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TOWARDS A BIOMETRIC PURPOSE IMAGE FILTER ACCORDING TO SKIN DETECTION

Vasif Nabiyev[1] and Asuman Günay[2]

Department of Computer Engineering, KTU, Trabzon, Turkey
[1]*vasif@ktu.edu.tr*, [2]*gunaya@ktu.edu.tr*

In biometric recognition, sign language processing, automatic age estimation, gait interpretation and other image processing oriented studies, detecting various regions of the human body such as face, hands ect. has great importance. Furthermore with the rapid development of internet, building up the image filters is required. In this study a biometric purpose image filter according to skin analysis is mentioned. For skin analysis various color spaces like RGB, normalized RGB, HSV, YCbCr and TSL studied and transformations in these spaces are performed.

1. Introduction

Skin detection is an important first step in face detection, recognition, facial expression extraction, face and hand tracking and other many recognition systems. For example in face detection with neural networks (NN), the NN processes every location of the image in order to detect faces anywhere. Before this process if skin detection is applied to the image, the NN only processes skin regions, so the performance of the system increases. As well as face detection with skin analysis, if the parameters changed, regions like hair, lips can be detected. In automatic lip reading, detecting only the lip region, for gender estimation detecting head and hair information is important. Also for age estimation skin analysis for wrinkle detection is required. The skin detector can also be used as the basis for an adult image detector [1]. There is a growing industry aimed at filtering and blocking adult content from web indexes and browsers.

There have been several studies and different approaches proposed on skin color modeling and recognition. The goal of skin color detection is to build a decision rule that will discriminate between skin and non-skin pixels based on color components. In order to obtain adequate distinction between skin and non-skin regions, color transformation effectively separating luminance from chrominance is needed.

Skin detection techniques usually use color components in the color spaces, such as HSV, YCbCr, TSL or YIQ even though the input image is generally in RGB format. That is because RGB components are subject to the lighting conditions. Skin tones vary significantly within and across individuals. Furthermore the skin detection methods are insufficient when the non-skin regions closed to skin tones takes place in the image.

A wide variety of color spaces have been applied to the problem of skin color detection [2]. Which color space is the most efficient one is still a contentious question. For Shin et al. RGB and YCbCr spaces has the best performance for skin detection [3]. From Terrillon *et al*. study it can be observed that the TSL chrominance space is very effective for skin segmentation when using a Gaussian model. This is also true where illumination conditions vary [4]. Pietrowcew's study it was confirmed that the best results in skin color selection are achieved for the TSL space [5]. Sun *et al*. reported that although skin colors of different people vary over a wide range in color space, the variation of human face color with respect to hue and saturation is much less than to brightness [6].

2. Color Spaces

A wide variety of color spaces have been applied to the problem of skin detection. In this study RGB, normalized RGB, HSV, TSL and YCbCr color spaces are analyzed and transformations in these spaces are performed.

2.1. RGB (Red, Green, Blue) and Normalized RGB Space

Red-green-blue space is one of the most common color spaces representing each color as an axis. The RGB components are dependent to illumination conditions. For this reason skin detection with RGB color space can be unsuccessful when the illumination conditions change. Peer et al. defined the boundaries of skin cluster in RGB color space [7]. RGB is classified as skin if the following conditions satisfied.

$$R > 95 \,\&\, G > 40 \,\&\, B > 20 \,\&\, \max(R,G,B) - \min(R,G,B) > 15 \,\&\, |R - G| > 15 \,\&\, R > G \,\&\, R > B \qquad (1)$$

In the study we change the coefficients of R, G and B components to transform color image to gray level image. We found that in skin regions the result of (-11R-2G+15B) is negative. Additionally (2G-R+0.5B)/4 color transform is used for skin detection [8]. The results are shown in section 3.

Normalized RGB space is formed independently from varying lighting levels. The red, green, and blue components of normalized RGB space can be obtained from the three components of RGB space using the following formulation:

$$r = R/(R+G+B),\ g = G/(R+G+B), b = B/(R+G+B)\ ,\ r+g+b=1 \qquad (2)$$

The advantage of color normalization is that it can reduce the lighting effects.

2.2. HSV (Hue, Saturation, Value) Space

Hue-saturation-Value (HSV) space is also a popular color space because it is based on human color perception. Similarly, HSI (I-Intensity) and HSL (L-Lightness) color spaces are derived from HSV. The intensity, value and lightness are related to the color luminance. Hue is generally related to the wavelength of a light. Saturation is a component that measures the "colorfulness" in HSV space. The intuitiveness of the color space components and explicit discrimination between luminance and chrominance properties made these color spaces popular.

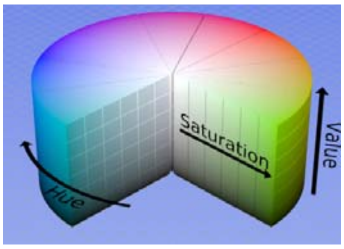


Figure 1. HSV color space

$$H = \begin{cases} 2 - \cos^{-1}\left\{ \dfrac{[(R-G)+(R-B)]}{2\sqrt{(R-G)^2 + (R-B)(G-B)}} \right. , B > G \\ \cos^{-1}\left\{ \dfrac{[(R-G)+(R-B)]}{2\sqrt{(R-G)^2 + (R-G)(G-B)}} \right. , otherwise \end{cases} \qquad (3)$$

$$S = 1 - \frac{3 * \min(R,G,B)}{I} \quad ; \quad V = \max(R,G,B)$$

(H,S,V) is classified as skin if the following conditions satisfied [9].

$$0 < H < 50, \quad 0.23 < S < 0.68 \qquad H = [0,360] \quad S = [0,1] \qquad (4)$$

2.5. YCbCr Space

YCbCr is a family of color spaces used in video and digital photography systems. Y is the luminance component and Cb and Cr are the blue and red chrominance components. The transformation simplicity and explicit separation of luminance and chrominance components makes this color space attractive for skin color modeling.

$$\begin{aligned} &Y = 0.299R + 0.587G + 0.114B, \quad Cb = 128 - 0.168736R - 0.331264 + 0.5B \\ &Cr = 128 + 0.5R - 0.418688G - 0.081312B \quad R, G, B, Y, Cb, Cr \in \{0,1,...,255\} \end{aligned} \qquad (5)$$

In this color space, a pixel is classified as skin if the following conditions satisfied [9].

$$85 \le Cb \le 135, \quad 135 \le Cr \le 180, \quad Y \ge 80 \qquad (6)$$

2.4. TSL (Tint, Saturation, Luminance) Space

A normalized chrominance-luminance TSL space is a transformation of the normalized RGB into more intuitive values, close to hue and saturation in their meaning. Tint is the mixture of a color with white. Using the following transformations the equivalent pixel representation is obtained on the ST color space.

$$T = \begin{cases} \arctan\left(\frac{r'}{g'}\right)/(2\pi)+\frac{1}{4}, & g' > 0 \\ \arctan\left(\frac{r'}{g'}\right)/(2\pi)+\frac{3}{4}, & g' < 0 \\ 0, & g' = 0 \end{cases} \qquad S = ([9.(r'^2 + g'^2)/5])^{1/2} \qquad L = 0.299R + 0.587G + 0.114B$$
$$r' = r - 1/3 \quad g' = g - 1/3, \quad r = R/(R+G+B) \quad g = G/(R+G+B) \qquad (7)$$

According to our training results, TSL is classified as skin if the following conditions satisfied:

$$0.4 < T < 0.6, \quad 0.038 < S < 0.25, \quad L >= 80 \qquad (8)$$

Except color spaces explained above, there are non-parametric methods such as Normalized Lookup Tables, Bayes Classifiers, Self Organizing Maps and parametric skin detection models like Single Gaussian, Elliptic Boundary Models to estimate skin color distribution [2 ,10].

3. Results

In this study RGB, HSV, YCbCr, TSL color spaces are used for skin detection. In Figure 2, the flow diagram of skin detection process for YCbCr is presented. After color space transformation applied to the input image, the skin region is produced according to specified intervals of color space components. Then morphological operators applied to reduce noises. Finally all small regions are searched and eliminated. The transformations in other spaces are similar.

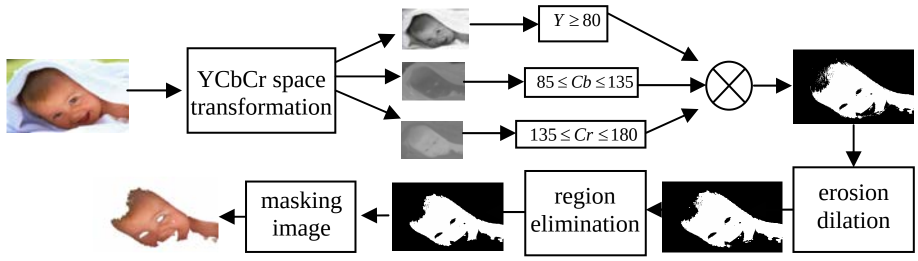
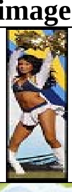
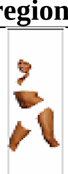


Figure 2. Flow diagram of skin detection with YCbCr color space

The performance and results of all skin detection methods are presented in Table 1 and Figure 3, respectively. In Table 1, the ratio of the number of skin pixels detected accurately to the total number of skin pixels (row 1) and the percentage of pixels detected as skin by the method (row 2) are calculated for every image.

Table 1. Performance of color spaces

Original image|	**Skin regions**		**RGB**	**HSV**	**YCbCr**	**TSL**	**-11R-2G+15B**	**(2G-R+0.5B)/4**
		**1**	**48.01**	**23.57**	**43.29**	**18.58**	**55.17**	**25.52**
		2	52.56	34.76	54.74	24.93	37.29	56.68
		**1**	**95.95**	**95.99**	**89.48**	**78.74**	**99.33**	**61.41**
		2	75.57	68.12	79.64	77.51	61.98	83.14
		**1**	**42.43**	**96.54**	**43.55**	**44.12**	**94.89**	**1.81**
		2	99.95	96.02	99.81	98.99	95.57	100
		1	**99.73**	**97.57**	**99.53**	**99.81**	**99.30**	**0.40**

		**1**	**99.73**	**97.57**	**99.53**	**99.81**	**99.30**	**0.40**
		2	98.32	95.32	98.03	96.81	94.73	55.24

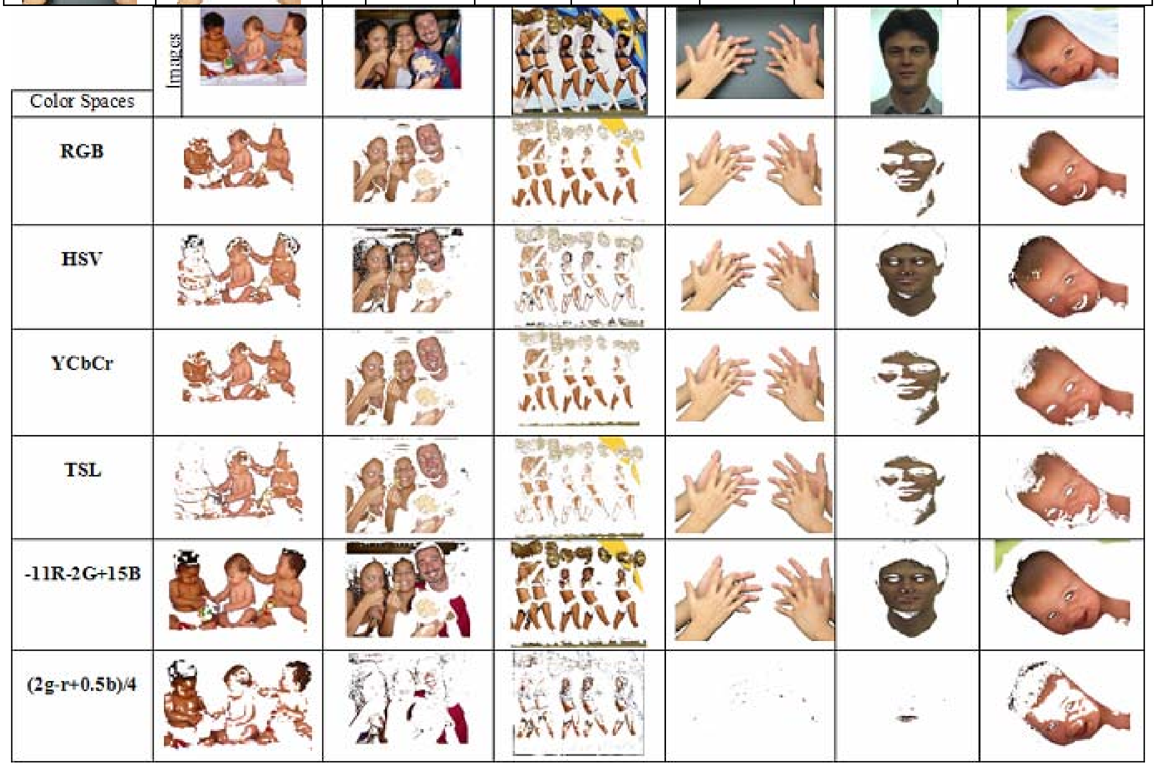


Figure 3. Comparative results of skin detection methods

Conclusion

With deeper analysis and adding an interpretation module, the decision about the pose and type of the image can be made, so the image filters can be developed. When the background is similar to skin tone, by adding the morphological information, the facial possibility of the detected part can be estimated.

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