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Skin Color Segmentation based Face Detection using Multi-Color Space

Rosali Mohanty[1], M.V Raghunadh[2]

M.Tech Student, Department of ECE, NIT Warangal, Warangal, India [1]

Associate Professor, Department of ECE, NIT Warangal, Warangal, India [2]

Abstract: Human face detection plays a very important role in various biometric applications like crowd surveillance, photography, human-computer interaction, tracking, automatic target recognition, artificial intelligence and many other security applications. Varying illumination conditions, color variance, brightness, pose variations affect face detection. So, automatic face detection and recognition is a challenging concept which has attracted much attention due to its many applications in different fields. Face detection still poses a problem and up to now, there is no technique that provides a robust solution to face detection in all situations. There are many techniques for face detection, but skin color based technique is most popular as it is simple, robust and processing color information is much faster than processing any other facial features. So this paper proposes a novel algorithm foe face detection using multi-color space based skin segmentation and region properties. First, skin regions are segmented from an image using a combination of RGB, HSV and YCgCr color models using thresholding concept. Then facial features are used to locate the human face based on knowledge of geometrical properties of human face by testing each segmented skin region. Experimental results are used to show that, our proposed algorithm is robust enough to achieve approximately 96% accuracy and can locate a face in both single and multiple face images. The proposed method has also a good performance on images with complex background and can detect faces of different sizes, poses and expressions under different environmental conditions.

Keywords: face detection, skin color segmentation, RGB, HSV, YCgCr, Sobel edge detector.

I. INTRODUCTION

Face is one of the most important external features of people, so it plays an extremely important role in interpersonal communication. Face detection is always in the spotlight as it is a critical aspect of automatic face recognition system. The aim of face detection system is to decide if an image contains human faces and if it contains human faces, then it should return the spatial location of the space by separating them from background. Now as the human-computer interaction technology is becoming active research field of artificial intelligence, face detection has become an independent field of study. It has a wide range of applications in e-commerce, content-based imge retrieval, intelligent human-machine interfaces and so on. Basically, there are four methods for face detection named: knowledge based approach, Template matching methods, Feature based approach and machine learning based approach. Every methods has some advantages and disadvantages. If we consider feature based approach, it is very advantageous as features are scale independent, rotation independent and are processed very fast. As the human face face is an extremely complex non-rigid model, the detection method with integration of multiple feature information is gaining momentum.

Skin color is one of the most significant features of human face. In color images, skin color detection is very effective as skin color is relatively concentrated; so skin is the stable region in the image which does not rely on the details of facial features and is not sensitive to changes in posture, orientation, expression or other changes and can tolerate occlusion. Color processing is also faster and robust in nature compared to other features like edge, shape and texture etc. Apart from above mentioned advantages, skin color based detection method has some disadvantages like sensitivity to illumination intensity, varying skin tone from person to person etc. We need to solve these problems in order to use skin color features for face tracking.

In this paper we have used color based segmentation technique to localize a face region from both single and multiple face images. There are many color space models for skin segmentation like, RGB, YUV, YIQ, HSV, YCbCr, YCgCr etc having varying levels of performance. And choosing an effective color space is very important as it can affect the detection process substantially. So,in this paper we have used the combination of RGB, HSV, YCgCr and edge information to achieve a better performance. First we use combination of color models to detect skin pixels and convert segmented image to binary form. Then we extract only face region in the image and remove non-human face skin area by using human face features and and region properties.

The paper is organized as follows, in section II we have discussed different ‘color spaces’, while section III presents ‘proposed algorithm’, section IV explains the implementation methodology and section V contains simulation results. Finally we concluded this paper in section VI.

II. SKIN COLOR MODELS

The inspiration to use skin color models for classification of an image into probable face and non-face regions comes from the fact that the color of human skin is different from the color of other natural objects of the world. The choice of color space plays a very important factor while building the statistical color model. If we use chrominance component in analysis, then segmentation of skin regions become simple and robust. Therefore in our proposed algorithm we have eliminated the variation of luminance component upto optimum extent by choosing the CgCr plane of YCgCr color model. Our main reason for the choice of YCgCr domain is its extensive use in digital video encoding applications and its excellent clustering performance. In recent years, the study of skin color based segmentation has gained immense popularity due to its active research in content-based image representation. We can exploit the ability to locate image objects as a face for image coding, editing, indexing and other interactivity purposes.. Furthermore, for face recognition and facial expression studies, face localization also provides a good stepping-stone. The proposed algorithm takes the advantage of face color correlation to limit face search to areas of an input image that have at least the correct color components. In literature [5] there are many color based face detection algorithm, but the proposed algorithm uses only three color spaces namely, RGB, YCgCr and HSV.

A-RGB COLOR SPACE

The RGB color space consists of the three additive primary color components: red, green and blue. This color space contains all the colors that are obtained by the combinations of the three primary colors. A 3-dimensional cube with red green and blue at the corners represents the RGB model on each axis (Figure 1). The RGB model simplifies the design of computer graphics systems but is not ideal for all applications due to the strong correlation among red, green and blue color components. As RGB color model is light sensitive, it cannot be used in techniques like histogram equalization which works only on the intensity component of an image.

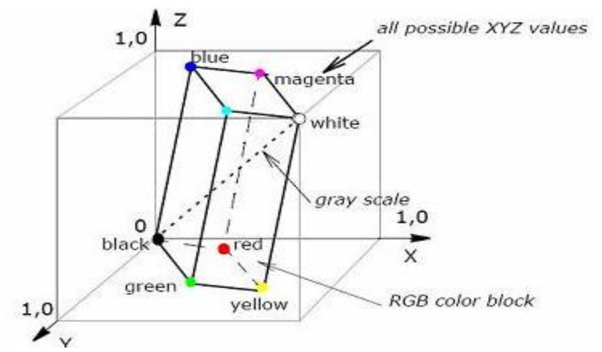

Fig 1: RGB color cube

B- HSV COLOR SPACE

The HSV color space is a perceptual color space which contains three color components: H- the hue component, which defines the color, S - the saturation component, which specifies the purity of color, and V - the value component, which defines the intensity or color-brightness. By considering only the H and S components we can make abstraction of different lighting conditions. The HSV color space is a hexacone in a 3D coordinate system, where H values vary from 0 to 1 on a circular scale, H=0 and H=1 representing the same color. S values vary from 0 to 1, 1 representing a color with 100% purity. V values vary from 0 to 1. Colors with S=0 represent different grey levels (the H component is not important). Colors with low S values cannot .be differentiated. In HSV model the skin pixels should satisfy the following conditions.

$$0 \leq H \leq 0.25 \text{ and } 0.15 \leq S \leq 0.9 \qquad (1)$$

Many image processing applications like histogram operations, intensity transformations and convolutions use the HSV color model.

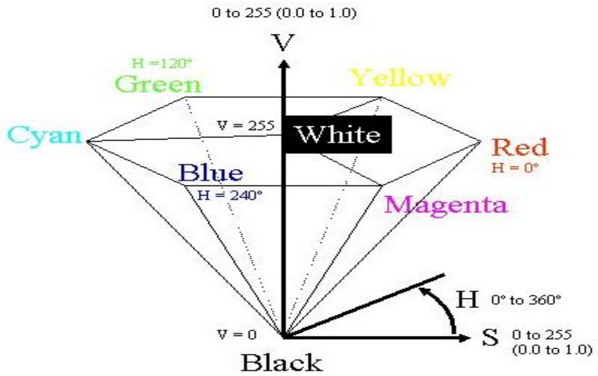

Fig 2: HSV color model

C- YCbCr COLOR SPACE

YCbCr is the main color space used for digital video encoding, where a color is represented by using brightness and two color difference signals. Y refers to the brightness (luminance) component, and is computed as a weighted sum of RGB values. Cb and Cr are the chrominance components, where Cb is computed as the difference between the blue component and a reference value and Cr is the difference between the red component and a reference value. The separation of the luminance component from chrominance makes the YCbCr color space luminance independent and more adequate than RGB for face detection by skin color segmentation. In YCbCr model the skin pixels should satisfy the following conditions.

$$135 < Y < 145;\ 100 < Cb < 110;\ 140 < Cr < 150 \qquad (2)$$

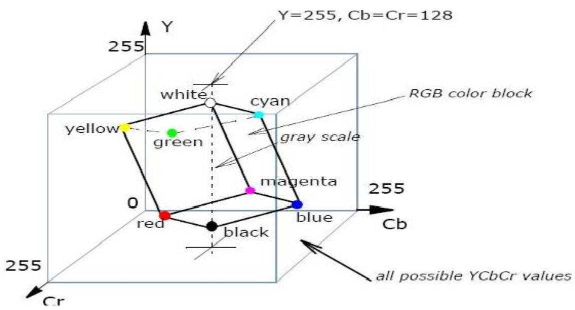

Fig 3: YCbCr color model

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D-YCgCr COLOR MODEL

This color space also contains one luminance component and two chrominance components like YCbCr color space. This color model uses the Cg component for chrominance channel instead of Cb and in this model the human skin regions are concentrated in a very small region of the Cg-Cr plane. This color model includes information about the green difference and has excellent clustering performance which is more useful for skin pixel detection compared to YCbCr. The conversion between RGB and YCgCr color space is given below.

$$\begin{bmatrix} Y \\ Cg \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0.256 & 0.504 & 0.097 \\ -0.318 & 0.439 & -0.121 \\ 0.439 & -0.367 & -0.071 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (3)$$

The results of face detection based on skin color are dependent on the color models used for classification of skin pixels. In our proposed method we have used a combination of RGB, HSV and YCgCr for detecting skin pixels as the combined color model becomes more robust to lighting variations, leading to far better results than those obtained with single color models.

III. PROPOSED ALGORITHM

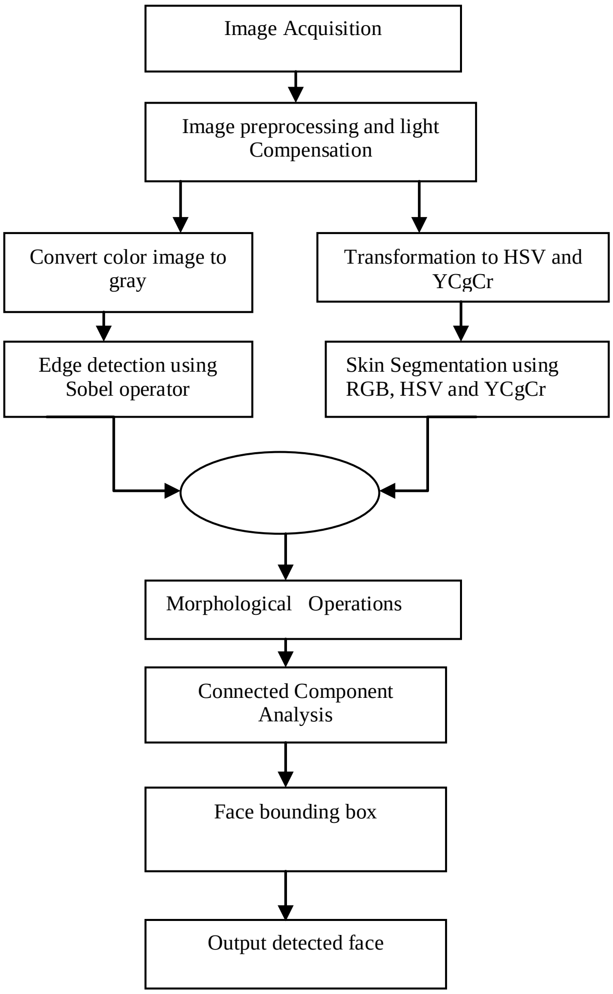

Fig 4: Flow chart of proposed algorithm

In this section we have proposed a new algorithm based on the combination of RGB, HSV, YCgCr color space and edge information. Acccording to literature, the above three algorithms work very well when there is only one face present in an image. In case of multiple face images, the above color models will result in some false detection (segmenting some region which does not contain a face). But the proposed algorithm will give better result in locating the face region for both single face and multiple face images in complex background and constrained lighting environments. In the implementation of this algorithm there are eight steps whose flow diagram is given in fig (4). The main steps in our proposed algorithm is image pre-processing, skin segmentation, feature extraction, face detection and localization which are described explicitly in section IV.

IV. IMPLEMENTATION METHODOLOGY

While simulating the proposed algorithm, we have used color images (24 bits).

A- ACQUISITION OF INPUT IMAGE

In order to execute the proposed algorithm, the input image should be acquired. We can take pictures using camera or can use database images for quicker access of a large no of images and faster debugging process. We have used images from FERET database and images taken with a digital camera of 13 mp in the simulation.

B-IMAGE PREPROCESSING

First, the input image is resized to (165 x 125) by using MATLAB function 'resize'. Then we perform some image pre-processing operations like histogram equalization, noise removal to make the image more suitable for further processing. Then image is decomposed into the original three primary color bands i.e Red, Green and Blue. As the skin color in images is often influenced by lighting conditions, which create huge differences from the real color of the skin; we need light compensation.

The aim of this step is to adjust the luminance component of the image so that all images can be considered as obtained under the same lighting conditions. We implemented light correction using a lighting compensation algorithm which is named Gray World Theory (GWT). The R', G' and B' are the light corrected values of R, G and B which are given as below:

$$K = [R_{avg} + G_{avg} + B_{avg}]/3 \quad (4)$$

$$R' = R*[K/R_{avg}] \quad (5)$$

$$G' = G*[K/G_{avg}] \quad (6)$$

$$B' = B*[B/B_{avg}] \quad (7)$$

Where R_{avg} , G_{avg} and B_{avg} are the averages of the R, G, B values of the image pixels and K is the average of all colors present in the image.

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C-SKIN SEGMENTATION USING RGB and HSV COLOR SPACES

We can convert input RGB to HSV image using the matlab function 'rgb2hsv'.

In the RGB color space, a pixel belongs to the skin color pixel if it satisfies the following conditions []:

a-For uniform daylight illumination

$$R > 95 \text{ and } G > 40 \text{ and } B > 20 \text{ and } (\max\{R,G,B\} - \min\{R,G,B\}) > 15 \text{ and } |R - G| > 15 \text{ and } R > G \text{ and } R > B \quad (8)$$

b-Under flashlight or daylight called lateral illumination

$$R > 20 \text{ and } G > 210 \text{ and } B > 170 \text{ and } |R - G| < 15 \text{ and } R > G \text{ and } G > B \quad (9)$$

In the HSV color space, we can work independently with the intensity component (V) and the chrominance components: hue (H) and saturation (S).A pixel which satisfies the following conditions is qualified as the candidate for skin color pixels.

$$V \geq 40 \quad (10)$$

$$0.2 \leq S \leq 0.6 \quad (11)$$

$$0 \leq H \leq 0.25 \quad (12)$$

The segmented image by using the above thresholds may include non-skin regions like hair, background etc. Any pixel of the input image which satisfies the above mentioned conditions from (8) to (12) will be assigned the value 1(skin pixel) in the segmented image, otherwise the value 0(non-skin pixel).

D-SKIN SEGMENTATION USING YCgCr COLOR SPACES

We converted the resultant segmented image into its original color space by multiplying it with the light corrected image color components (Red, Green and Blue). Then the image is converted to YCgCr color space, which is an encoded non-linear version of RGB color space, by using the formula mentioned in equation (3). This YCgCr color space is an attractive model for skin color segmentation because of its transformation simplicity and explicit separation between the luminance and chrominance components. A pixel belongs to the skin region if it satisfies the following conditions:

$$75 < Cg < 250 \text{ and } 10 < Cr < 100 \text{ and} \quad (13)$$

$$Y > 80 \quad (14)$$

The result is a binary image having value 1 for skin regions and 0 for non skin regions. We have used the median filter to remove the noise in the result binary image, implemented by MATLAB function "medfilt2". This filter helps in removing noise, with comparative less attenuation of edges.

E-EDGE DETECTION

An image may have background regions with color similar to skin color. Generally, after skin color segmentation, such regions are connected with the face region. We need to separate such background regions from face region for easy localization of the face in the image. This can be done with the help of edges from the initial grayscale image. Some common methods of edge detector are Sobel, Prewitt, Roberts and Canny edge detectors, LOG (Laplacian of Gaussian) edge detector. Sobel edge detector can detect weak edges and helps in retaining strong boundary. Therefore, we used the Sobel edge detector to determine the edges from the input image, converted to grayscale. The output of Sobel edge detector is a binary image where the boundary pixels are assigned value 1 and the others value 0.Then, the segmented image from the previous step is combined with the complemented output image of the Sobel edge detector using the AND logical operation.

F-MORPHOLOGICAL OPERATIONS

In image processing, morphological operations like erosion and hole filling is widely used. In erosion, pixels situated on an object boundary are removed iteratively leading to object thinning. Hole filling operations fills the gaps with white spaces, so that there is no problem in further image processing. We used MATLAB function "imfill" and "imerode" with a neighborhood specified with square structuring element on the segmented image for hole filling and erosion respectively.

G-CONNECTED COMPONENT ANALYSIS

We perform connected component analysis for locating the human face region. Here we have performed 4-connected component analysis followed by 8-connected component analysis for accurate localization of human face. In MATLAB "regionprops" is used to count the number of connected components.

H-EXTRACTING FACE AREA

After rejection of human non-face regions and morphological operations, we need to draw a bounding box around the human face region. Generally, shape of human face is likely to be oval, so those region which have shape probable likely to be oval shape are not rejected by this method, and those regions whose shape are not oval are rejected [II]. For finding shape of skin regions, we used region properties based eccentricities MATLAB function, for each region, the function gives its eccentricity value. An ellipse (skin region) whose eccentricity is 0 is actually a circle, while an ellipse whose eccentricity is 1 is a line segment. The oval shape of a face can be approximated by an ellipse so we calculated the eccentricity of all skin connected regions and discarded all skin regions whose eccentricity is greater than 0.89.

Finally, we got images square shaped boundary box drawn around every human face.

V. RESULTS AND DISCUSSION

We have implemented our proposed approach on two face image databases named 'LFW database' and 'Bao database', which includes individual picture, family picture etc. and we have also used pictures taken with the help of a digital camera of 13 mp resolution. The above

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mentioned databases also include image of a person with different orientations and pose variations. The proposed algorithm is compared with the three single color space based face detection methods i.e RGB, HSV and YCbCr based skin color segmentation methods.All the above approaches work well for frontal and single faces, but Performance is degraded for images containing non frontal and multiple face images. The face detection system was implemented using MATLAB R2014b on a 2.4 GHz Intel Core i3 machine running on 4 GB RAM. Tables Show the comparison between the proposed approach, RGB based approach, HSV based approach and YCbCr based skin color segmentation approach. Table I, II and III show that our approach increases the accuracy of detection.

To evaluate our experiments, we have defined two performance metrics: Correct Detection Rate (CDR) and False Detection Rate (FDR). FDR is defined as the number of false detections over the total number of detections.

FDC=(no of false detection/total no of detection)*100 (15)

Correct Detection Rate (CDR) is defined as the number of correctly detected faces over the total number of faces in the image.

CDR =(no of correct detection/total no of faces)*100 (16)

TABLE I RESULT FOR DETECTION OF FRONTAL FACES WITH DIFFERENT LIGHTNING CONDITION ON LFW DATABASE

Detection Method	**Total Faces**	**Hits**	**False Alarms**	**CDR (%)**	**FDR (%)**
Proposed Algorithm	350	348	12	99.4	3.3
RGB	350	345	25	98.5	6.75
HSV	350	344	14	98.2	3.91
YCbCr	350	347	19	99.14	5.19

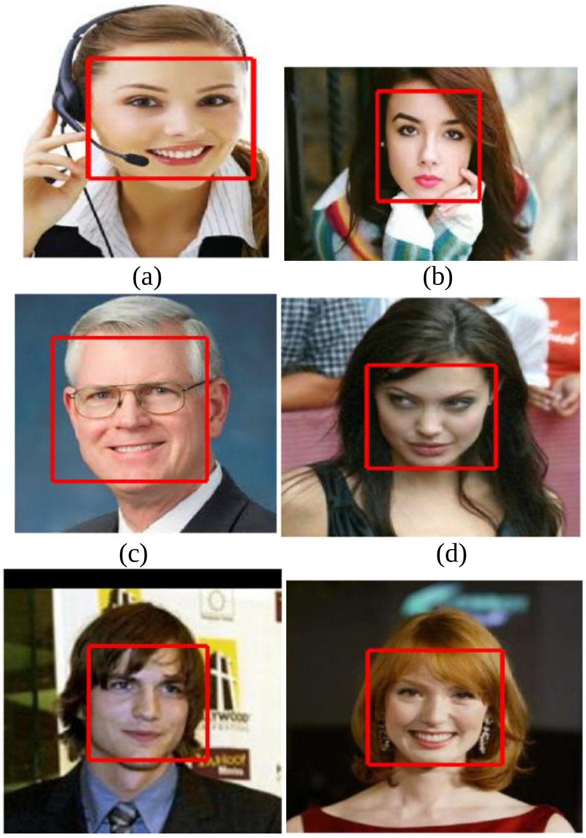
TABLE II RESULT FOR DETECTION OF MULTIPLE FACES IN IMAGE WITH DIFFERENT ORIENTATION CONDITION ON BAO DATABASE

Detection Method	**Total Faces**	**Hits**	**False Alarms**	**CDR (%)**	**FDR (%)**
Proposed Algorithm	200	193	14	96.5	6.63
RGB	200	189	24	94.5	11.2
HSV	200	185	16	92.5	7.96
YCbCr	200	191	18	95.5	8.61

TABLE III PERFORMANCE COMPARISON OF DIFFERENT METHODS WITH COMPEX BACKGROUN FACE IMAGE

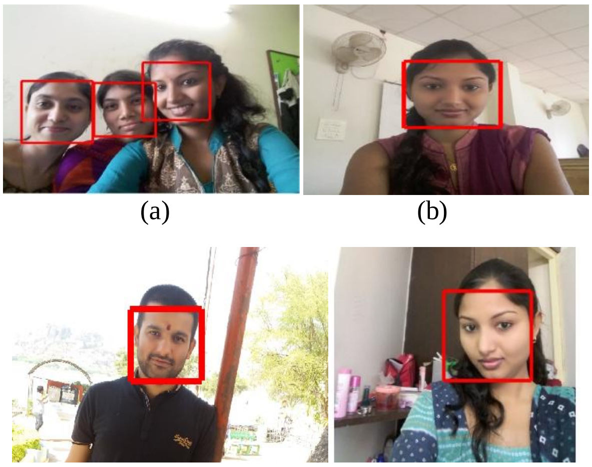
Detection Method	**Total Faces**	**Hits**	**False Alarms**	**CDR (%)**	**FDR (%)**
Proposed Algorithm	100	88	9	88	9.27
RGB	100	79	18	79	18.55
HSV	100	75	12	75	13.79
YCbCr	100	83	15	83	15.3

From the tables I, II and III, it can be inferred that the proposed algorithm, which is a combination of three color space models, performs better than the individual RGB, HSV and YCbCr color space models. The proposed algorithm has detection rate of approximately 99% in case of single face image and detection rate of 96.5% in multiple face images and false detection rate is also reduced compared to existing approaches. The proposed algorithm also performs considerably well in case if images with complex background and varying environmental conditions. So, overally we can say that the proposed algorithm can be used for real-time applications.



(a) (b) (c) (d) (e) (f)

Fig 5 (a, b, c, d, e, f) : LFW face database results



(a) (b) (c) (d)

Fig 6(a, b, c, d): Results of images taken by camera

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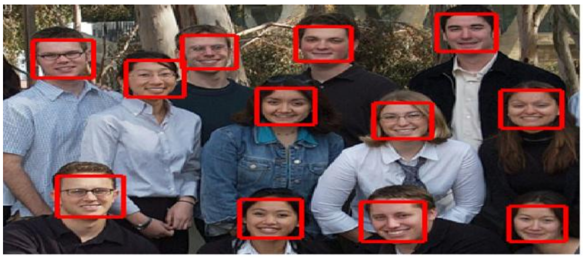
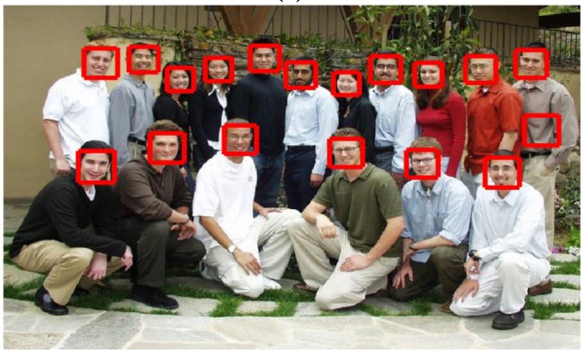
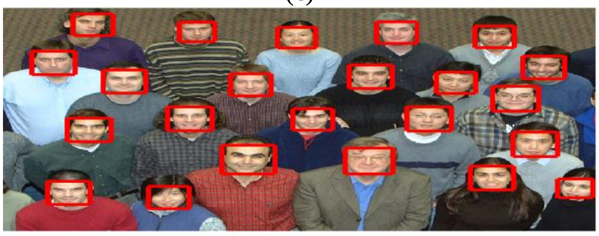


(a)

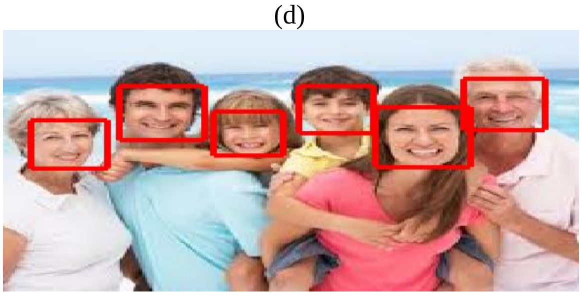


(b)

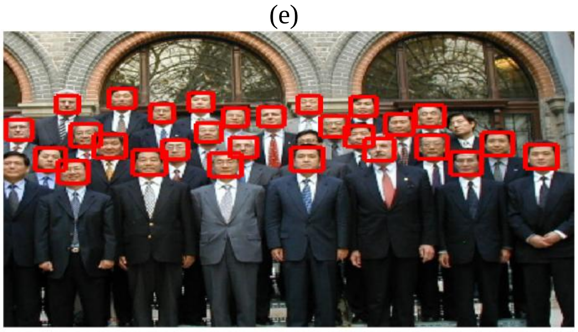
(c)



(d)



(e)



(f)

Fig 7(a, b, c, d, e, f): Bao face database results

VI. CONCLUSION

In this paper skin segmentation based face detection using multiple color spaces has been presented. The proposed system is based on first segmenting the skin regions in an image using color properties and edge information. Then with the help of region properties, face regions are extracted and tracked for further application. Use of skin color segmentation in three color spaces and application of morphological operations like denoising, hole filling and erosion were proved to be valuable enhancements as the proposed system gave very good results in proper lighting conditions. Also, the performance of the proposed algorithm is satisfactory under poor or low lighting conditions. Simulations results show that the proposed algorithm is fast, efficient and can detect faces irrespective of scale and pose variation, in presence of occlusion, complex background and also reduces computational complexity. The overall performance of the proposed algorithm is quite satisfactory and it can be used in real-time applications with indoor and outdoor images and for advanced uses like robotics, terrorist screening, passport authentication etc.

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