Skin Color Segmentation Using Multi-Color Space Threshold

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Abstract— **Skin color segmentation has proven to be useful in various application, such as face detection, hand gesture analysis, image content filtering, etc. There are some challenges on skin-color detection, such as wide variety of illumination condition and skin-like color objects appear in the background of image. Therefore, a method is required to cope with illumination condition while detecting skin color. In our proposed method, we combine the chrominance channels of three color spaces, namely HSV, YCbCr and Normalized RGB, to produce better rate result for skin color segmentation. The result shows that the proposed method is able to detect skin pixel and get up to 91.05% correct result while being tested in ECU and HGR Dataset. This result is significantly higher than the other single color spaces.**

Keywords— skin color segmentation, color space, skin modeling, threshold technique

I. INTRODUCTION

Skin color segmentation is one of challenging topic for many researchers, which aims to detect human's skin region in an image. It has significant roles in various application, such as face detection [1][2], face recognition [3][4], face tracking [5], hand gesture analysis [6], objectionable image filtering [7], Content-Based Image Retrieval (CBIR) [8], steganography [9], etc. There are several factors that impact on skin-color detection, such as [10]:

- *Illumination*: The most important problem in skin color segmentation. A change in the light source distribution and in the illumination level (indoor, outdoor, highlights, shadows, non-white lights) produces a change in the color of the skin in the image (color constancy problem).
- *Camera characteristics*: The color reproduced by a camera is dependent on the spectral reflectance, the prevailing illumination conditions and the camera sensor sensitivities.
- *Ethnicity*. Skin color also varies from person to person belonging to different ethnic groups and from persons across different regions (Asian, African, Caucasian and Hispanic).
- *Individual characteristics*, such as age, sex and body parts.
- *Other factors*, such as subject appearances (makeup, hairstyle and glasses), background colors, shadows and motion.

In this research, we combine all chrominance channels from three color spaces, HSV, YCbCr and Normalized RGB, to solve some problems in skin color segmentation. Section II describes several related work in skin color segmentation. Section III discuss about skin color model that will be used in this paper. Section IV describes the proposed method. Experimental results are presented on Section V. Section VI describes the summary and suggestions for future research.

II. RELATED WORK

Skin color segmentation has been carried out in different method. The final goal of skin color segmentation is to determine between skin and non-skin pixels. There are several types of skin modelling method, namely explicitly defined skin region, non-parametric and parametric skin distribution modeling, and dynamic skin distribution models. Due to the simplicity and intuitiveness of the classification rules, the method that utilizes explicitly defined skin region has attracted many researchers [11].

The main difficulty of explicit threshold-method is to find effective skin-color threshold of color spaces. Various color spaces have been used to label skin pixel, such as RGB [12], Normalized RGB [13], HSV [14], YCbCr [15], HSI [16], YUV/YIQ [17] and combination of various color spaces. The accuracy of skin color segmentation also depends on the selection of color spaces. In 2013, Subban and Mishra [18], combined and tested 21 different combinations of two color spaces to produce better result for skin detection. They concluded that the combinations of two color spaces had produced good results with the alternate human face skin tone color as well as lighting conditions.

Therefore, this paper proposes the combination of multi-color spaces to increase the skin detection rate compared to one or two color spaces. In addition, our proposed method is to overcome the light changing or shadow noises problem in skin detection and will be tested in two dataset of image in a wide variety of illumination condition and different backgrounds.

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III. COLOR SPACE MODEL

As we mentioned above, there are many different types of color spaces used for skin detection. Due to some factors that sensitively impact on skin-color detection, they chose specific color space that is expected to become more robust to adapt to light changing or shadow noises. In this paper, we use only the chrominance channel of RGB, HSV, and YCbCr color spaces. We analyze how it affects skin-color segmentation if luminance channel is discarded.

A. RGB Color Space

RGB color space consist of three channels, Red (R), Green (G) and Blue (B) which are added together in various ways to reproduce a broad array of colors. This color space is commonly used in digital images and also in skin detection literature because of its simplicity [12]. It is visualized as a 3D cube where R, G and B are the three perpendicular axes as shown in Fig. 1.

Normalized RGB space is formed independently of the various lighting levels. Red, green and blue of the normalized RGB space can be obtained from the three components of RGB space using equation 1 to equation 3 as follows [19]:

$$R' = \frac{R}{R+G+B} \quad (1)$$

$$G' = \frac{G}{R+G+B} \quad (2)$$

$$B' = \frac{B}{R+G+B} \quad (3)$$

The third component does not hold any significant information and can be omitted because the sum of three normalized components is known ($R' + G' + B' = 1$). This causes reduction in the dimensionality of space. In previous research, Gomez and Morales [20] produced a rule for skin detection using normalized RGB, formulated as equation 4 to equation 6.

$$\frac{R'}{G'} > 1.185 \quad (4)$$

$$\frac{R'.G'}{(R'+G'+B')^2} > 0.107 \quad (5)$$

$$\frac{R'.G'}{(R'+G'+B')^2} > 0.112 \quad (6)$$

B. HSV Color Space

HSV color space is represented by three components, Hue (H), Saturation (S) and Value (V). Hue and Saturation represents the chrominance and the luminance is represented by Value. This color space is popular in color segmentation because of the explicit discrimination between the luminance and chrominance and also the intuitiveness of color space components [19]. Representation of HSV color spaces is shown in Fig. 2.

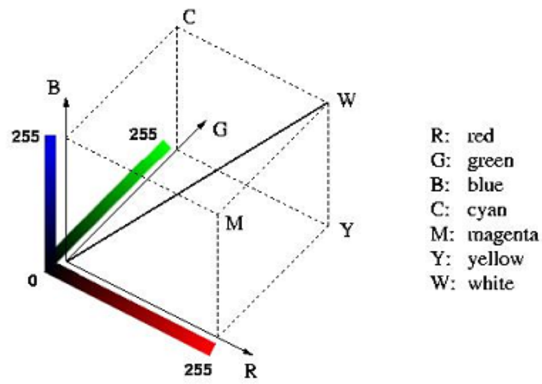

Fig. 1. Representation of RGB Color Space [19]

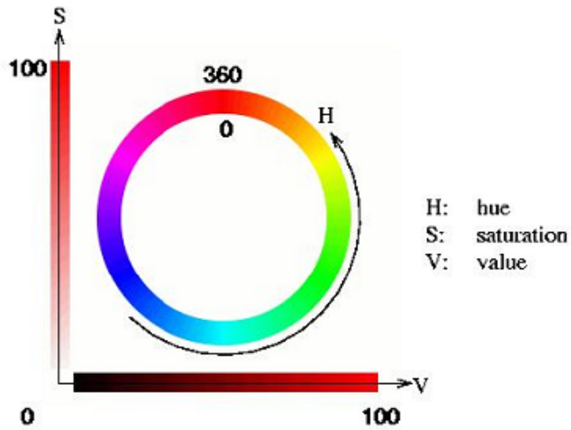

Fig. 2. Representation of HSV Color Space [19]

HSV can be obtained by converting the normalized RGB using equation 7 to equation 10 as follow [21].

$$V = \max(R', G', B') \quad (7)$$

$$S = \begin{cases} \frac{V - \min(R', G', B')}{V}, & if\ V \neq 0 \\ 0 & \end{cases} \quad (8)$$

$$H = \begin{cases} \frac{60(G'-B')}{V-\min(R',G',B')}, & if\ V = R \\ 2 + \frac{60(B'-R')}{V-\min(R',G',B')}, & if\ V = G \\ 4 + \frac{60(R'-G')}{V-\min(R',G',B')}, & if\ V = B \end{cases} \quad (9)$$

$$If\ H < 0, then\ H = H + 360 \quad (10)$$

In previous research, Tsekeridou and Pitas [22] had selected pixels having skin color by setting thresholds as equation 11 to equation 13.

$$V \geq 40 \quad (11)$$

$$0.2 < S < 0.6 \quad (12)$$

$$0 < H < 25\ or\ 335 < H < 360 \quad (13)$$

C. YCbCr Color Space

YCrCb color space has two elements, *luminance* (Y) that represents the light intensity and *chrominance* (Cb and

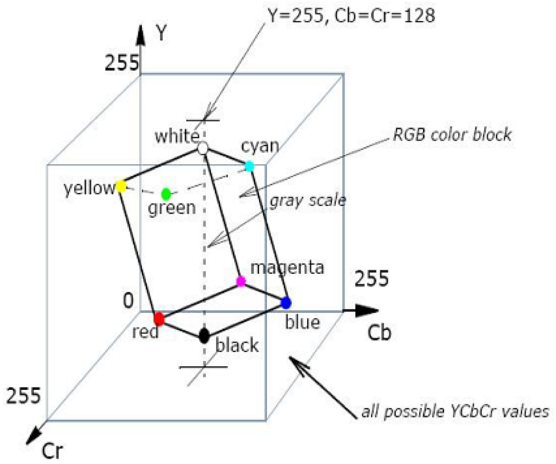

Fig. 3. Representation of YCbCr Color Spaces [23]

Cr) that represents blue-difference and red-difference chroma components. Same as HSV, it is commonly used in skin detection because of the explicit separation of luminance and chrominance and also because of the simplicity of transformation. The representation of YCbCr color space can be seen in Fig. 3 and the transformation from RGB to YCbCr is formulated as equation 14 to equation 16.

$$Y = 0.299.R + 0.587.G + 0.114.B \quad (14)$$

$$Cr = (R - Y).0.713 + delta \quad (15)$$

$$Cb = (B - Y).0.564 + delta \quad (16)$$

Chai and Ngan [24] used the chrominance components to detect pixels that appear to be skin and formulated the threshold as equation 17 to equation 18 below.

$$77 \leq Cb \leq 127 \quad (17)$$

$$133 \leq Cr \leq 173 \quad (18)$$

IV. PROPOSED METHOD FOR SKIN COLOR SEGMENTATION

Due to some factors that sensitively impact on skin-color segmentation, we use only the chrominance channel of the three color spaces mentioned above, normalized RGB, HSV and YCbCr. Fig. 4 shows the proposed method for skin color segmentation, which has four steps, and will be explained clearly in the following pseudo-code.

Step 1 : Normalize RGB value from the image using equation 1 to equation 3. Initialize value R' and G' as normalized red and normalized green values respectively.

Step 2 : Convert the normalized RGB to HSV using equation 7 to equation 10 as above. Initialize value H and S as hue and saturation values respectively.

Step 3 : Convert RGB value to YCbCr using equation 14 to equation 16 as above. Initialize value Cb and Cr as chrominance-blue and chrominance-red values respectively.

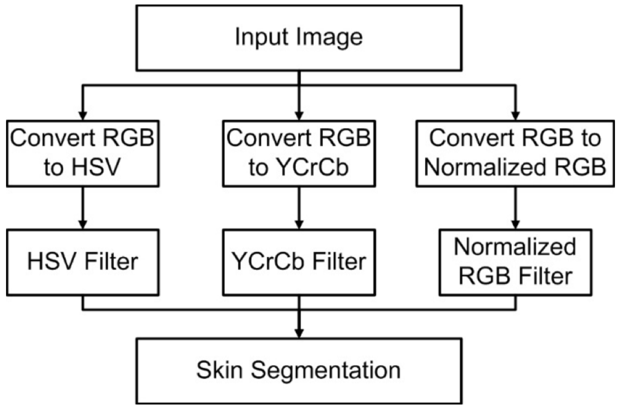

Fig. 4. General Architecture

Step 4 : Check the value of channel normalized R' (red) and normalized G' (green) using equation 4; the value of channel H (hue) and S (saturation) in every pixel of HSV image using equation 12 and equation 13; and the value of channel Cb (chrominance-blue) and Cr (chrominance-red) in every pixel of YCrCb image using equation 17 and equation 18.

```
FOR every pixels of image (x, y)
    IF NOT (((R’ / G’) > 1.185) AND
        ((H >= 0) AND (H <= 25)) OR
        ((H >= 335) AND (H <= 360)) AND
        ((S >= 0.2) AND (S <= 0.6)) AND
         ((Cb > 77) AND (Cb < 127)) AND
         ((Cr > 133) AND (Cr < 173))
    THEN
        SET RGB (x, y) = 0,0,0 (black)
    END IF
END FOR
```

V. EXPERIMENTAL RESULTS

In this section, the dataset, comparison between different color spaces and the result and analysis of the proposed method, will be discussed and analyzed separately.

A. Datasets

Accuracy of skin color segmentation also influenced by the dataset. A good method for skin color segmentation should be able to detect different skin types under a wide variety of illumination condition and different backgrounds [10]. In this research, experiments are conducted by using two datasets, namely the ECU dataset [25] and the HGR dataset [26] [27].

ECU dataset consists of 4000 color images, which include indoor and outdoor lighting with varied backgrounds and the skin types include whitish, brownish, yellowish and darkish skins. The ground-truth images were meticulously prepared by manually segmenting the skin regions.

HGR dataset consist of 899 color images of hand gesture presented by 12 individuals. The data were acquired in uncontrolled lighting conditions, and skin-like color objects appear in the background. The images from this dataset are associated with ground truth skin binary mask indicating the skin regions.

B. Result and Analysis

In this section, we analyze and compare our proposed method with several different methods that explicitly defined skin region, namely single color space, only chrominance channel of single color space and combination of two color spaces. All methods will be tested using two datasets mentioned above.

Table 1 describes the condition for all tested-methods. Our proposed method uses the combination from equation 4, equation 12, equation 13, equation 17 and equation 18. The comparison between our proposed method and different color spaces are tested using ECU and HGR Dataset is shown in Fig. 4 and Fig. 5.

Table 1. Condition for all tested-methods

No.	Method	Threshold value for each channel
1	HSV	Equation 11 ∩ Equation 12 ∩ Equation 13
2	YCbCr [28]	$(Y > 80)$ && $(85 < Cb < 135)$ && $(135 < Cr < 180)$
3	Normalized RGB	Equation 4 ∩ Equation 5 ∩ Equation 6
4	HS	Equation 12 ∩ Equation 13
5	CbCr	Equation 17 ∩ Equation 18
6	Nrg	Equation 4
7	HS-CbCr	Equation 12 ∩ Equation 13 ∩ Equation 17 ∩ Equation 18
8	**Proposed Method**	Equation 4 ∩ Equation 12 ∩ Equation 13 ∩ Equation 17 ∩ Equation 18

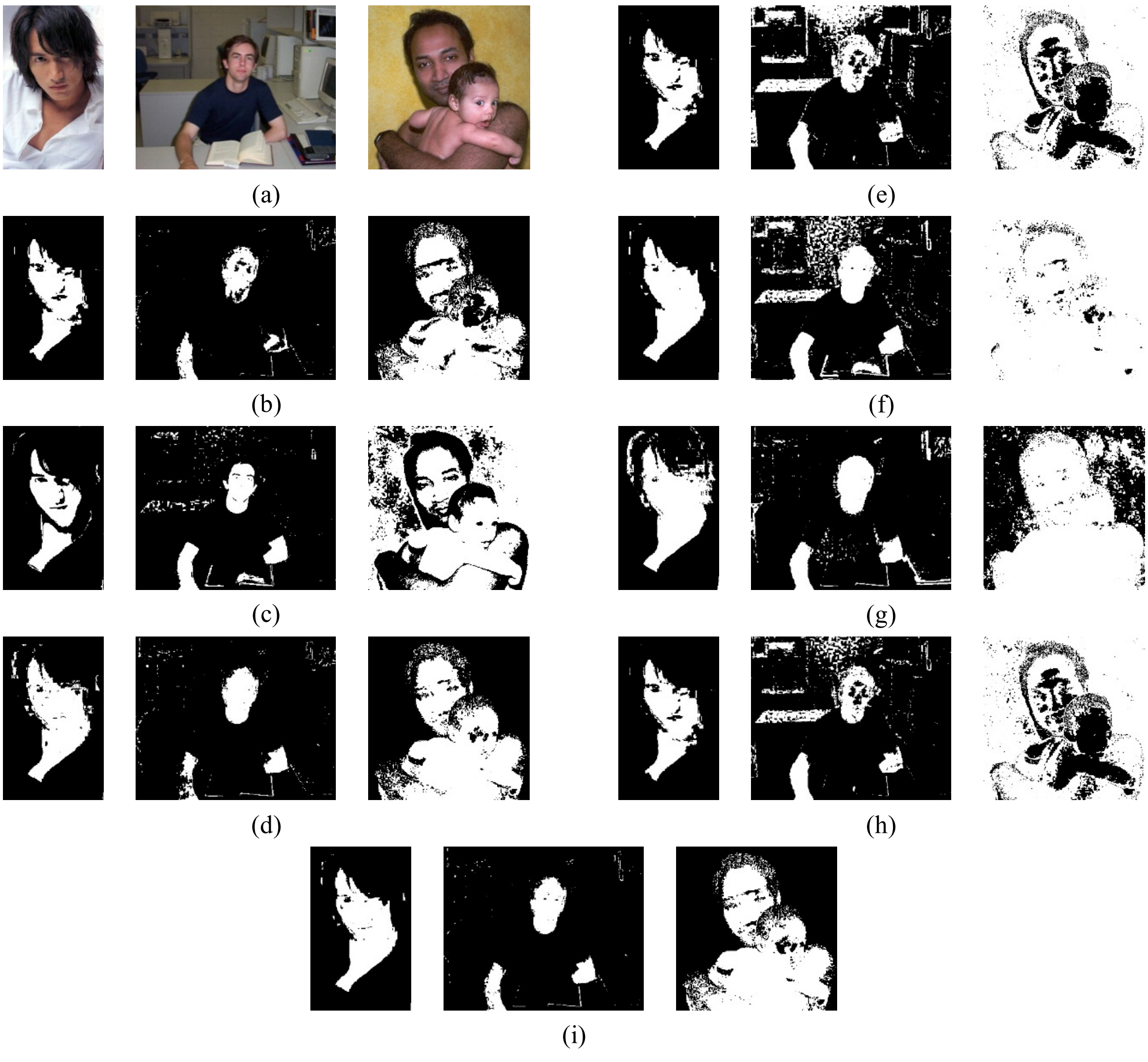

Fig. 4. Comparison of skin color segmentation results by different color spaces using ECU Dataset; (a) Original images, (b) HSV, (c) YCbCr, (d) Normalized RGB, (e) HS, (f) CbCr, (g) Nrg, (h) HS-CbCr, (i) Proposed method

Fig. 5. Comparison of skin color segmentation results by different color spaces using HGR Dataset; (a) Original images, (b) HSV, (c) YCbCr, (d) Normalized RGB, (e) HS, (f) CbCr, (g) Nrg, (h) HS-CbCr, (i) Proposed method

In this research, we calculate the detection rate, false positive ratio, and false positive ratio, to evaluate our proposed method, as written by [29]. To calculate them, there are several used parameters, such as the total number of skin color pixels (N_F), the number of correctly detected skin color pixels (N_S), the total number of non-skin color pixels (N_{NF}), the number of non-skin color pixels which are detected incorrectly as skin color (N_{FP}) and the number of skin color pixels that are detected incorrectly as non-skin color pixels (N_{FN}). The measurement is formulated as equation 19 to equation 21 below.

$$Detection\ Rate\ (\%) = \frac{N_S}{N_F} x\ 100 \tag{19}$$

$$False\ Positive\ Rate\ (\%) = \frac{N_{FP}}{N_{NF}} x\ 100 \tag{20}$$

$$False\ Negative\ Rate\ (\%) = \frac{N_{FN}}{N_F} x\ 100 \tag{21}$$

From Fig. 4 and 5, we can conclude that the combination of chrominance channel will give better accuracy of skin detection rate. Table 2 below shows the result of skin detection testing.

According to Table 2, our proposed method is more accurate than other methods. It gives 86.71% of accuracy while tested using ECU and 95.4% of accuracy while tested using HGR Dataset. The accuracy percentage of the proposed method reaches 91.05% for all measurements.

Table 2. Skin Detection Testing Result

Method	**ECU**			**HGR**			**Avg of DR (%)**
	DR	***FPR***	***FNR***	***DR***	***FPR***	***FNR***	
HSV	84.94	5.16	15.06	93.36	1.9	6.64	89.15
YCbCr	85.03	13.4	14.97	85.52	9.29	14.48	85.27
Normalized RGB	85.07	6.62	14.93	92.9	2.18	7.1	88.99
HS	81.05	7.01	18.95	85.69	13.5	14.31	83.37
CbCr	76.5	22.3	23.5	79.18	20.8	20.82	77.84
Nrg	73.57	23.12	26.43	82.64	17.1	17.36	78.1
HS-CbCr	82.79	12.02	17.21	86.14	13.02	13.86	84.46
Proposed Method	**86.71**	**5.2**	**13.29**	**95.4**	**1.76**	**4.6**	**91.05**

VI. CONCLUSIONS AND FUTURE WORK

Based on all testing results, there are several conclusions obtained in this research. First, the proposed method can detect skin color in uncontrolled lighting conditions and generate up to 91.05% correct result while being tested in ECU and HGR Dataset. Our proposed method in this research can be fast and easily implemented for skin color segmentation, but the generated accuracy depends on the difficulty and variety of lighting conditions in the tested image dataset.

Future work for skin-color segmentation can be done by adding a method for dynamic skin distribution models. A machine learning can be also implemented to get the higher percentage of accuracy for defining skin-region explicitly.

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