A Comparison of Human Skin Color Detection for Biometric Identification

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***Abstract*—Human skin color detection performs a critical part in the biometric identification and recognition system. In this paper, androgenic hair pattern recognition system compared 10 rules of human skin color detection, employing color spaces such as RGB, HSV, YCbCr, CIE Lab and YIQ color spaces. There were 400 images of androgenic hair pattern investigated, obtained from 25 male respondents. Detected human skin area images were converted into grayscale images and binary images. Precision of the recognition system was measured for each rule by employing 2-fold cross validation and Euclidean distance to calculate the nearest neighbor. The recognition system did not use any feature extraction algorithm. The experimental results showed that binary images were more suitable for simple recognition system without any feature extraction method and the best recognition precision was obtained by using color space that divided luminance component and chrominance component such as YCbCr, CIE Lab, HSV, and applied only chrominance components to the rules of human skin detection. The best precision recognition, achieved by utilizing YCBCr color space (using of Cb and Cr only), was 84.35 % from database with binary images.**

Keywords—androgenic hair pattern; biometric identification; color space; recognition system; skin color detection

I. INTRODUCTION

Human skin color plays an important part in the biometric identification system. Commonly, to be able to extract information of biometric trait, such system needs to detect human biometric trait from neighborhood or surrounding area. One way to extract that kind of information by doing the human skin color detection. Skin detection still becomes a challenging topic because the difficulties to detect skin color that has a broad range of variation due to ethnicity and race [1]. No single range of pixel value that can be able detect human skin color in any color space [2]. Furthermore, the condition in lighting when the images were captured also played significant role in the detection of human skin color.

There are numerous number of color spaces to be used in skin color detection. The color spaces such as RGB, CIE Lab, HSV, YCbCr, YIQ were used in this paper. We investigated color spaces that mix (RGB) and separate (YCbCr, HSV, CIE Lab and YIQ) luminance and chrominance components. Moreover, we also combined color spaces, such as YCbCr and HSV, and by using chrominance components of the intended color spaces, we hoped to be able to detect skin color more accurately. Previous study in [2] also combined Cb and Cr in YCbCr and H, S in HSV color spaces to detect skin color. They obtained 93.9 % of true positive rate as the percentage of skin color detected as skin color from 10 images as testing data. In [3], the authors combined RGB, H in HSV color space and CbCr in YCbCr color spaces. The authors obtained 90.83% detection success rate as the number of correctly detected faces from total faces in the image by using parallel combination of opening, box ratio and eccentricity operators from 100 images of test data set containing total 600 faces.

In this paper, the system was not only detected human skin color area but also recognized the identified biometric trait with detected human skin color to the correct individual. The biometric trait that we used was androgenic hair pattern, firstly developed in [4] in 2014. Previous works for this biometric trait [5-10] haven't studied the role of human skin color detection in many color spaces. In [8-10], the authors used CIE Lab and employed chrominance components, a and b, to detect human skin color area. Moreover, this paper also studied the difference between grayscale converted images and binary converted images as the input images for the recognition system after the area of skin human color was detected. To summarize, the aim of this paper is to find the color space and its range to detect human skin color (we called it as rule) and applied it to androgenic hair pattern images and investigated in the recognition system. In Section II, the human skin color modelling is explained. Section III describes the proposed system and Section IV discuss the experimental results. And finally, conclusion is drawn in Section V.

II. HUMAN SKIN COLOR MODELLING

Overall, the skin detection methods are divided into 8 categories [11]: the explicitly defined methods which are stand on the color space of the skin area, the statistical method that is calculated from extracted information (histogram) for non-parametric method and probability of a pixel that is a skin color or non-skin color for parametric method, neural network model for information such as color and texture, spatial analysis method that also analyses neighbouring pixels, adaptive method that dynamically updates classifier build on local or global information, non-visible spectral method that works in various spectral bands, SVM-based method for model that

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works with support vector machine and the combination of previous methods which we called the mixture technique.

In this paper, we employed the human skin detection method depended on explicit defined method with several color spaces threshold value for comparison. We utilized RGB, CIE-Lab, HSV, YCbCr, YIQ color spaces and their combination. We chose these color spaces because the RGB is a color space that combines both luminance and chromatic meanwhile the CIE-Lab, HSV. YCbCr and YIQ color spaces separate the luminance and chrominance components.

A. RGB

The RGB color space came from red, green, blue colors that are combined and producing broad color from it. It is a device-dependant color model that means every device detects or produces different value of RGB. RGB color space combines the luminance and chromatic component and it is one of the essential color space that is generally utilized since RGB is the model that usually employed by camera. In this paper, we used rules from [12] which was described by (1) for daylight and (2) for under flashlight.

$$skin\ colour = \begin{cases} R > 95 \ \ and\ G > 40\ and\ B > 20 \\ max\{R, G, B\} - min\{R, G, B\} > 15 \\ |R - G| > 15\ and\ R > G\ and\ R > B \end{cases} \tag{1}$$

$$skin\ colour \ = \begin{cases} R > 220 \ \ and\ G > 210\ and\ B > 170 \\ |R - G| \le 15 \\ R > B\ and\ G > B \end{cases} \tag{2}$$

B. CIE-Lab

The Commision International d'Eclairage (CIE) established CIE Lab that has three components: component L for luminance and component a and b represent chroma information. The L provides from black to white while a indicates green to magenta and b indicates blue to yellow [13]. The CIE Lab is a color space that has perceptual uniformity characteristic. It acts as two colors vary in presentation to human eyes so uniform color spaces were defined so all colors are organized by the perceptual difference of the color [14]. In this paper, we used only component a and b which present chroma components.

C. HSV

HSV color space is a perceptual color space and the H stands for hue, while S stands for saturation and V for value. Hue is the variety of color from red to green, saturation defines variety from red to pink and value determines changing from black to white or we called it image brightness [1, 14]

The following rule proposed in [15] for human skin color using HSV.

$$0.23 < S < 0.68 \text{ and } 0 < H < 50 \tag{3}$$

In this paper we want to investigate other rule for HSV color space, so we defined it as

$$S > 0.35 \tag{4}$$

D. YCbCr

YCbCr is the color space that has orthogonal property and was defined into luminance component (Y) and chrominance components (CbCr). The luminance component is calculated from weighted addition from RGB color space and the chrominance components were obtained from the subtraction of Y from B values for Cb and Y from R values for Cr.

The human skin color for YCbCr color space was defined by several rules. Equation (5) comes from [13] and (6) comes from [16].

$$\begin{gathered} 76 < Cb < 127 \\ 132 < Cr < 173 \end{gathered} \tag{5}$$

$$\begin{gathered} 85 < Cb < 135 \\ 135 < Cr < 180 \\ Y > 80 \end{gathered} \tag{6}$$

In this paper, we examined the range for YCbCr color space as

$$\begin{gathered} 101 < Cb < 125 \\ 130 < Cr < 155 \end{gathered} \tag{7}$$

E. YIQ

YIQ is employed in NTSC encoder [17]. This color space has two components, luminance (Y) and chrominance (I and Q) that are derived from RGB. From [18], the range from human skin color using this color space is

$$\begin{gathered} 44 < Y < 223 \\ 0 < I < 64 \end{gathered} \tag{8}$$

F. Combination of Color Spaces

In this paper, we also combined several color spaces such as HSV in (4) and YCbCr in (5) into (9) and in HSV and YCbCr in (7) into (10).

$$skin\ colour = \begin{cases} S > 0.35 \\ 76 < Cb < 127 \\ 132 < Cr < 173 \end{cases} \tag{9}$$

$$skin\ colour = \begin{cases} S > 0.31 \\ 101 < Cb < 125 \\ 130 < Cr < 155 \end{cases} \tag{10}$$

III. Design of The Proposed System

The aim of this paper was to know the comparison of systems' performance of recognition using different rules to detect human skin color. Figure 1 shows the system designed for the research in this paper. The input images were lower right leg human male androgenic hair pictures [8] in RGB color spaces as it shown in Figure 2. There were 400 images from 25 male respondents and 16 images per person in androgenic hair database. We assigned 10 rules to be applied in the recognition system to target the human skin color region. The 10 rules of the detection of human skin color can be seen in Table 1. The rule of detection detected the skin area and removed other part of image that did not belong to the skin area according to the rule's algorithm. Then, the input images with detected skin region were converted into grayscale and binary images. The recognition system used nearest neighbor with Euclidean distance because its simplicity and 2-fold cross validation because it is faster. 2-fold cross validation divides the data set into half between training set and testing set. The performance of recognition system employed precision calculation in to measure the system performance with desired rule of skin detection. The precision compares the true positive results with total results and in this paper, it was presented in percentage.

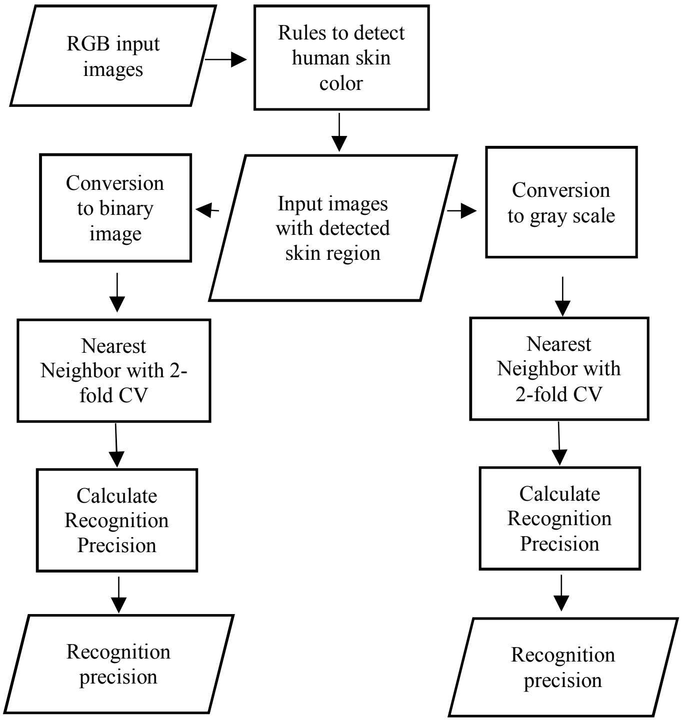

Fig. 1. Flowchart of the Recognition System

Fig. 2. Examples of Androgenic Hair RGB Images in Database [8].

TABLE I. THE 10 RULES OF SKIN DETECTION

Rule No	Methods	
	Color Space	***Rule***
1	RGB	Eq (1) and (2)
2	CIE Lab	a and b components only
3	HSV	Eq (3)
4	HSV	Eq (4)
5	YCbCr	Eq (5)
6	YCbCr	Eq (6)
7	YCbCr	Eq (7)
8	YIQ	Eq (8)
9	Combination of HSV and YCbCr	Eq (9)
10	Combination of HSV and YCbCr	Eq (10)

IV. RESULTS AND DISCUSSION

The results of the research conducted in this paper are presented in Figure 3, Figure 4 and Table 2. Figure 3 demonstrates the results of skin detection using 10 rules as described in Table 1 in a grayscale conversion and Figure 4 in a binary image conversion. The detected skin region showed in its original color and the not-skin region will be removed (blackened). Table 2 displays the precision results for each rule.

From Table 2, we can see that the system using images which were converted into binary images showed better performance compared to the system using converted grayscale images. The system tested in this paper did not use any feature extraction method. The detected and converted images in the database directly calculated into the nearest neighbor algorithm. Using the grayscale images, the system exploited more information compared into binary images, such as androgenic hair that grows on the legs, the different lighting condition reflected on the legs'surface and the shape of human legs themselves. While using the binary images, the system only utilized less information, white color as the detected human skin area and black as the other part of the image. Using this less information, our system displayed better performance as in higher recognition precision. We suspected that more information did not go along with the system with no feature extraction algorithm at all. There hadn't any method to extract reliable and important information from abundant data that came from our grayscale images database. Moreover, not all data from grayscale images were good data, there was a chance that they had more noise than reliable data from the grayscale images. On the other hand, binary images were simple in information, whether it was skin area or not skin area. Our simple recognition system proved that it was better to use binary images database for the recognition system without any feature extraction method.

The best recognition precision of binary images database, 84.35% and 84.1% was achieved by using YCbCr color space (rule 7 and rule 5 respectively) with only utilized chrominance components (Cb and Cr). When the system employed combination of color spaces, such as in rule 9 and rule 10, we obtained good results, 81.125% and 82.075%, in the binary images database, compared to other rules. Combination using YCbCr and HSV color spaces, both rule 9 and 10 applied chrominance components only, Cb and Cr in YCbCr color space and S component in HSV color space. Studies show that pixels that belong to human skin color have similarity in chrominance components and showed best discrimination between skin and not skin area [3]. Furthermore, when the images from database were taken under medium level of lighting, even though they were different in skin color (white, yellow, black, brown), still possessed marked similarity in chrominance components so it can be used to separate skin area and not skin area [19]. This happened also in HSV color space, when we used only H and S chrominance components in rule 3, which gave 81.125% precision and S component only in rule 4, which produced 80.95%. This results of better performance using chrominance components went both for grayscale images and binary images converted database. The precision of recognition dropped around 9% to 75.6%, when we employed Y component (luminance) into the YCbCr color space rule as in rule 6 in binary images database and dropped around 2% to 70.975% in grayscale images database. The CIE Lab produced 83.075% of recognition precision for binary images using only component a and b in the CIE Lab color space which also present chroma information. In the previous works [8], the authors used CIE Lab and utilized chrominance components, a and b. They obtained 71.28% using grayscale images conversion as the database, meanwhile in this research, we obtained almost the same results using grayscale images, 72.2% of precision recognition. The RGB color space could only produce 65,325% because it combined both luminance and chrominance in the color space and the YIQ gave us 72% using both Y component (luminance) and I component (chromatic).

V. CONCLUSION

This paper presented comparison of 10 rules of color spaces both for simple recognition system using detected area of human skin color that were converted into grayscale images and binary images. The results showed that binary images were more suitable for simple recognition system without any feature extraction method and the best recognition precision was obtained by using color space that divided luminance component and chrominance component such as YCbCr, CIE Lab, HSV, and applied only chrominance components to the rules of human skin detection. The best precision recognition, achieved by utilizing YCBCr color space (rule of Cb and Cr only) that was 84.35 % from database with binary images.

Our future work will include feature extraction algorithm into the system so we can further analyze the color information into the system of recognition.

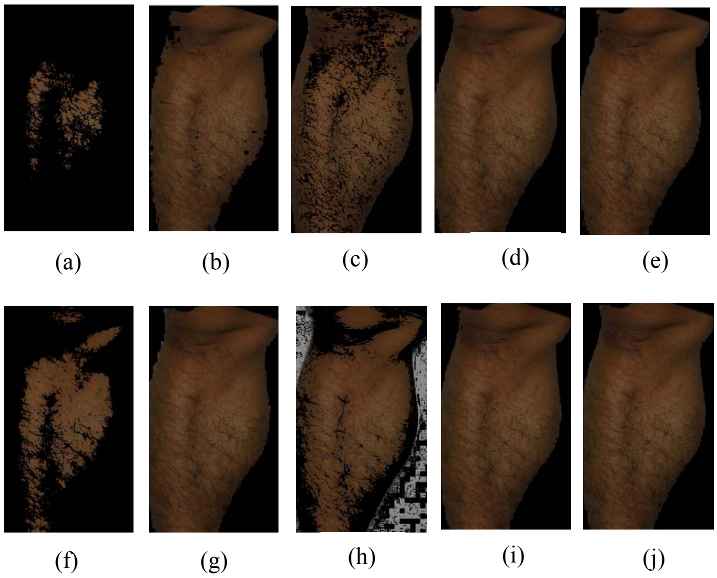

Fig. 3. Example of Results of Human Skin Detection Grayscale Conversion using Rule 1 (a) until Rule 10 (j).

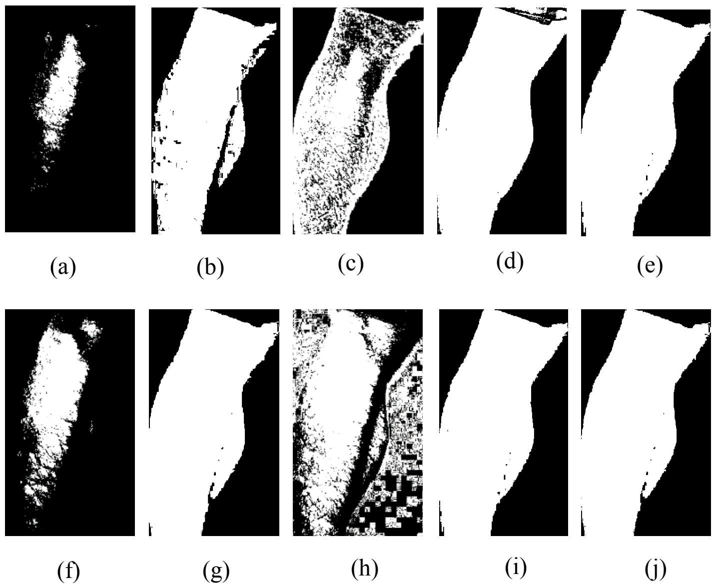

Fig. 4. Example of Results of Human Skin Detection Binary Image Conversion using Rule 1 (a) until Rule 10 (j).

TABLE II. PRECISION OF RECOGNITION (PR) FROM 10 RULES OF SKIN DETECTION

Rule No	Precision of Recognition (PR) Results		
	Color Space	***PR with grayscale***	***PR with binary images***
1	RGB	63,05 %	65,325 %
2	CIE LAB	72,2 %	83,075 %
3	HSV	72,15	81,125 %
4	HSV	72,75 %	80,95 %
5	YCbCr	71,45 %	84,1 %
6	YCbCr	70,975 %	75,6 %
7	YCbCr	72,65 %	84,35 %
8	YIQ	50,8 %	72 %
9	Combination of HSV and YCbCr	72,525 %	81,125 %
10	Combination of HSV and YCbCr	72,125 %	82, 075 %

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