An Appropriate Color Space to Improve Human Skin Detection

BENCHERIET CHEMESSE ENNEHAR[1]
OUDJANI BRAHIM[1]
TEBBIKH HICHAM[2]

"May 8, 1945" University, BP 401 Guelma 24000, Algeria
Laboratory of Automatics and Informatics of Guelma (LAIG)
[1]cbencheriet@yahoo.fr, Oudjani@gmail.com
[2]tebbikh@yahoo.com

Abstract. Skin color detection is often an effective means used to define a set of candidate areas likely to contain faces, hands, or other human organ in a scene. This can be performed by using human skin color models or by threshold of the appropriate color space. A few papers comparing different approaches have been published, however, a study of color space influence on skin detection is still missing. In this paper we present two contributions the first one a comparative study of skin detection obtained by series of tests performed on 11 color spaces (YCbCr, HSV1, HSV2, RGB, RGBn, YUV, Ydbdr, Ypbpr, Hlab, YIQ, Yxy) chosen among the most used, using two methods: skin segmentation by skin Gaussian model created from a large variety of skin samples kept from images of different races people the second method is using threshold according Color space where we give our second contribution that consist to propose threshold for six color spaces, that we didn't find in scientific literature. Experimental results reveal that using threshold or skin model, HLab is the most appropriate Color space to skin detection in color image. By our contribution we present a significant and useful tool to direct any faces detection system based on skin segmentation to use the appropriate color space that can increase positive detection rate and decrease the negative one.

Keywords: Color space, skin detection, skin-color model, Gaussian model , thresholds

(Received May 01, 2010 / Accepted November 22, 2010)

1 Introduction

Skin color is a very effective descriptor used for face detection [20][24]. There are many possibilities of attributes to characterize skin color as histogram, moments, and color [18]. This one may be represented by a large number of color spaces. Use a particular (this or that) color space can influence image information representation [12][15]. Our interest is precisely oriented to this last point precisely the influence of color representation on human skin detection. We present a series of tests performed on 11 color spaces (YCbCr, HSV1, HSV2, RGB, RGBn, YUV, Ydbdr, Ypbpr, Hlab, YIQ, Yxy) chosen among the most used [15][16][23], and using two methods of skin segmentation: The first one is using threshold following color space were we present our contribution that consist to propose threshold for six color spaces, that we didn't find in scientific literature, while the second is based on using of skin Gaussian model created from a large variety of skin samples kept from images of different races people.

2 Related Work

Numerous techniques for skin color modeling and recognition have been proposed during several past years [11] [7] [14]. Terrillon and Akamatsu [21] compared the performance of nine chrominance spaces in the context of faces detection. These color spaces were evaluated using two metrics. The first is the mean square deviation (MSDN), which was calculated from the normalized histogram constructed for each color space. The second metric is the degree of overlap between the distributions referred to skin and non skin called HIN. The paper concluded that the discrimination between the skin class and non-skin class is higher in the normalized spaces. Zarit, Super and Quek [25] have provide a comparison of five color spaces (actually their chrominance planes) and two non-parametric skin modeling methods (lookup table and by skin probability map). Brand and Mason [6] have evaluated three different skin color modeling strategies. Albiol, Toress and Delp [2] have claimed that for every color space there is an optimum skin detector with comparable performance. A skin detector can be found with the same performance regardless of the chosen color space, provided there is an invertible transformation between color spaces compared. Three color spaces RGB, YCbCr, and HSV were compared. The paper concluded that the operational characteristics of three-dimensional color spaces were identical, and performance of the YCbCr color space was lower since the transformation of any three-dimensional color space to two-dimensional color space is not invertible.

3 Color Spaces

The first step in skin detection is to choose an appropriate color space. The choice of a particular space often depends on the method and result that color space is used to encode the images, the use of a particular method requires use of a transformation allowing to move from original space to desired space and inverse transformation in order to store the resulting image. The space selected must produce robustness to illumination variations; this is achieved if the color space effectively separates chrominance to luminance. We talk briefly about the most popular color spaces and their properties.

3.1 RGB Color Space

This is the basic natively supported by most video cards. By combining the three primitive's red, green and blue, we can get (almost) all visible colors. It is also widely used for processing and storage of digital images. However, mixing of chrominance and luminance data make RGB not a very favorable choice for color analysis and color based recognition algorithms. (see figure 1)

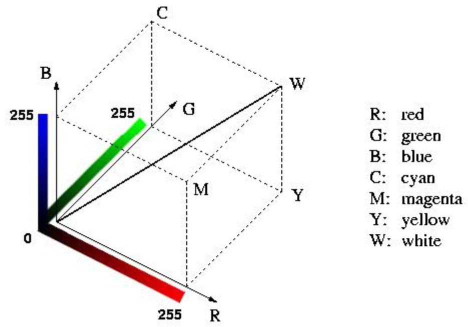

Figure 1: Representation of RGB Color Space

3.2 Normalized RGB Color Space (RGBN)

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 [23]:

$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B} \quad (1)$$

The sum of three normalized components is known (r + g + b = 1) , third component does no significant information and can be omitted, which causes a reduction in the dimensionality of space. The remaining components are often called "pure colors".

3.3 HSV Color Space

This color space is more intuitive. The colors, rather than being decomposed into primitive such as RGB, are represented by evident notions: Hue, Saturation, and Value [23]. (see figure 2)

The HSV space color was introduced when there was a need for the user to specify the digital properties of color. They describe the color with intuitive values. The intuitiveness of the color space components and the explicit discrimination between the luminance and chrominance properties has made this space popular in color segmentation [23].

$$H = \arccos \frac{1/2((R-G)+(R-B))}{\sqrt{(R-G)^2+(R-B)(G-B)}}; \quad (2)$$

$$S = 1 - 3\frac{min(R,G,B)}{R+G+B}; \quad (3)$$

$$V = \frac{1}{3}(R+G+B) \quad (4)$$

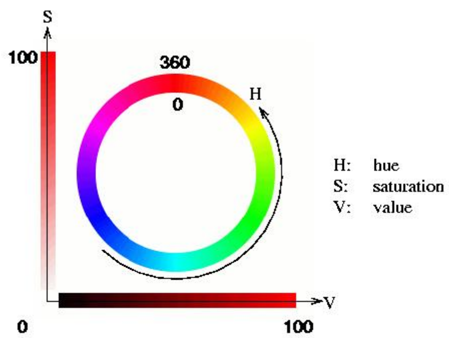

Figure 2: Representation of HSV Color Space

3.4 YCbCr Color space

The YCbCr color space has been defined in response to increasing demands of numerical algorithms in manipulation of video information, and became a model widely used in digital video. It belongs to the family of television transmission color spaces, generally used by television studios and in image compression.

The simplicity of transformation and explicit separation of luminance and chrominance components makes this attractive color space to model skin color [23].

$$\begin{pmatrix} +0.299 & +0587 & +0.114 \\ -0.169 & -0.441 & +0.500 \\ +0.500 & -0.418 & -0.081 \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} Y \\ Cr \\ Cb \end{pmatrix} \tag{5}$$

3.5 YPbPr Color space

YPbPr is a space of color used in the electronic video. It is the analogical version of the color space YCbCr, both are numerically equivalent, but YPbPr is conceived to be used in the analogical systems but YCbCr is intended for the digital video. YPbPr is converted by the RGB of the video signal, which is divided into three constituents Y, Pr and Pb [16].

Y: Information of luminance (luminosity).

Pb: is the difference between the blue and the luminance components so: Pb = B-Y

Pr: is the difference between the red and the luminance components so: Pr = R-Y.

3.6 YIQ Color Space

The TVs in North America and Japan use the YIQ space to encode color images. If the decoder is a black and white TV, only the Y component is used. Where Y represents the luminance used only by black and white televisions and additive synthesis by color televisions. I and Q are respectively the chromatic components representing the opposition cyan-orange and magenta-blue. The transformation is given by [16]:

$$\begin{pmatrix} +0.299 & +0.587 & +0.114 \\ +0.596 & -0.275 & -0.322 \\ +0.212 & -0.523 & +0.311 \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} Y \\ I \\ Q \end{pmatrix} \tag{6}$$

3.7 YUV Color Space

This space uses the R, G and B components but different than those defined by CIE and by the NTSC standard. The formula for Y is the same that defined for the YIQ space. However, the YYUV values are slightly different of YYIQ values due to the use of different primary RGB. The components of the YUV space are written as follows [16]:

$$\begin{pmatrix} Y \\ U \\ V \end{pmatrix} = \begin{pmatrix} +0.299 & +0.587 & +0.114 \\ -0.147 & -0.289 & +0.436 \\ +0.615 & -0.515 & -0.100 \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix} \tag{7}$$

3.8 XYZ Color Space

This color space comes to us of the CIE (International Committee (Commission) of the Lighting) and date 1930s. In this time, we wondered how to represent again colors in the television. Here also the component Y represents the luminance. Two other constituents, X and Z, are constituents with which it is not easy to associate intuitive notions. The transformed is given by [16]:

$$\begin{pmatrix} +0.431 & +0.342 & +0.178 \\ -0.222 & +0.707 & +0.071 \\ +0.020 & -0.130 & -0.939 \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \tag{8}$$

3.9 Yxy Color Space

Yxy expresses the values of space XYZ in terms of chromatic coordinates x and y, a little similar to the coordinates of tint and saturation of HSV space. Coordinates are indicated in formulae below, used to convert XYZ in Yxy [16]:

$$\begin{gathered} Y = Y \\ x = X/(X+Y+Z) \\ y = Y/(X+Y+Z) \end{gathered} \tag{9}$$

3.10 Hunter Lab Color Space

Hunter has developed in 1948 a uniform color space known Hunter Lab, which can be read directly with a photoelectric colorimeter, it is still used in many fields of industry in USA to measure the color such as chemical, paint, paper, plastic and textile. The Hlab is calculated from the square roots of XYZ [16]. XYZ transform is given in eq. 8.

$$\begin{gathered} L = 10 * sqrt(Y) \\ a = 17.5(((1.02 * X) - Y)./sqrt(Y)) \\ b = 7 * ((Y - (0.847 * Z))./sqrt(Y)) \end{gathered} \tag{10}$$

4 Skin color segmentation

Human skin has the unique color properties. The idea of using color in the pretreatment step of face detection has been suggested because it is invariable against graduation, rotations and translation. The two basic challenges are to decide what color space should be used, and how to model the color distribution. The skin detection can be achieved by a simple threshold technique or skin model color from a selected database [1] [9] [19].

4.1 Skin detection by threshold

The skin detection by threshold is to classify each pixel independently of its neighbors. A skin detector color can be defined in terms of the relationship between the chrominance and the intensity, hue and saturation components or red, green and blue components. This change depends on the color space used. The method separates the skin color from not skin color, this method propose a set of fixed skin thresholds in a given color space. Working on different color spaces, we have implemented eleven different thresholds tested in this paper, six of them are the result of tests series performed by us [17], the other five are from the scientific literature, appointed by the color space adopted : YCbCr, HSV(HSV1, HSV2), RGB, RGBn, YUV, Ydbdr, Ypbpr, Hlab, YIQ, Yxy.

4.1.1 YCbCr

Chai and Ngan [8] have developed an algorithm that exploits the spatial distribution of human skin color. A skin color map is derived and used on the chrominance components of the input image to detect pixels that appear to be skin. The algorithm employs a set of novel regularization processes to reinforce regions of skin-color pixels that are more likely to belong to the facial regions and eliminate those that are not. Working in the YCbCr space, the authors have found that the range of Cb and Cr are most representative for the skin color reference map where:

$$\begin{gathered} 77 \leqslant Cb \leqslant 127 \\ 133 \leqslant Cr \leqslant 173 \end{gathered} \tag{11}$$

4.1.2 RGB

Kovac, Peer and Solin [13] work in the RGB color space; they classify the skin color by heuristic rules that take into account two different conditions: uniform daylight and flash or lateral illumination.

Uniform daylight illumination:

$$\begin{gathered} R > 95, G > 40, B > 20 \\ (max(R, G, B) - min(R, G, B)) < 15 \\ |R - G| > 15, R > G, R > B \end{gathered} \tag{12}$$

Flashlight or daylight illumination:

$$\begin{gathered} R > 220, G > 210, B > 170 \\ |R - G| \leq 15, B < R, B < G \end{gathered} \tag{13}$$

4.1.3 HSV

Tsekeridou and Pitas [22] have working in the HSV color space and select pixels with the skin colors by thresholds defined in section 4.1.4 and 4.1.5

4.1.4 HSV1

(Transformation by Matlab function " rgb2hsv ") The range of H chosen limit reddish colors of segmentation and the saturation range chosen ensure the exclusion of pure red colors and very dark red, both are caused by small variations in the conditioning light. The threshold V presents the elimination of dark colors

$$\begin{gathered} V \geq 40, \\ 0.2 < S < 0.6, \\ 0° < H < 25° \end{gathered} \tag{14}$$

were: $335° < H < 360°$

4.1.5 HSV2

Transformation by the application of "HSV" values described in subsection 3.3 and after several tests helped by skin color histogram on this color space we have reached to set the following thresholds [4][17] :

$$\begin{gathered} V \geq 0.4, \\ 0.10 < S < 30, \\ 0.03 < H < 0.07 \end{gathered} \tag{15}$$

4.1.6 RGBn

Gomez and Morales [10] have used an approach of constructive induction to determine the map of skin. Beginning with the three RGB components in a normalized format and a simple set of arithmetic operators, the authors produce a rule for the skin detection. Among different combination rules presented by the authors, we chose those that the precision and success rates are highest:

$$\begin{gathered} \frac{r}{g} > 1.185 \\ \frac{r.b}{(r+g+b)^2} > 0.107 \\ \frac{r.g}{(r+g+b)^2} > 0.112 \end{gathered} \tag{16}$$

Where r, g, b are the normalized coordinates obtained by eq. 1

4.1.7 Threshold of other Color Space

Not finding in the scientific literature, we proposed our thresholds of skin color segmentation for remaining color spaces (YUV, Ydbdr, Ypbpr,Yiq, Yxy, Hunter lab) obtained (see Table 1) after several tests obtained by representation of skin colors histogram (see Figure 3) applied on a large skin database include white, brown, black and yellow human skin color [3][17].

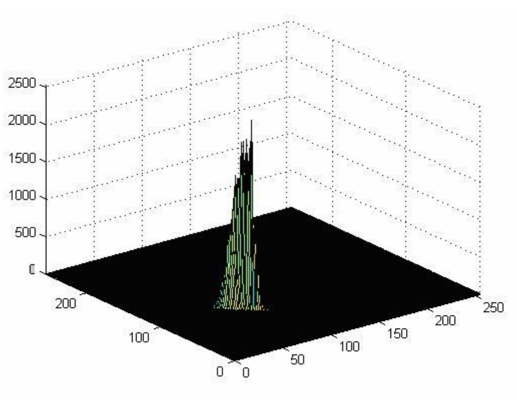

Figure 3: skin color distribution

Table 1: Thresholds Proposed To Skin Detection

Color Space	Proposed thresholds
YUV	80<Y<180, 20<U<100, 100<V<160
$Ydbdr$	125<Y<200, 105< db<240, 180< dr<240
$Ypbpr$	120<Y<236 ,33<pb<107, 75<pr<130
Yiq	110<Y<242, 80<i<153, 53<q<122
Yxy	115<Y<240, x=1,y=1
$HLab$	0< a <0.55, b>0.99

5 Skin detection by Gaussian model

The inspiration to use skin color analysis for the initial classification of an image into regions that likely can be faces or non-faces comes from a number of simple but powerful features of skin color. The skin detection can use parametric or nonparametric models of skin distribution. In the case of parametric modeling, a predefined statistical model is chosen to model the skin distribution. In the case of non-parametric modeling, a histogram analysis of learning data follows a probability function describing skin color distribution. In this study we have adopted parametric approach which steps are described as follows:

1. Transform the image of the original space to the space in which we intend to detect skin (see Figure 4 (B) and Figure 5 (B)).

2. Create a skin model for each color space. For that it was necessary to use multiples images with different skin colors of people. In our case we took 200 images extract from UCD color database (part database results) [19] (see Figure 6).

3. From these images we extracted images containing only skin sections (see Figure 7) which are thereafter represented in the chosen color space.

4. These samples were subsequently filtered by a low pass filter to reduce noise in each image. The impulse response of low pass filter is given by:

$$\frac{1}{9}\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \tag{17}$$

5. Thereafter the means r and b and covariance C are determined in each color space used:

$$\begin{gathered} means : m = E[x] \\ were : x = (r,b)^T \end{gathered} \tag{18}$$

is the transpose of coordination vector. r is the mean of the first representative coordinate, and b the second.

Covariance :

$$C = E[(X-m)(X-m)^T] \tag{19}$$

6. Using the mean and covariance values, the skin color model can be adapted to a Gaussian model N(M,C) (Figure 8)

7. After creation of the skin model, we determine regions that are most likely to be regions of skin in the original image using the following skin distribution model to determine the likely skin regions:

$$P(r, b) = exp[-0.5(x-m)^T C^{-1}(x-m)] \quad (20)$$

   r, b ratings are the means of the most representative coordinates for every color space. This algorithm determines the probability that a pixel is a skin region using skin model already created.

8. After determining the probability of each pixel of the image, we get an image in grayscale giving the probability based on gray levels (see Figure 4 (C) and Figure 5 (C)).

9. After obtaining likelihood skin image in grayscale, a threshold is necessary for obtaining a binary image (see Figure 4 (D) and Figure 5 (D))

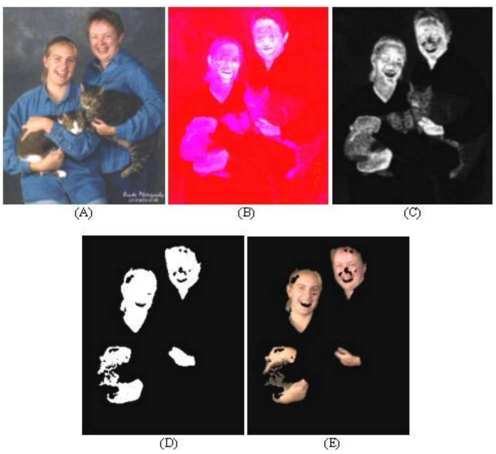

Figure 4: Steps of skin detection by Gaussian model with Hunter lab color space: (A) : Original image, (B) : Converted image in Hlab color space, (C): Probability image, (D) : Binary image, (E): Skin image.

6 Result and Discussion

Both methods were applied on a test set of 100 images: 50 are from BAO database [9] and 50 from UCD color database [19] (Figure 9) to detect human skin, in our experiments; we use ten different color spaces: RGB, HSV (HSV1, HSV2), RGBn, YCbCr, YUV, Ydbdr, Ypbpr, YIQ, Yxy and Hunter lab. On this test series we obtained the results in (Table 2 and Table 3). Were we tested influence of space color on two methods of segmentation often used in the literature (by threshold

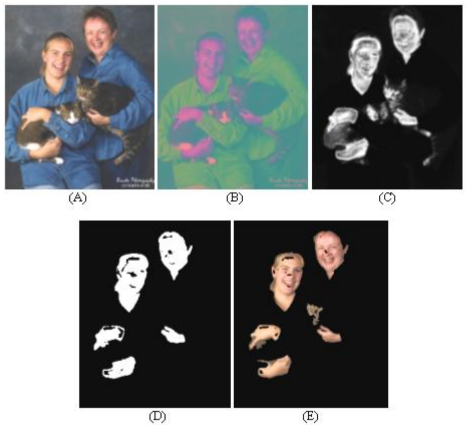

Figure 5: Steps of skin detection by Gaussian model with YCbCr color space

Figure 6: Example images of UCD color database used to create skin model

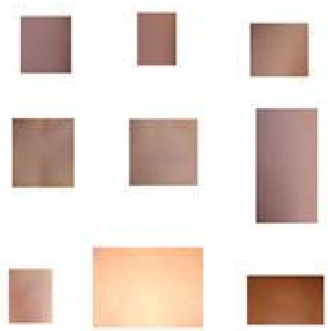

Figure 7: Skin Samples

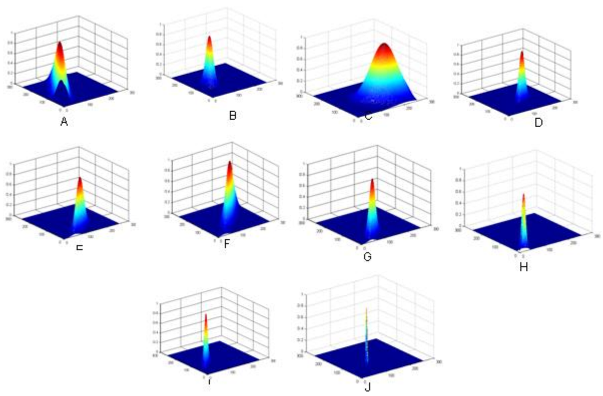

Figure 8: Skin Gaussian Model of the 10 flowing colorspaces: (A): RGB, (B): RGBN, (C): HSV, (D): YCbCr, (E): YUV, (F): Ydbdr, (G): Ypbpr, (H): HLab, (I): Yiq, (J): Yxy

and model) [5][20][23] the decision whether a pixel is skin or not is only with the color values of that pixel alone.

$$\mathrm{CR} = \frac{\text{number of detection skin regions}}{\text{Number of real skin regions}} \qquad \mathrm{FR} = \frac{\text{Number on false detections}}{\text{Number of detection}} \tag{21}$$

were CR : Correct detection rate and FR : False detection rate.

Parametric methods can be really slow as the Gaussian approach, seven times more slowly than the threshold method, and their performance depends heavily on the form of skin distribution. In addition, most methods of parametric model skin ignore the statistics of non-skin color, which leads "causing" false detections. The best performance was achieved by the Hunter lab and YCbCr color spaces on the skin model approach with a good detection rate of 93.6 and 94.00 respectively and a false detection rate of 9.5 and 14.00. Several studies on the skin detection do not provide a strict justification for their color space choice, perhaps because the possibility of obtaining acceptable skin detection with almost any color space.

Only a few works have been devoted to the comparative study of different color spaces used for skin detection, as in [21] [2]. In the parametric approach, several papers seriously doubt any significant influence of choice the color space on the final result of skin detection, as in [2]. Unlike, the performance of parametric approaches for skin detection depends strongly on the choice of color space, this can be observed by the results obtained in [21]. We tested whether a color transformation improves the performance of the detection or not, where we find that the transformation of the color space helps in a significant way for a better segmentation of booth approaches (threshold and modeling), whatever the segmentation method, the number of skin regions depends largely on the color space used. Thus in the method of threshold and for some color spaces, we ignored the illumination component because it does not add much information to separate skin from not-skin color. On the basis of results presented in the tables above, we can conclude that using the RGB and RGBn color spaces are not significant in both methods because of their very high false detection rate, in the threshold method, and even for HSV1, HSV2 produced lower false detection rate, but the correct detection rate remains low. While the skin model method, HSV produces a reasonable result. The result of segmentation for YXY in both methods remains poor. The color spaces YPbPr, Ydbdr, YUV and YIQ, give an acceptable result for the model method.

A good segmentation was obtained by the model method with Hlab and YCbCr color spaces.

For the threshold method the HLab and YCbCr color spaces gave us good results, but the disadvantage is that they are not able to segment certain skin colors that differ from one person to another (people of black color for example), and it's said for all color spaces used in the threshold method. The HLab color space only achieved the best segmentation for two approaches with a minimum false detection. We also found that the skin model approach made a difference on the detection performance, it is significantly better than the threshold approach, but we must be careful in choosing of color space.

7 Conclusion

Skin detection is an important preliminary process in face and hand detection. This work provides a testing methodology that takes into account the choice of the best approach to skin detection. This analysis indicates that the transformation of the color space improves performance.

The skin color detection using model approach is significantly better than the threshold approach, but we must be careful in choosing the color space. We found that the best performance for skin detection was obtained by transforming the pixel color to Hunter lab and YCbCr color spaces with using skin model approach. The capabilities of generalization and interpolation of this approach can produce acceptable performance.

In this study, we provided a tool to select the best approach; between thresholding and modeling skin color; and the best color space to detect skin designed for face detector. So our results are focused only in two simple segmentation methods and these results could be very specific for these two techniques. Adopting other more sophisticated techniques, as for example, Artificial Neural Networks, can produce different results.

Acknowledgment

This work was supported by the LAIG Laboratory of Automatic and Informatics of Guelma, "May 8, 1945" University, BP 401 Guelma 24000, Algeria

References

[1] Abdallah, S. A., Mohamad, A. E., and Lynn, A. A new color image database for benchmarking of automatic face detection and human skin segmentation techniques. *WASET*, 36, 2007.

[2] Albiol, A., Toress, L., and Delp, E. Optimal color spaces for skin detection. *ICIP*, 2001.

[3] Bencheriet, C., Boualleg, A. H., and Tebbikh, H. An hybrid method for faces detection based on skin color in rgb and hsv space and template matching. *37th International Conference on Computers and Industrial Engineering, Alexandria - Egypt*, pages 20 – 23, Octobre 2007.

[4] Bencheriet, C., Boualleg, A. H., and Tebbikh, H. Segmentation de la couleur de peau par seuillage selon différents espaces de couleur. *3èmes Journées Internationales sur l'Information Graphique JIG'2007, Constantine, Algérie*, pages 29–30, Octobre 2007.

[5] Bencheriet, C., Boualleg, A. H., and Tebbikh, H. Faces detection method based on mixture of skin gaussian model and template matching. *10th Maghrebian Conference on Information Technologies MSCEAI'08, USTMB Oran, Algeria*, pages 28–30, April 2008.

[6] Brand, J. and Mason, J. A. comparative assessment of three approaches to pixellevel human skin-detection. *In Proc. of the International Conference on Pattern Recognition*, pages 1056–1059, 2001.

[7] Caetano, T. S. and Barone, D. A. C. A probabilistic model for human skin color. *Proceedings of ICIAP 2001-IEEE International coference on image analysis and processing, Palermo, Italy*, pages 279–283, September 2001.

[8] Chai, D. and Ngan, K. N. Face segmentation using skin color map in videophone applications. *IEEE Transactions on Circuits and Systems for video Technology*, pages 551–564, 1999.

[9] Frischholz, R. Bao face database at the face detection homepage. *Available: http://www.facedetection.com*.

[10] Gomez, G. and Morales, E. F. Automatic feature construction and a simple rule induction algorithm for skin detection. *Proc. of the ICML workshop on Machine Learninng in Computer Vision, Sydney, Australia*, pages 31–38, 2002.

[11] Jones, M. J. and Rehg, J. M. Skin color modeling and detection. *Hewlett-Packard Company*, June 2002.

[12] Kawato, S. and Ohya, J. Automatic skin-color distribution extraction for face detection and tracking. *ICSP2000: The 5th Int. Conf. on Signal Processing, Beijin, China*, II:1415–1418, August 2000.

[13] Kovac, J., Peer, P., and Solin, F. 2d versus 3d color space face detection. *4th EURASIP Conference on Video/Image Processing and Multimedia Communication, Croatia*, pages 449–454, 2003.

[14] Lee, J. Y. and Yoo, S. I. An elliptical boundary model for skin color detection. *the 2002 international conference on imaging sciencesystems, and technology, Las Vegas, USA*, June 2002.

[15] Marian, S. Evaluation of rgb and hsv models in humain faces detection. *CompSysTech: Conference on Computer Systems and Technologies*, IIIA:1–5, 2004.

[16] Murat, K., Goesta, G., and Michel, K. Traitement numérique des images. *Presses polytechnique et universitaires Romande*, 2, 1993.

[17] Oudjani, B., Bencheriet, C., and Tebbikh, H. Détection de visages par méthode hybride couleur de peau et adaboost. *Journée des Jeunes Chercheur en informatique JCI'08, Guelma, Algérie*, July 2008.

[18] Rajkiran, G. and K.Asari, V. Learning skin distribution using a sparse map. *ICIP*, pages 199–202, 2004.

[19] Sharma, P. and Reilly, R. B. A color face image database for benchmarking of automatic facial detection algorithms. *Proc. 4th European Conference of Video/Image Processing and Multimedia Communications*, pages 423 – 428, July 2003.

[20] Stan, Z. L. and Anil, K. J. Handbook of face recognition. *Springer*, 2005.

[21] Terrillon, J. C. and Akamatsu, S. Comparative performance of different chrominance spaces for color segmentation and detection of human faces in complex scene images. *International Conf on Face and Gesture Recognition*, pages 54–61, June 2000.

[22] Tsekeridou, S. and Pitas, I. Facial feature extraction in frontal views using biometric analogies. *Proc. of the IX European Signal Processing Conference*, I:315–318, 1998.

[23] Vezhnevets, V., Sazonov, V., and Andreeva, A. A survey on pixel-based skin color detection techniques. *In Proceedings of the GraphiCon*, pages 85–92, 2003.

[24] Yang, M. H., Kriegman, D. J., and Ahuja, N. Detecting faces on images: A survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 24(01):34–58, 2002.

[25] Zarit, B. D., Super, B. J., and Quek, F. K. H. Comparison of five color models in skin pixel classification. *In ICCV'99 Int'Workshop on Recognition, Analysis and Tracking Faces and Gestures in Real Time Systems*, pages 58–63, 1999.

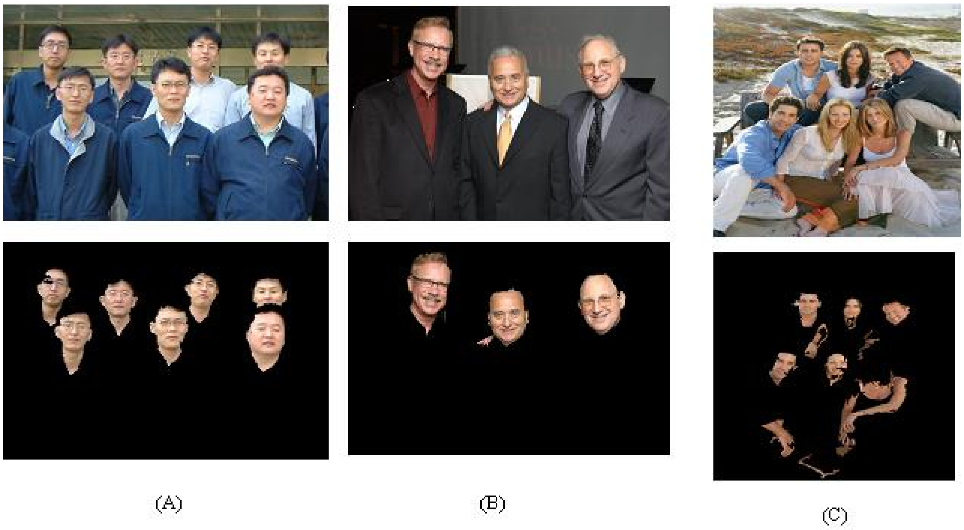

Figure 9: Illustration of some results of skin detection applied on:(A) (B) BAO database, and (c) UCD color database

Table 2: Performance of Skin Detection By Threshold

	RGB	RGBn	HSV1	HSV2	YCbCr	YUV	Ydbdr	Ypbpr	HLab	Yiq	Yxy
CR	98.40	93.00	90.5	90.7	94.00	90.00	91.09	88.6	93.6	89.00	87.5
FR	26.82	22.31	31.00	9.6	17.00	12.50	15.2	15.6	11.00	18.00	16.5

Table 3: Performance of Skin Detection by Skin Model

	RGB	RGBn	HSV	YCbCr	YUV	Ydbdr	Ypbpr	HLab	Yiq	Yxy
CR	97.00	93.00	90.0	94.00	94.00	90.66	92.00	93.6	91.02	89.8
FR	34.5	25.90	18.56	14.00	16.50	17.00	17.80	9.5	16.05	20.66