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Face Detection in Color Images Using Skin Color

Md. Mehedi Hasan, Jag Mohan Thakur, Prajoy Podder

Abstract— Because of the increasing demands of security for the present society, intelligent biometric identification such as face detection has got more application. Human face detection plays an important role in applications which are personal identification, face modelling, fitness, face reconstruction, and face animation, facial expression analysis, video surveillance, control systems and security purpose. Face can be detected automatically with the help of computer but it is a challenging task for various face position, face shape, orientation, lighting condition, colour etc. In this article, a new assistive frame work has been introduced for fast and efficient detection of face. The goal of this paper is to detect the face by skin colour segmentation technique. Skin colour segmentation process helps to avoid the challenges of face colour, size and orientation. The brightness problem has been reduced by YCbCr colour space conversion. The experimental result shows that the proposed method has reliable performance than the existing methods. The accuracy of the proposed fame work is 99.27%.

Index Terms— Color space, Face detection, Knowledge base approach, Morphological technique, Region localization, Skin color segmentation, YCbCr color space .

1 Introduction

SECURITY in our complex world is a vital issue. Network banking, financial abuse of bank, Credit cards sabotage makes the security topic more important. So, at present intelligent biometric system has been issued for the security purpose. Face detection is a biometric identification system, which has been used in individual identification area.

During the last few years, many methods have been proposed for face detection. Face detection methods are classified into three categories. They are Knowledge based methods, Template matching methods and Appearance based methods. Knowledge based methods are also called rule based methods, used to get image position of a single face. Knowledge based methods has been classified into two types which are Top down methods and Bottom up methods [1]. Top down methods used different rules and conditions to get the facial features of human face. A human face consists of mouth, nose and two eyes which are symmetric to each other. Features relationship can be obtained by using relative position and distances of image. Bottom up methods uses different facial features, multiple features, texture, skin colour etc. to detect face [2]. Feature invariant approaches also called structural features, use random labelled graph matching and colour information to locate faces [3]. Template matching methods uses different rules and constraints to template face. Template matching method has been classified into two sub categories, which are predefined templates and deformable templates. Predefined template works in two steps. Firstly face is located and separated from image using templates. Secondly the existence of face is determined by focusing the areas of face [4]. Deformable Template also called parameterized template, which are used to determine different facial features. Edges of the input images, peaks, valleys are parameters of the template and used to describe energy function. An energy function of the different parameters is minimized to get elastic model [5]. Appearance based methods is a set of training images, which is used to capture the variation of facial appearance. Machine learning and statically analysis [6] has been used to determine the relevant features of face and non-face images. This method has been divided into two types, which are Neural Networks [7] and Support Vector Machines [8]. Neural network is used to detect faces from anywhere of an image, at any image locations. In order to detect faces which are larger than 20x20 pixels, input image is sub scaled repeatedly and at each scale network is applied. Multi-layer neural network has been used to get face and non-face patterns from face and non-face images. A neural network is a first component of this method to get a 20x 20 pixel of an image region. And the output score ranges from -1 to 1. According to given test pattern, the trained neural network uses output -1 to represents non-face and 1 is used for face pattern. In support vector machine (SVM) approach [8], polynomial function, radial base function and neural networks classifier is trained to get desired result. Training classifier methods has been used to minimize the training error. Structural risk minimization uses induction principle to minimize the upper bound of an expected generalization error.

Skin colour is a good feature for detection of the human face. There are two main approaches in face detection based on skin colour. Pixel-Based Model is the first approach, which is used to detect all parts of human skin colour by processing the pixels of skin. Each pixel is processed independently to detect whether it is skin colour or not. Skin colour detection has classification problem and primary step to select suitable colour

- *Mehedi Hasan is currently pursuing B.Sc. degree program in electronics & comcmunication engineering in Khulna University of engineering & technology (KUET), Bangladesh, PH-008801790853171. E-mail: mehedihasanece@gmail.com*
- *Jag Mohan Thakur is currently pursuing B.Sc. degree program in electronics & communication engineering in Khulna University of engineering & technology (KUET),Bangladesh,PH-008801675850718.E-mail: jagmohanthakur43@yahoo.com*
- *Prajoy Podder is currently pursuing B.Sc. degree program in electronics & communication engineering in Khulna University of engineering & technology (KUET),Bangladesh,PH-008801714078499.E-mail: prajoypodder@gmail.com*

International Journal of Scientific & Engineering Research Volume 5, Issue 6, June-2014
ISSN 2229-5518

space. So that, colour space can easily discriminate skin and non-skin pixels. Second approach used to determine the status of the region of the image. Necessary effort has been made to separate face from the given image. And after using the knowledge and information of previous image, it is decided that the given image belongs to face or not. Many different colour space RGB (Red Green Blue), HSV [9] (Hue Saturation Value), YES, YCbCr, CIE Lab, TSV, HIS (Hue Saturation Intensity) [10], TSL are used for face detection. In this paper, a pixels based skin colour segmentation process has been introduced. YCbCr [11] is the main colour space. The YCbCr is a colour space that has red, blue components. In case of YCbCr colour space [11], [12] Cb is smaller than Cr components. RGB colour image has been used as input for the proposed method. After the skin colour segmentation, there have been some small noise. This noise has been reduced by image erosion, image dilation through morphological process. Image filling operator fills the unwanted holes in face region and exterior boundary points of face region has been traced to determine the top, bottom, left and right sides.

The rest of the paper is oriented as follows. Color models for skin colour are described in section– II. The overview of the proposed algorithm is described in section– III. Under this section face detection process is explained clearly. The experimental results and comparison with different colour space are explained in section-IV. Finally, section-V concludes the paper.

2 Skin Color Classification

2.1 RGB colour space

An RGB colour space is mainly used due to its simplicity and easiness of implementation. Red, Green and Blue chromaticity has been used to produce any primary colour. The mixing of chrominance and luminance data is not suitable choice for colour analysis because of non-uniformity and high correlation between the channels. An RGB colour model has been used to represent digital images. RGB output has been used by most of the image display devices. It is mainly used in all computer systems, videos, cameras, etc. RGB and Adobe RGB are the mostly used RGB colour spaces [13]. Adobe Wide Gamut RGB is another colour space recently developed by Adobe.

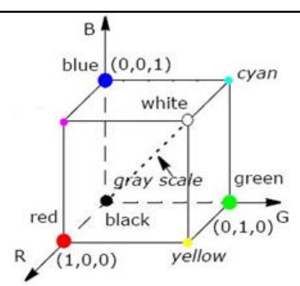

Fig.1. RGB colour cube

2.2 HSV colour space

HSV [14] stands for Hue, Saturation and Value. The level of brightness has been shown by the Value. HSV colour space is much simpler and can be linearly transformed from RGB. HUE is defined by the dominant colour of the area such as Red, Purple and Yellow. Saturation is provided by the colourfulness of the area, which is in proportion to the brightness of the image. Chrominance and luminance separation has been obtained in this space. Invariant to highlight, surface orientation, etc. are the most important properties of colour segmentation. This makes this colour space most popular. Discriminating information has been providing by H and S, which is related to skin. H, S, and V values for face and non-face pixels have been plotted with the help of reference image to detect any valuable trends.

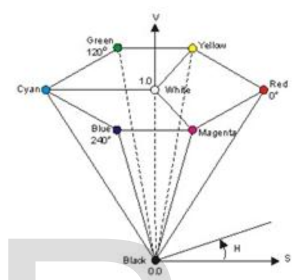

Fig.2. HSV colour cube

The conversion of RGB to HSV is provided by the following equations,

$$\mathrm{H} = \begin{Bmatrix} H i if B \le C \\ 360 - H i if B > C \end{Bmatrix} \quad (1)$$

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

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

$$\mathrm{V} = \frac{max(R,G,B)}{255} \quad (4)$$

2.3 TSV and TSL colour space

TSV and TSL colour space has been used for skin detection. This is complex perceptual colour Spaces used in place of HSV. TSL colour space is best choice for Gaussian Skin colour modelling [15].

$$\mathrm{T} = \begin{Bmatrix} \frac{\frac{1}{2\pi} arctan\, r'}{g'} + \frac{3}{4}\; if g' < 0 \\ 0 \quad if g' = 0 \\ \frac{\frac{1}{2\pi} arctan\, r'}{g'} + \frac{1}{4} \quad if g' > 0 \end{Bmatrix} \quad (5)$$

where, r' =r-1/3, g'=g-1/3

International Journal of Scientific & Engineering Research Volume 5, Issue 6, June-2014
ISSN 2229-5518

$$S = \sqrt{\frac{1}{5}(r' \uparrow 2 + g' \uparrow 2)} \quad (6)$$

$$V = \frac{R+G+B}{3} \quad \& \quad L = 0.299R + 0.587\,G + 0.114\,B \quad (7)$$

2.4 HSI colour space

HSI [16] stands for Hue, Saturation and Intensity, which is used to describe colour. HSI colour space can be easily produced without knowing the percentage of Blue or Green. By adjusting Hue, we can easily produce any type of colour. Adjusting the saturation, deep red to pink can be easily changed. Altering the intensity, lighter or darker colour can be easily made. HSI colour model has many applications. HSI colour space is used for Machine vision to identify the colour of different objects. In image processing, intensity image are operated by convolutions, intensity transformations and histogram.

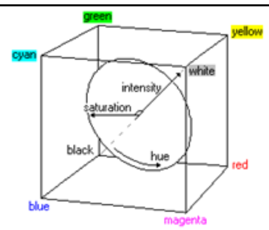

Fig.3.HSI colour cube

2.5 YCbCr colour space

The YCbCr colour space also known as family of colour spaces because the Chroma components Cr and Cb can be easily calculated. Luminance is denoted by Y. Blue difference and red difference Chroma components are denoted by Cb and Cr. The three components of YCbCr can be easily calculated by linearly combinations of R, G and B components of image. In order to get the skin region, it must satisfy the following equations [17],

$$140 <= Cr <= 165 \text{ AND}$$

$$140 <= Cb <= 195$$

The pixels related to skin regions of human faces have similar characteristics as Cb and Cr components. Skin colour is mainly determined by the darkness or fairness of the skin. The difference in brightness of colour mainly determines the Y component rather than Cb and Cr components [18]. In order to get skin regions, some restrictions are made on these two components and Hue. Hence, Skin colour can be easily detected by Chrominance and luminance colour due to all this property and its simplicity [19].

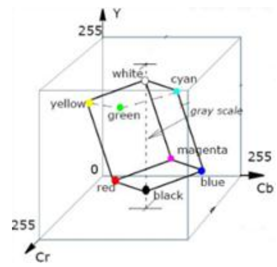

Fig.4. YCbCr colour cube

2.6 Normalized RGB colour space

Normalized RGB has been used to reduce the dependencies of RGB values by changing its luminance. It is clear that from this equation, (r+g+b=1). Third components can be easily obtained by knowing any two components of r, g and b [20]. Color space detection has been used to separate chrominance from luminance. N-RGB is the mostly used colour space among researchers because of its simplicity in transformation and all its advantages. Normalized RGB is obtained by the following equations,

$$r = R/R+G+B, \quad (8)$$

$$g = G/R+G+B, \quad (9)$$

$$b = B/R+G+B. \quad (10)$$

2.7 CIE LUV and CIE Lab colours space

CIE LUV and CIE Lab colour space [22] are the nonlinear transformation of CIE XYZ. CIE LUV provides much better perceptual uniformity in the comparison to its predecessors. Both colour spaces are device independent. Chrominance and Luminance can be easily separated in this colour space. These colour spaces are not suitable for skin detection due to its complexity and computational expensiveness.

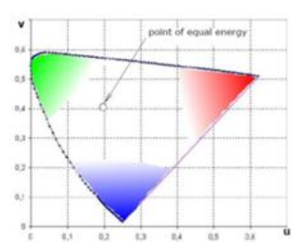

Fig.5. CIELab colour cube

3 Overview of Proposed Algorithm

Face detection is a challenging task for different face structure, face position, orientation, facial expressions and skin colour. Here an easy frame work has been introduced for face detection.

Fig.6 describes the total evaluation process of the activity of the proposed method. Firstly, face image is used as input then the face area is localized from the input face image. After area localization, face is detected from that localize region. The to-

International Journal of Scientific & Engineering Research Volume 5, Issue 6, June-2014
ISSN 2229-5518

tal processes of the proposed algorithm are explained as follows.

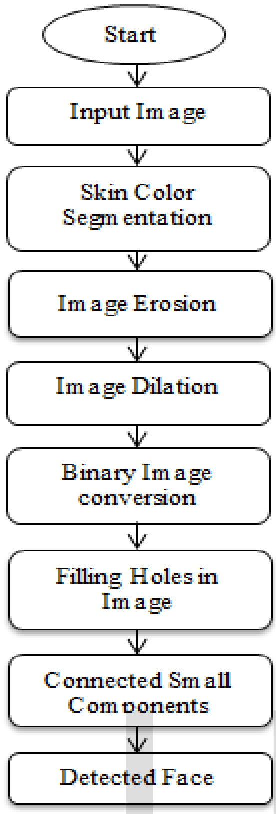

Fig.6. Block diagram of proposed method

4 Face Detection by Proposed Method

Skin colour segmentation is used in face detection procedure. Which is knowledge based approach that helps to avoid challenges of face size, colour and orientation. The impact of brightness problem is reduced by the conversion of RGB to YCbCr. Besides Processing of skin colour is much faster than processing other facial features for detection of face. Luminance component (Y) of YCbCr is independent of the colour, so it is used to solve the illumination variation problem. Following conditions are applied to detect face region,

$$\left.\begin{array}{l} Cb>=80 \text{ AND } Cb<=120 \\ Cr<=173 \text{ AND } Cr>=140 \text{ AND} \\ Y<=255 \text{ AND } Y>=60 \end{array}\right\} \quad (11)$$

After skin colour segmentation there remains some small noise. Those are reduced by using image erosion through morphological structure. Image erosion shrinks the object. The binary erosion of A by B, denoted A Θ B, is defined as the set operation.

$$A\Theta B = \{z \mid B_z \subseteq A\} \quad (12)$$

In other words, it is the set of pixel locations z, where the structuring element translated to location z overlaps only with foreground pixels in A.

Then binary image conversion is done to help image filling operation that fills unwanted holes in face region. Now it is helpful for exterior boundary detection. Large area of face region is achieved through maximum connected area. Exterior boundary points of the face region are traced to determine left, right, top and bottom side points. Exterior boundary of an object is obtained by first eroding the object by a structuring element and then taking the set difference of the object and its erosion. Boundary of a set A is denoted by β (A).

$$B(A) = A-(A-B) \quad (13)$$

Where, (AΘB) denotes the erosion operation. Fig. 7(a) illustrates the mechanism of boundary extraction top, bottom,

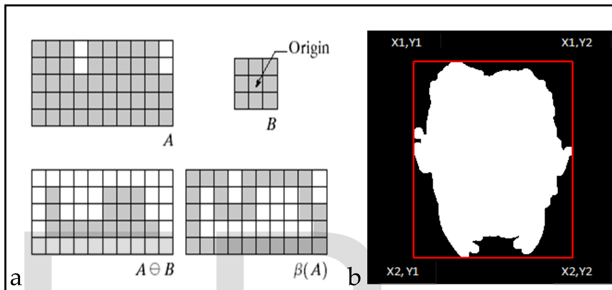

Fig.7. Exterior boundary extraction

Left and right side points are obtained from following equations. Bounding box is obtained from those side points shown in fig 7 (b).

X1= maximum (x_coordinates of boundary). (14)

X2= maximum (x_coordinates of boundary). (15)

Y1= maximum (y_coordinates of boundary). (16)

Y2= maximum (y_coordinates of boundary). (17)

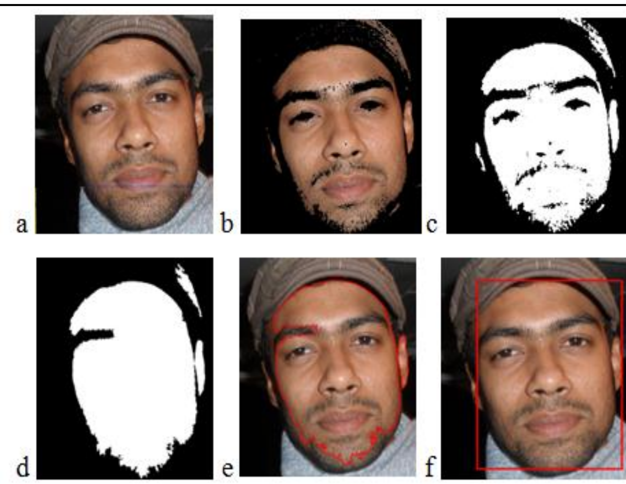

Fig.8. Face detection process by proposed method

International Journal of Scientific & Engineering Research Volume 5, Issue 6, June-2014
ISSN 2229-5518

Fig. 8 shows the total process of face detection by proposed method. Fig. 8(a) is the input image, fig. 8(b) represents the skin colour segmentation image, fig. 8(c) represents after morphological process image, fig. 8 (d) represents image after used image filling operator, fig. 8(e) represents the boundary detection image and fig. 8(f) represents the detected face image.

5 Experimental Result

For performance measurement the proposed methods has been experimented through matrix laboratory software (MATLAB). The images which are used as input is obtained by the Samsung company digital camera. The proposed algorithm has been experimented on 275 face images. The face in the images of the experimented people was different face position, face structure, pose, facial expression, colour condition and orientation. All the face images have been used as input to the previous existing methods and proposed method.

Fig.9 shows face detection result at different pose, brightness and facial expression. Fig. 9 (b, h, k, o, r, s, u) represents different pose of detected face, fig. 9 (c, d, f, h, j, k, n) represents various brightness of detected face and fig. 9 (e, h, k, m, o, s, t) represent various facial expression.

TABLE 1

Face Detection by the Previous System

Color Space	No of Images	Perfect Detection	False Detection	Efficiency
RGB	275	155	120	56.46%
HIS	275	226	49	82.18%
CIELab	275	236	39	85.8%
LCCS	275	247	28	89.8%

TABLE 2

Face Detection by the Proposed System

Color Space	No of Images	Perfect Detection	False Detection	Efficiency
YCbCr	275	273	2	99.27%

Table 1 show the outcome of the previous system, where RGB, HIS, CIELab, LCCS colour space are used. In case of RGB, the experimental results are not very much friendly with face detection based on skin colour. The face detection rate is 56.46%. HIS colour space shows that the face detection by this colour segmentation is 82.18%. CIELab colour space face detection rate is 85.8% and Log-Chromaticity Color Space (LCCS) shows that the face detection rate is 89.8%.

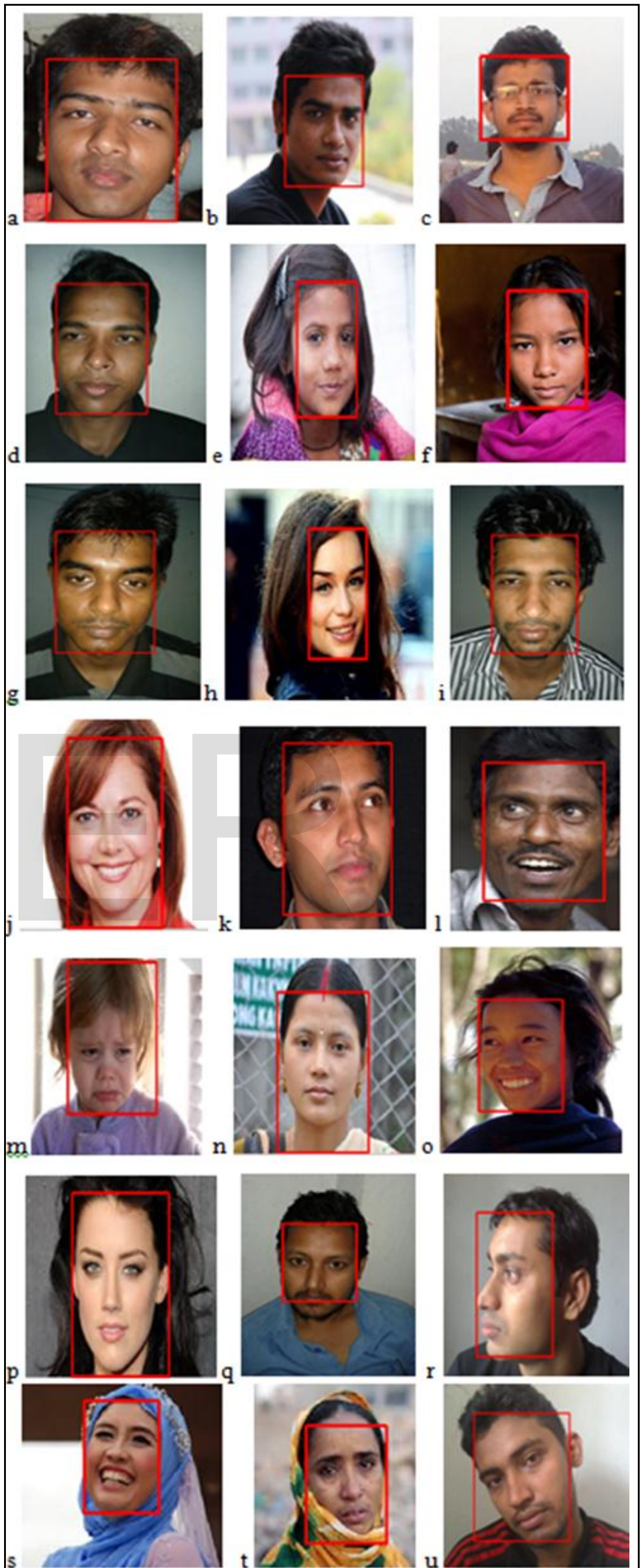

Fig.9. Results of face detection using proposed method at various pose brightness and facial expression.

International Journal of Scientific & Engineering Research Volume 5, Issue 6, June-2014
ISSN 2229-5518

Fig.10. Multiple faces detection at same image

Fig. 10 (a) and fig. 10 (b) shows, multiple face detection results at same image

Fig. 11 shows the comparative chart between the previous and proposed colour space methods. Where RGB detection rate is 56.46%, HIS detection rate is 82.18%, CIELab detection rate is 85.8%, LCCS detection rate is 89.8% and YCbCr detection rate is 99.27%.

Table 2 shows the accuracy of the proposed system, where YCbCr colour space has been used. The face detection rate is 99.27%, which is better than other existing colour space.

TABLE 3

COMPARATIVE RESULTS BETWEEN THE PROPOSED METHOD WITH PREVIOUS METHOD

Method	Color space	No of images	Efficiency
Previous method	RGB	275	56.46%
	HIS	275	82.18%
	CIE Lab	275	85.8%
	LCCS	275	89.8%
Propose method	YCbCr	275	99.27%

Table 3 shows the comparisons result between the existing methods and proposed method.

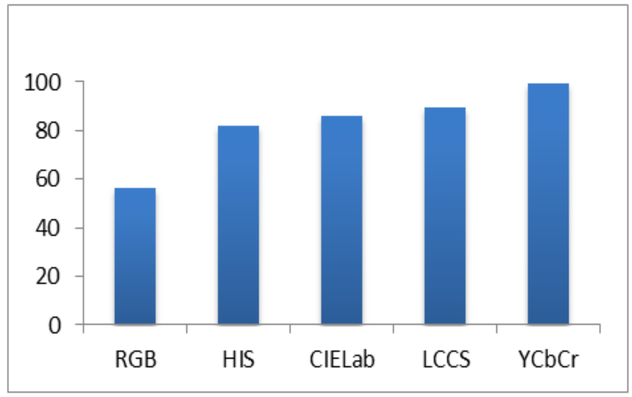

Fig.11. Comparative chart between previous (RGB, HIS, CIELab, LCCS) and proposed (YCbCr) method.

6 CONCLUSION

At present, facial information is used for various applications. So, in this paper, Author proposed to detect face from image with varying lighting conditions and complex background with the help of color spaces and color models of people. The practical model for human skin color has been discussed. We can easily obtain the threshold value of each color component with the help of color space model. The face detection algorithm is based on YCbCr color space method with lighting compensation technique and nonlinear color transformation. At first skin region is detected from image and then face area are found from grouping skin region. This proposed system works well on wide range of facial variation in color, position, scale and orientation with photo collection including both indoors and outdoors. The experimental result shows that the proposed method is much better than the other existing methods.

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International Journal of Scientific & Engineering Research Volume 5, Issue 6, June-2014
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