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Skin Segmentation Using YUV and RGB Color Spaces

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Abstract—Skin detection is used in many applications, such as face recognition, hand tracking, and human-computer interaction. There are many skin color detection algorithms that are used to extract human skin color regions that are based on the thresholding technique since it is simple and fast for computation. The efficiency of each color space depends on its robustness to the change in lighting and the ability to distinguish skin color pixels in images that have a complex background. For more accurate skin detection, we are proposing a new threshold based on RGB and YUV color spaces. The proposed approach starts by converting the RGB color space to the YUV color model. Then it separates the Y channel, which represents the intensity of the color model from the U and V channels to eliminate the effects of luminance. After that the threshold values are selected based on the testing of the boundary of skin colors with the help of the color histogram. Finally, the threshold was applied to the input image to extract skin parts. The detected skin regions were quantitatively compared to the actual skin parts in the input images to measure the accuracy and to compare the results of our threshold to the results of other's thresholds to prove the efficiency of our approach. The results of the experiment show that the proposed threshold is more robust in terms of dealing with the complex background and light conditions than others.

Keywords—Skin Segmentation, Thresholding Technique, Skin Detection, Color Space

1. INTRODUCTION

Skin detection is an interesting and challenging topic for many researchers as it is used in many applications such as, hand and face tracking, sign language recognition, human-computer interaction, and others. The difficulty of skin detection is due to the variation of people's race where each race has a different skin tone from the others. The difference in people's skin is not the only problem as there other factors such as the light conditions where the variation in luminance limits the accuracy of skin segmentation.

There are many skin color spaces like RGB, HSV, YCbCr, YIQ, YUV, etc. that are used for skin color segmentation. The RGB color model represents the colors that are in the red, green, and blue planes and does not separate the luminance from the chrominance components, which makes it a poor choice for color analysis and color based recognition [1]. The conversion from RGB color space to the HSV color model is time consuming due to the time it takes to do a non-linear transmission [2]. To overcome the previous problems, we have proposed a new threshold,

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which is based on the YUV and RGB color spaces. Our approach is able to benefit from the characteristics of each color model for enhancing the accuracy of skin detection.

2. RELATED WORK

There are many techniques for skin color segmentation, such as the Gaussian Mixture Model, color histogram, and thresholding. Some of the skin detection methods that adopt the threshold manner will be discussed in this paper. Sobottka and Pitas [3] presented a method for skin color segmentation based on HSV color space using fixed threshold values to extract the face region. Due to the variation in light conditions, they adopted shape features to enhance the face detection feature. Jusoh et al. [4] introduced an approach for skin color detection, which is based on HSV and RGB color spaces, to improve the segmentation process by using two thresholds. The first threshold is applied to the hue channel, and the second threshold is applied to the RGB model. Another method that combines two color models (HSV and YCgCr) was proposed by Ghazali et al. [5] for extracting the face region. It is based on thresholding techniques. Segmentation by combining more than one color model improves the accuracy of skin detection. Ghotkar and Kharate [6] described a hand segmentation method by using a threshold technique for hand gesture recognition. They made a comparison between three color spaces (HSV, HSL, and HTS) and found that the last one gave better results than the others. Jagadesh et al. [7] presented an approach for skin segmentation using the bivariate Pearsonian Type-IIb Mixture Model. They used the hue and saturation components of HSV color space to distinguish the skin and non-skin pixels, which they based on the threshold values and the Likelihood method, to enhance the accuracy of the results. However, using HSV color space in skin segmentation is time consuming due to the time it takes for non-linear transformation to occur between the RGB and HSV color models.

Chai and Ngan [8] suggested a method for extracting the face region from an input image using the thresholding technique. The color space used in this approach is the YCrCb color model. It was used due to its efficiency for modeling skin color and for its use in video coding. Another method that uses YCbCr color space with fixed thresholding to extract the face region is described by Marius et al. [9]. It applies morphological operations to reduce the unwanted regions. However, skin detection using the YCbCr color model in the previous methods is unsuitable for some races, such as black people.

Kukharev and Nowosielski [2] extracted the skin regions by using the RGB and YCbCr color spaces to improve the accuracy of the skin detection. For fast face segmentation de Dios and Garcia [10] proposed a YCgCr color model with two thresholds. Although they enhanced the face detection by rotating the Cr and Cg axis in the chrominance channel, the process of conducting segmentationat a higher level of accuracy still needs to be improved. Almohair et al. [11] introduced a method to distinguish the human skin from the color images that contain luminance. They did so by using the thresholding technique, which is considered to be an effective tool for enhancing the segmentation process. A new color model for skin segmentation that is based on RGB color space has been introduced to speed up the process of classifying the pixels by converting the 3D space of RGB to 1D. This method uses the thresholding technique to distinguish skin pixels from the non-skin pixels. Although the segmentation is fast, the results need to be enhanced due to the absence of the red channel [1]. A Fuzzy YCbCr color space and threshold technique was described by Iraji and Yavari [12] to deal with the lighting effects and to enhance the accuracy of the skin color segmentation. Prema and Manimegalai [13] presented a hybrid approach to extract the skin regions in an image with a complex background by using a fixed threshold.

The previous discussion presents the idea that using more than one color space with a threshold is considered to be an effective tool for skin color segmentation. In this paper, a new skin segmentation method, which adopts a threshold technique that is based on the YUV and RGB color models to improve the accuracy of skin detection, is introduced. To prove the effectiveness of this method, we compared it with the methods in [2,3,14]. The results show that the proposed method detects more skin regions than the other methods do.

3. COLOR MODELS

Many different types of color models are used for skin detection. Each one differs from the others in terms of the manner of transformation (linear or non-linear), the robustness to adapt to light changing, and shadow noises. The paragraphs below are a short description for the color models that were used in this experiment.

3.1 RGB Color Model

It consists of the three main colors: red, green, and blue. Combining the luma and chromatic components in this color space make it more sensitive to noise than others. The results of the proposed threshold were compared to the results of the RGB color space, which was based on the following threshold values described by [14]:

$$\begin{cases} \mathrm{R} > 95 \ \& \ G > 40 \ \& \ B > 20 \\ \max(\mathrm{R,G,B}) - \min(\mathrm{R,G,B}) > 15 \\ |\mathrm{R}-\mathrm{G}| > 15 \ \& \ R > G \ \& \ R > B \end{cases} \tag{1}$$

3.2 HSV Color Model

This color model is represented by hue, saturation, and value. The hue channel defines the color itself, whereas, the saturation channel describes the light combined with hue, and the value determines the image brightness. The conversion from RGB to HSV is based on the following equations mentioned by [15]:

$$\mathrm{H} = \begin{cases} \mathrm{Hi} & \mathrm{B} \leq \mathrm{G} \\ 360 - \mathrm{Hi} & \mathrm{B} > G \end{cases} \tag{2}$$

Where:

$$\mathrm{Hi} = \arccos\left(\frac{\frac{1}{2\{(\mathrm{R-G})+(\mathrm{R-B})\}}}{\sqrt{(\mathrm{R-G})\uparrow 2+(\mathrm{R-G})(\mathrm{G-B})}} \right) \tag{3}$$

$$\mathrm{S} = \frac{\max(\mathrm{R,G,B}) - \min(\mathrm{R,G,B})}{\max(\mathrm{R,G,B})} \tag{4}$$

$$\mathrm{V} = \frac{\max(\mathrm{R,G,B})}{255} \tag{5}$$

The threshold values used to distinguish the skin regions, as proposed by Sobottka and Pitas [3], are as follows:

$$\begin{cases} 0.23 < S < 0.68 \\ 0 < H < 50 \end{cases} \tag{6}$$

3.3 YCbCr Color Model

The YCbCr color space consists of the Y channel, which represents the luminance component, and the Cb and Cr channels, which describe the chrominance components. The separation of luma from chromatic makes this color model interesting for skin color detection. The transformation from RGB to YCbCr is simple and is defined as follows [15]:

$$\begin{gathered} \mathrm{Y} = 0.299\mathrm{R} + 0.587\mathrm{G} + 0.114\mathrm{B} \\ \mathrm{Cb} = (\mathrm{B} - \mathrm{Y}) * 0.564 + 128 \\ \mathrm{Cr} = (\mathrm{R} - \mathrm{Y}) * 0.713 + 128 \end{gathered} \tag{7}$$

The skin pixels can be extracted by using the threshold values, as follows [2]:

$$\begin{cases} 135 < Cr < 180 \\ 85 < Cb < 135 \\ \mathrm{Y} > 80 \end{cases} \tag{8}$$

3.4 IHLS Color Model

The Improved Hue, Luminance, and Saturation (IHLS) color model is introduced to reduce the effect of the lighting variations by removing the normalization of the saturation. The saturation of achromatic pixels is low and the luminance and saturation are independent of each other. The IHLS color model is generated from the RGB color model using the following equations [16]:

$$\mathrm{Y} = 0.2126\mathrm{R} + 0.7152\mathrm{G} + 0.0722\mathrm{B} \tag{9}$$

$$\mathrm{S} = \frac{\max(\mathrm{R,G,B}) - \min(\mathrm{R,G,B})}{255} \tag{10}$$

$$\mathrm{H}' = \arccos\left(\frac{\mathrm{R} - \frac{\mathrm{G}}{2} - \frac{\mathrm{B}}{2}}{(\mathrm{R}^2 + \mathrm{G}^2 + \mathrm{B}^2 - \mathrm{RG} - \mathrm{RB} - \mathrm{BG})^{\frac{1}{2}}}\right) \tag{11}$$

$$\mathrm{H} = \begin{cases} 360^{\circ} - \mathrm{H}' & \mathrm{B} > G \\ \mathrm{H}' & \text{otherwise} \end{cases} \tag{12}$$

The skin color regions are detected based on the following static thresholds [17]:

$$\begin{cases} 0 \leq \mathrm{H} \leq 50 \\ 0.1 \leq \mathrm{S} \leq 0.9 \end{cases} \tag{13}$$

3.5 YIQ Color Model

The YIQ color space is used in Japanese and North American TVs to encode color images. It consists of three components: the Y component represents the luminance, whereas, the I and Q components represent the chromatic. The independence of the luminance component from chromatic components decreases the lighting effects. The transformation from the RGB color model to YIQ color model is given by the following formulations [18]:

$$\begin{pmatrix} \mathrm{Y} \\ \mathrm{I} \\ \mathrm{Q} \end{pmatrix} = \begin{pmatrix} +0.299 & +0.587 & +0.114 \\ +0.596 & -0.275 & -0.322 \\ +0.212 & -0.523 & +0.311 \end{pmatrix} \cdot \begin{pmatrix} \mathrm{R} \\ \mathrm{G} \\ \mathrm{B} \end{pmatrix} \tag{14}$$

The following static filters that are described by [19] are used for skin color segmentation:

$$\begin{cases} 44 < Y < 223 \\ 0 < I < 64 \end{cases} \tag{15}$$

3.6 YIQ and HSV Color Model

The combination of two color models for skin color segmentation is more robust than using a single color model. As such, skin detection is obtained based on the combination between YIQ and HSV color models using the following thresholds [20]:

$$\begin{cases} 20 \le \mathrm{I} \le 90 \\ 0.20 < S < 0.75 \\ \mathrm{V} > 0.35 \\ 0 < H < 25 \end{cases} \tag{16}$$

3.7 YUV Color Model

The YUV color model is used in some TV systems, such as NTSC (National Television System Committee) and PAL (Phase Alternation Line). The luminance channel (Y) is separated from the chromatic channels (U, V) to reduce the effect of lighting variations. The conversion of the RGB color model to YUV color model is achieved using the equations given below [21]:

$$\begin{pmatrix} \mathrm{Y} \\ \mathrm{U} \\ \mathrm{V} \end{pmatrix} = \begin{pmatrix} +0.257 & +0.504 & +0.098 \\ -0.148 & -0.291 & +0.439 \\ +0.439 & -0.368 & -0.071 \end{pmatrix} \cdot \begin{pmatrix} \mathrm{R} \\ \mathrm{G} \\ \mathrm{B} \end{pmatrix} + \begin{pmatrix} 16 \\ 128 \\ 128 \end{pmatrix} \tag{17}$$

The following equations represent the range of skin colors [23]:

$$\begin{cases} 65 < Y < 170 \\ 85 < U < 140 \\ 85 < V < 160 \end{cases} \tag{18}$$

3.8 YIQ and YUV Color Models

The YIQ and YUV color models are combined together for robust skin color detection. Listed below are the static filters that are described by [21] for skin regions extraction:

$$\begin{cases} 70 < Y < 175 \\ 20 < U < 102 \\ -48 < \theta < 150 \end{cases} \tag{19}$$

Where:

$$\mathrm{\theta} = \tan^{-1}(|\mathrm{V}|/|\mathrm{U}|) \tag{20}$$

3.9 RGB and YUV Color Models

The RGB and YUV color models are combined together to overcome the control limits in these two color models for achieving the best skin color segmentation. The saturation parameter Ch in the YUV color model is used to reduce the noise and it's described as follows [22]:

$$30 \leq \mathrm{Ch} \leq 220 \tag{21}$$

Where:

$$\mathrm{Ch} = \sqrt{\mathrm{U}^2 + \mathrm{V}^2} \tag{22}$$

3.10 YCgCr Color Model

The YCgCr color model is a variant of the YCbCr color model in which the Cg component is used instead of the Cb component. The transformation from RGB to YCgCr is given below [23]:

$$\begin{pmatrix} \mathrm{Y} \\ \mathrm{Cg} \\ \mathrm{Cr} \end{pmatrix} = \begin{pmatrix} +65.481 & +128.553 & +24.966 \\ -81.085 & +112 & -30.915 \\ +112 & -93.768 & -18.214 \end{pmatrix} \cdot \begin{pmatrix} \mathrm{r} \\ \mathrm{g} \\ \mathrm{b} \end{pmatrix} + \begin{pmatrix} 16 \\ 128 \\ 128 \end{pmatrix} \tag{23}$$

The following thresholds are introduced by [25] to extract the skin color regions:

$$\begin{cases} 76 \leq \mathrm{Cg} \leq 125 \\ 136 \leq \mathrm{Cr} \leq 202 \end{cases} \tag{24}$$

4. THE RESEARCH METHOD

The YUV color space was chosen due to the fast transformation of the RGB model. The Y channel represents the luminance of the color, while the U and V channels represent the chrominance. Separating the luma from the chromatic reduces the effect of light changing and shadow noises. This method starts by converting the RGB color space to the YUV color space using the following equations [18]:

$$\begin{pmatrix} \mathrm{Y} \\ \mathrm{U} \\ \mathrm{V} \end{pmatrix} = \begin{pmatrix} +0.299 & +0.587 & +0.114 \\ -0.147 & -0.289 & +0.436 \\ +0.615 & -0.515 & -0.100 \end{pmatrix} \cdot \begin{pmatrix} \mathrm{R} \\ \mathrm{G} \\ \mathrm{B} \end{pmatrix} + \begin{pmatrix} 0 \\ 128 \\ 128 \end{pmatrix} \tag{25}$$

The skin detection threshold, which is based on the YUV color model, was built based on 200 faces with different colors. The threshold values used to detect human skin using U and V channels were determined by testing the boundary of skin colors with the help of the color histogram, as shown in Fig. 2 The threshold values, which are used to segment skin regions based on the RGB color space, were extracted by Kovac et al. [14] and were modified for our proposed method, as shown in Eq. (26).

$$\begin{cases} 80 < U < 130 \\ 136 < V < 200 \\ \mathrm{V} > U \\ \mathrm{R} > 80 \,\&\, G > 30 \,\&\, B > 15 \\ |\mathrm{R} - \mathrm{G}| > 15 \end{cases} \tag{26}$$

The following flowchart shows the process of skin color segmentation:

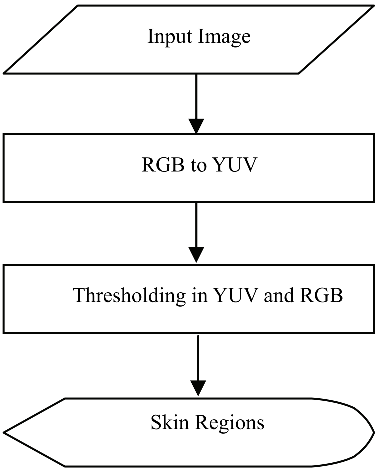
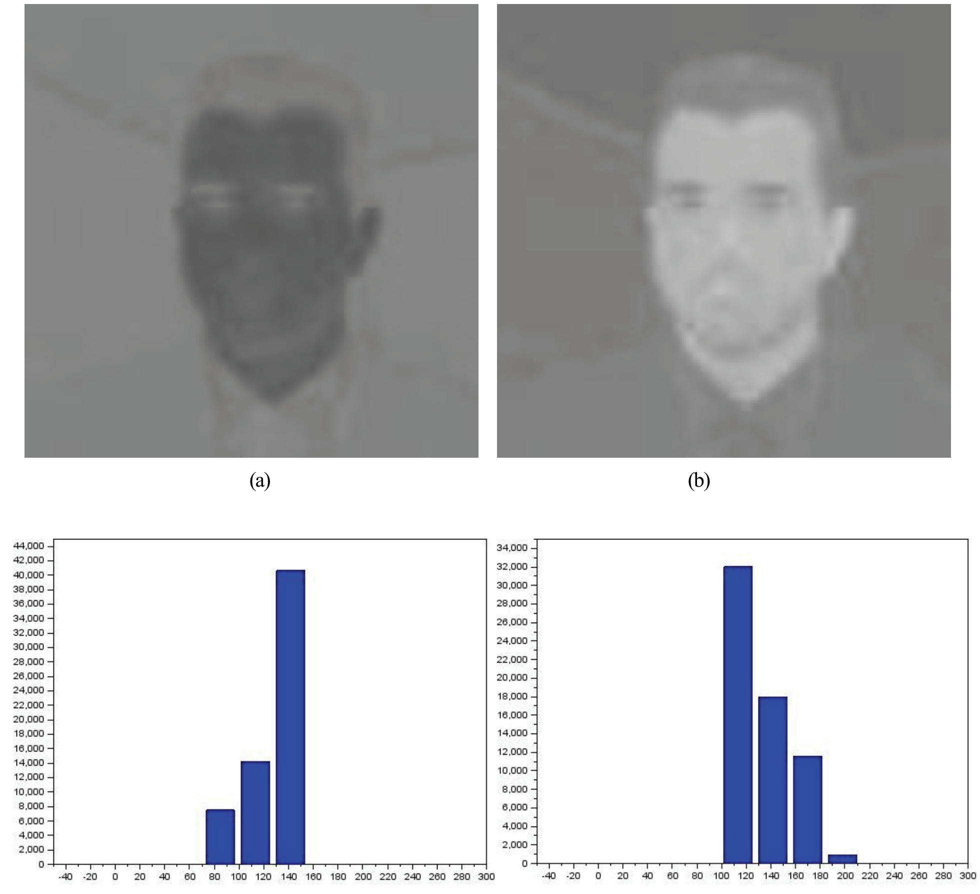


Fig. 1. Skin segmentation process

5. RESULTS

The presented method was tested on 300 images selected from the Labeled Faces in the Wild Home database [24]. The size of each image is 250×250 and they vary in brightness and background. They also represent different races of people. A comparison was made between the introduced method and the previous methods in the color spaces of RGB, YCbCr, HSV, IHLS, YIQ, YUV, YIQ-HSV, YIQ-YUV, RGB-YUV, and YCgCr to prove the effectiveness of our suggested method. The experimental results show that the proposed method detected skin regions with low false positive and false negative rates and at a high detection rate.



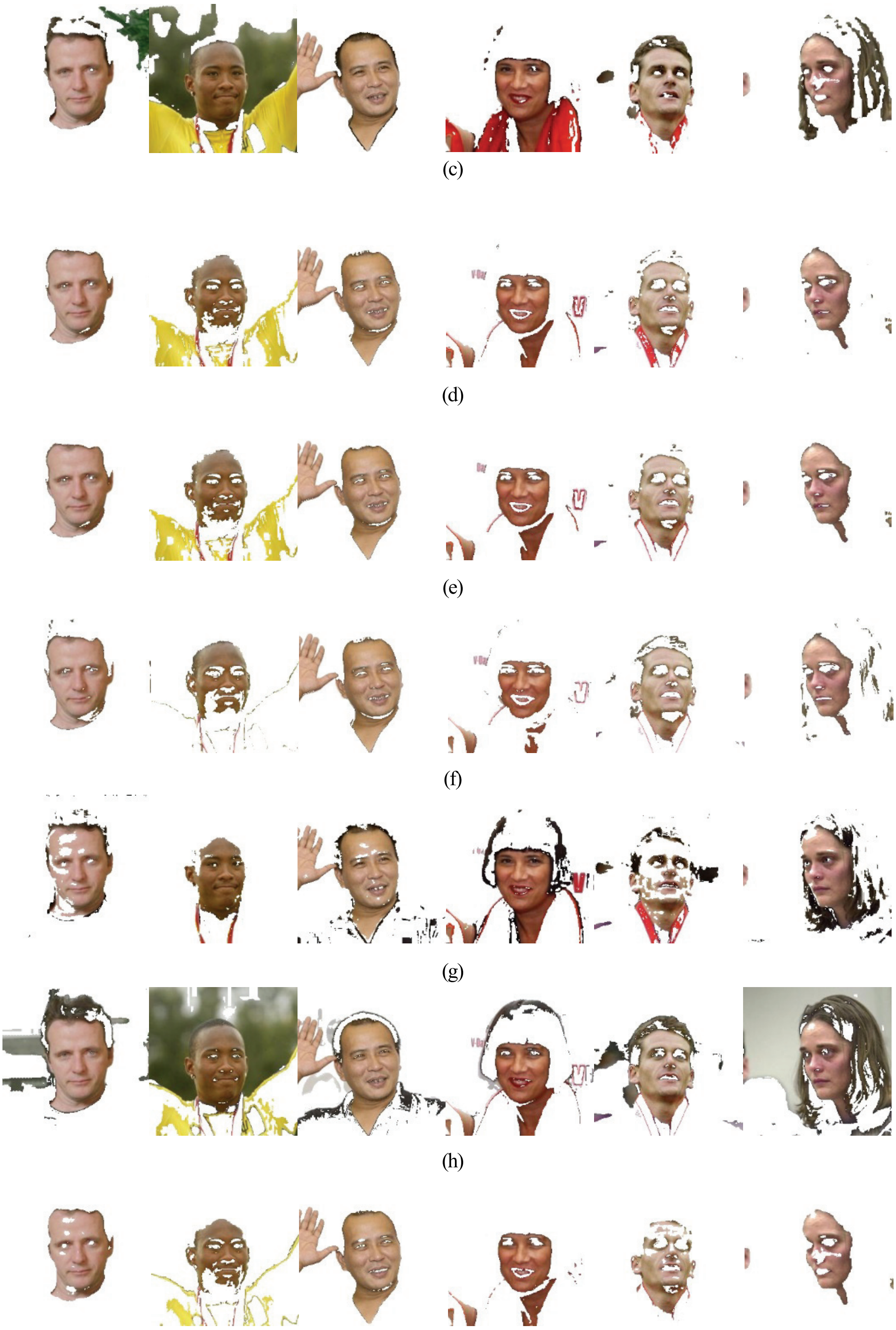
(a) (b)

(c) (d)

Fig. 2. Shows the U and V channels and their respective histograms: (a) U channel, (b) V channel, (c) histogram of the U channel, and (d) histogram of the V channel

(a)

(b)



(c)

(d)

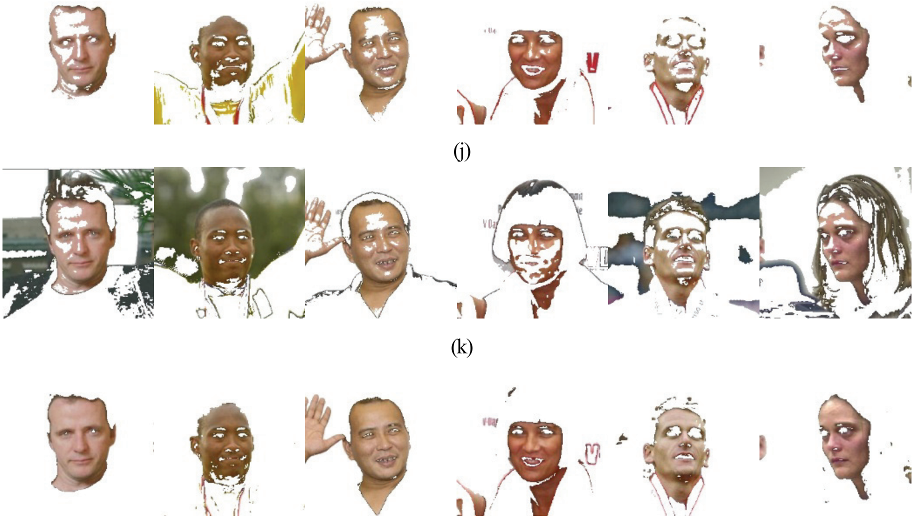
(e)

(f)

(g)

(h)

(i)



(j)

(k)

(l)

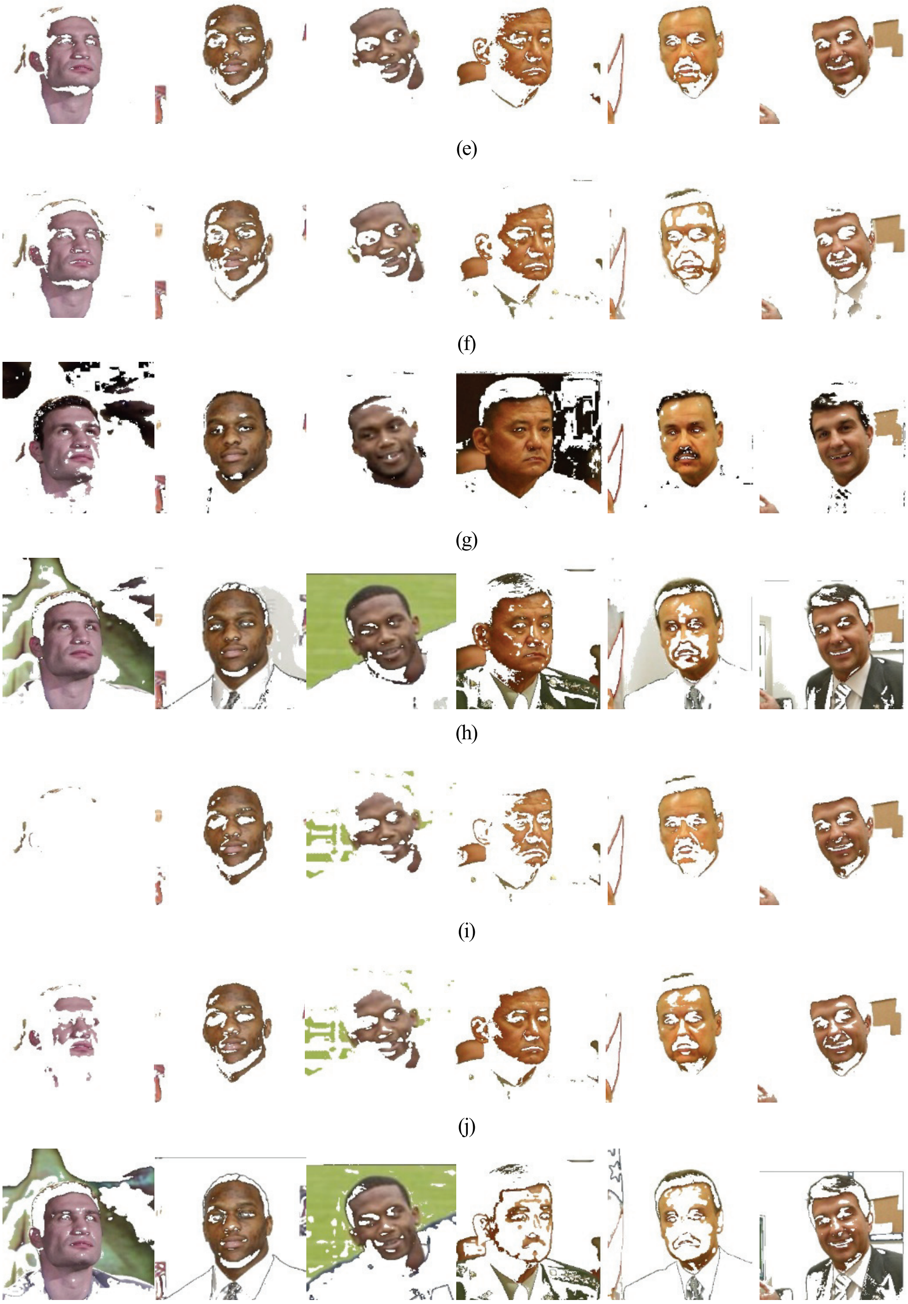
Fig. 3. Shows some of the results of the skin color segmentation process using different color models: (a) original images, (b) HSV, (c) IHLS, (d) RGB, (e) RGB&YUV, (f) YCbCr, (g) YCgCr, (h) YIQ, (i) YIQ&HSV, (j) YIQ&YUV, (k) YUV, and (l) YUV & RGB (proposed method).

(a)

(b)

(c)

(d)



(e)

(f)

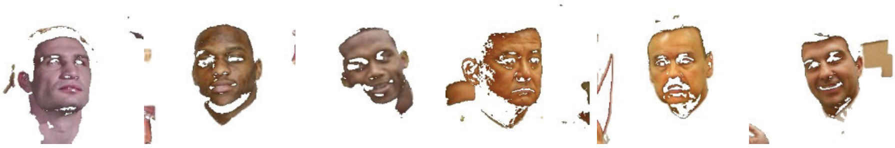
(g)

(h)

(i)

(j)

(k)



(l)

Fig. 4. Shows some of the results of the skin color segmentation process using different color models: (a) original images, (b) HSV, (c) IHLS, (d) RGB, (e) RGB&YUV, (f) YCbCr, (g) YCgCr, (h) YIQ, (i) YIQ&HSV, (j) YIQ&YUV, (k) YUV, and (l) YUV & RGB (proposed method)

(a)

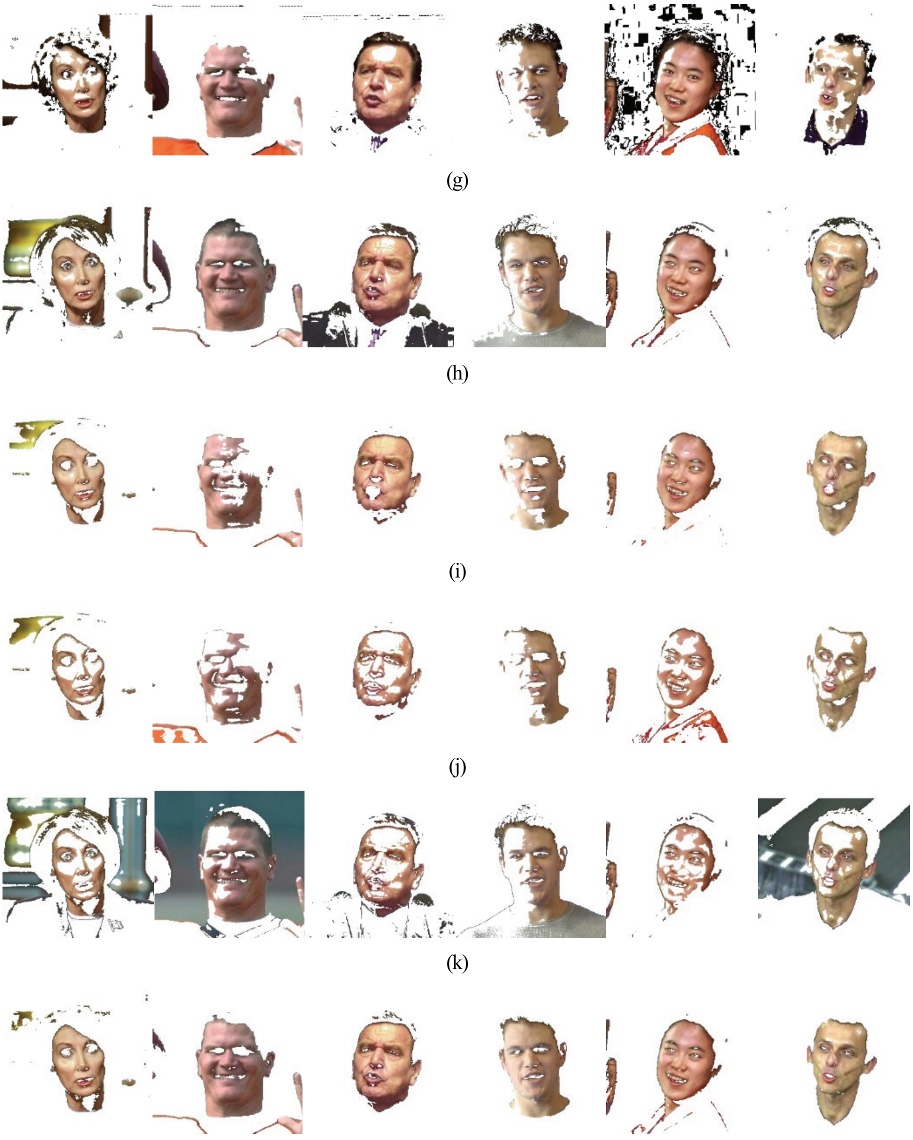
(b)

(c)

(d)

(e)

(f)



(g)

(h)

(i)

(j)

(k)

(l)

Fig. 5. Shows some of the results of the skin color segmentation process using different color models: (a) original images, (b) HSV, (c) IHLS, (d) RGB, (e) RGB&YUV, (f) YCbCr, (g) YCgCr, (h) YIQ, (i) YIQ&HSV, (j) YIQ&YUV, (k) YUV, and (l) YUV & RGB (proposed method)

6. DISCUSSION

Three different measures were used to evaluate the proposed method. The Detection Rate (DR) is defined as the number of pixels that are correctly detected as skin color pixels (*Ns*) over the total number of skin color pixels (*Nf*). The False Positive Rate (FPR) is defined as the number of non-skin pixels that are detected incorrectly as skin color (*Nfp*) over the total number of non-skin color pixels (*Nnf*). The False Negative Rate (FNR) is defined as the number of skin color pixels that are detected incorrectly as non-skin color pixels (*Nfn*) over the total number of skin color pixels (*Nf*), as written by [25].

$$\text{Detection Rate }(\%) = \frac{\text{Ns}}{\text{Nf}} \times 100 \tag{27}$$

$$\text{False Positive Rate }(\%) = \frac{\text{Nfp}}{\text{Nnf}} \times 100 \tag{28}$$

$$\text{False Negative Rate }(\%) = \frac{\text{Nfn}}{\text{Nf}} \times 100 \tag{29}$$

These measures were used for achieving the comparison between our proposed method and the other methods. The results are shown in Table 1.

Table 1.Te performance of the proposed method and the other methods

Method	DR	FPR	FNR
HSV	85.798	5.098	14.202
YIQ & HSV	85.845	4.834	14.155
YUV	86.256	22.885	13.744
YIQ & YUV	86.706	8.923	13.294
YCgCr	88.959	10.329	11.041
YCbCr	89.647	7.580	10.353
IHLS	90.868	11.760	9.132
YIQ	91.759	18.868	8.241
RGB	92.756	4.720	7.244
RGB & YUV	92.597	3.749	7.403
Our Proposed Method	95.114	4.473	4.886

From the results, we noticed that our proposed method has the highest Detection Rate (DR) value and the lowest False Positive Rate (FPR) and False Negative Rate (FNR) values.

7. CONCLUSION

Skin color segmentation is an important and challenging problem for many of the image processing and computer vision applications. To achieve better skin detection for images with complex backgrounds and different brightness, a new approach that is based on the RGB and YUV color spaces has been described. The results show that the proposed method can achieve a high skin detection rate compared to the other methods. In future work, other features, such as texture, will be used for more accurate detection in dealing with more complex backgrounds and colored hair that is similar to the skin color pixels.

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