, it can be seen that the YCbCr model and the proposed algorithm have high correct detection rate in processing the image with simple background, the percent of average correct detection even can reach above 95%, while the HSV and Lab model present the common performance, the percent of average correct detection is only about 85%. When we process these images with complex background, due to the YCbCr model is easy to be disturbed by red and yellow, the error detection and missed detection numbers increase sharply, so the correct detection rate decreases rapidly. Besides, the experimental results are not tolerate in the HSV model and the skin color clustering is weak in the Lab model. While the proposed algorithm still maintains high correct detection rate, even for the image with complex background, the percent of average correct detection is above 87%, the result is higher than other methods. It shows that the proposed algorithm has more stable and practical in the color segmentation application.

5. Conclusion

From the perspective of complex background, we propose a new skin color model of Cr*a*b based on the YCbCr and Lab model and realize the skin color segmentation by selecting the appropriate threshold. Experimental results show that the proposed algorithm can improve overly sensitive to red and yellow in the YCbCr model, it also can overcome the defect of the skin color weak clustering in the Lab model. For the image with complex background environment, it still has very good segmentation effects in the skin color region and has the virtues of the practicability, stability and adaptability.

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Reference

[1] S. J. Wang, J. Yang and M.-F. Sun, "Sparse Tensor Discriminant Color Space for Face Verification", IEEE Transaction on neural networks and learning systems, vol. 23, no. 6, **(2012)**, pp. 876-888.
[2] Z. Jin, Z Lou and J. Yang, "Face detection using template matching and skin-color information", Neurocomputing, vol. 70, **(2007)**, pp. 794-800.
[3] T. Ji and W. Wang, "A Fast Face Detection Method based on Skin Color", Journal of Convergence Information Technology, vol. 6, no. 9, **(2011)**, pp. 50-58.
[4] J. M. Chaves-González, M. A. Vega-Rodríguez and J. A. Gomez-Pulido, "Detecting skin in face recognition systems:A colour spaces study", Digital Signal Processing, vol. 20, **(2010)**, pp. 806-823.
[5] Y. Ban, S.-K. Kim and S. Kim, "Face detection based on skin color likelihood", Pattern Recognition, vol. 47, **(2014)**, pp. 1573-1585.
[6] B.-H. Oh and K.-S. Hong, "Finger Gesture-based Three-Dimension Mobile User Interaction Using a Rear-facing Camera", International Journal of Multimedia and Ubiquitous Engineering, vol. 8, no. 5, **(2013)**, pp.119-130.
[7] H.-M. Sun, "Skin detection for single images using dynamic skin color modeling", Pattern Recognition

vol. 43, **(2010)**, pp. 1413-1420.
[8] L. Sigal, S. Sclaroff and V. Athitsos, "Skin Color-Based Video Segmentation under Time-Varying Illumination", IEEE Transaction on pattern analysis and machine intelligence, vol. 26, no. 7, **(2004)**, pp. 862-887.
[9] M. Kawulok, J. Kawulok and J. Nalepa, "Spatial-based skin detection using discriminative skin-presence features", Pattern Recognition Letters, vol. 41, **(2014)**, pp. 3-13.
[10] X.-N. Zhang, J. Jiang and Z.-H. Liang, "Skin Color Enhancement Based on Favorite Skin Color in HSV Color Space", IEEE Transactions on Consumer Electronics, vol. 56, no. 3, **(2010)**, pp. 1789-1793.
[11] R. Khan, A. Hanbury and J. St. Öttinger, "Color based skin classification", Pattern Recognition Letters, vol. 33, **(2012)**, pp. 157-163.
[12] N. Razmjooy, B. Somayeh Mousavi and F. Soleymani, "A hybrid neural network Imperialist Competitive Algorithm for skin color segmentation", Mathematical and Computer Modelling, vol. 57, **(2013)**, pp. 848-856.
[13] Marami, Ermioni,Tefas, Anastasios,Pitas, Ioannis. Nutrition assistance based on skin color segmentation and support vector machines. Man-Machine Interactions2, Advances in Intelligent and Soft Computing, 2011,103:179-187.

