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A Novel Face Detection And Recognition System Using Hybrid Skin Color Model

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Abstract: Human face detection plays a very significant role in various biometric applications like crowd surveillance, human-computer interaction, automatic target recognition, artificial intelligence etc. Varying illumination conditions, color variance, pose variations affect face recognition performance. So, automatic facial detection and recognition is an interesting concept that has evoked considerable attention because of its applicability in various areas. Our work suggests a novel algorithm for enhancing the facial detection and recognition performance, which comprises of two major steps: first, we locate the faces and then the located faces are recognized. We have utilized multiple color space based skin color segmentation and morphological operations for facial detection that is faster and has more accuracy when compared with the other existing algorithms. 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 depending on understanding of geometrical features of human face. The face recognition method contains four stages: Gabor feature extraction, dimensionality reduction by making use of PCA, selecting features using LDA, and classification using SVM. Simulation results show that, our suggested approach is sufficiently robust for achieving approximately 96% accuracy and recognizes faces with lesser misclassification compared to existing schemes.

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

I. INTRODUCTION

Face is the most significant external features of people, so it has a considerably important aspect in interpersonal communication. The aim of a facial detection scheme is identification and localization of human faces in a given image [1]. Now as the human-machine interaction technique is becoming active research area of computer vision, face recognition has become an independent field of study. It has a large range of applications in e-commerce, content-based image retrieval, intelligent human-computer interfaces and so on. Basically, there are four approaches for facial detection named: knowledge based approach, Template matching approach, Feature based approach and machine learning based approach [2]. As the human face is an exceptionally complex non-rigid model, the detection method with combination of multiple feature information is gaining momentum.

Skin color based detection is very efficient 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 insensitive to changes in posture, orientation, gesture, expression or other changes and can tolerate occlusion. Processing of color information 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 [3]. In our paper we have used color based segmentation technique for localizing the face region in case of images containing both single and multiple faces. We have used the combination of RGB, HSV, YCgCr and edge information for achieving enhanced 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 the use of region properties and human face features.

Undoubtedly, face recognition is the biggest practical applications of pattern recognition and analysis. Although several facial recognition algorithms have been suggested in the last few years, it still remains an interesting concept. This is due to the fact that employing the facial recognition system in natural environmental conditions gives drastically different results compared to that of the test database. In our proposed method we have used the combination of Extraction of Gabor features; dimensionality reductance using PCA, LDA based feature selection, and classification by making use of SVM for achieving desired result.

In section II of this paper we have discussed various color spaces, while section III explains proposed face detection

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algorithm, section IV explains proposed face recognition algorithm. Section V contains simulation results. Finally we concluded this paper in section VI.

II. SKIN COLOR MODELS

The motivation behind using skin color models for separation of an image into potential face and non-face areas arises due to the fact that the human skin color is distinguished from the color of any other natural object 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 selecting the CgCr plane of YCgCr color model. Our main basis for the selection of YCgCr model is its substantial use in digital video encoding application and its excellent clustering performance [4].

The proposed method makes use of skin color correlation property to reduce the facial search to areas of a given image having the right color components. Although several color based face detection algorithms exist in the literature [5], the proposed algorithm uses only three color models named, RGB, YCgCr and HSV.

A-RGB COLOR MODEL

The RGB color space is made up of the three additive primary color elements: red, blue and green. The color model consists of all the colors that are obtained by the possible permutations of the three primary colors. A 3-dimensional cube having red, blue and green at the corners represents the RGB color model on each axis (Figure 1). Although the RGB model results in simplification of the computer graphics designing systems still it is not suitable for most applications due to strong correlation among red, blue and green color elements.

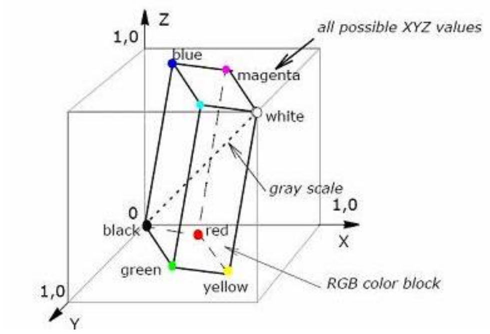

Fig. 1: RGB color model

According to the RGB color model, a pixel belongs to the skin color pixel if it satisfies the following conditions [6]:
a-In uniform daylight illumination condition

$$R > 90 \text{ and } G > 35 \text{ and } B > 25 \text{ and } (\max\{R,G,B\} - \min\{R,G,B\}) > 15 \text{and} \quad (1)$$

$$|R - G| > 20 \text{ and } R > B \text{ and } R > G$$

b-In flashlight or daylight called lateral illumination

$$R > 15 \text{ and } G > 215 \text{ and } B > 165 \text{ and}$$
$$|R - G| < 20 \text{ and } G > B \text{ and } R > G \text{ and} \quad (2)$$

B- HSV COLOR MODEL

The HSV color model is a perceptual color space which contains three color elements: H- the hue element that represents the color, S - the saturation element that defines the purity of color, and V - the value element that represents the intensity or color-brightness. By taking into account only the Hue and Saturation elements we can make abstraction of different illumination environments [6]. The HSV color model is represented by a hexacone in a 3D coordinate system, where the H value changes from 0 to 1 on a circular scale, H=0 and H=1 depicting the same color. S value changes from 0 to 1, 1 depicting a color with 100% purity. V value changes from 0 to 1. In HSV model a pixel which satisfies the following conditions is qualified as the candidate for skin color pixels.

$$V \geq 40 \quad (3)$$

$$0.2 \leq S \leq 0.6 \quad (4)$$

$$0 \leq H \leq 0.25 \quad (5)$$

Many image processing applications like histogram equalizations, t ransformation of intensity and convolution operations use the HSV color model.

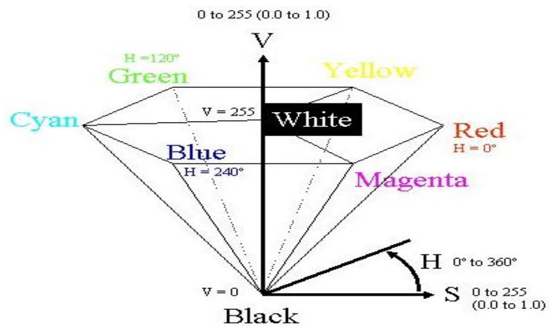

Fig. 2: HSV color model

C- YCbCr COLOR MODEL

YCbCr is the principal color model used for digital video encoding, where we represent a color by using brightness and two chrominance components. Y refers to the illumination (luminance) component, and is calculated as a weighted sum of RGB values. Cb and Cr are the color elements, where Cb is calculated as the difference between the blue element and a reference value and Cr is calculated as the difference between the red element and a reference component. The separation of the brightness component from color element makes the YCbCr color model brightness independent and more suitable than RGB for facial detection by skin color segmentation [7]. In YCbCr model the skin pixels should fulfill the following conditions.

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

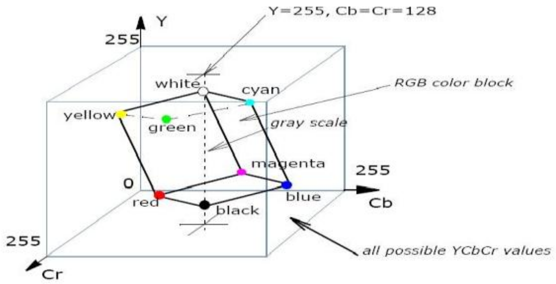


Fig 3: YCbCr color model

D-YCgCr COLOR MODEL
This color model also contains one brightness component and two color 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 compact area of the Cg-Cr plane [4]. The color model contains information about the green difference and has excellent clustering performance which is more suitable for skin pixel detection compared to YCbCr. The transformation between RGB and YCgCr color space is given below [8].

$$\begin{bmatrix} Y \\ Cg \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0.256 & 0.504 & 0.097 \\ -0.318 & 0.439 & -0.121 \\ 0.439 & -0.367 & -0.071 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (7)$$

A pixel belongs to the skin region if it satisfies the following conditions:

$$75 < Cg < 250 \text{ and } 10 < Cr < 100 \text{ and} \quad (8)$$

$$Y > 80 \quad (9)$$

This YCgCr color space is an attractive model for skin color segmentation because of simplictity in transformation and exclusive separation between the brightness and color components.

III. PROPOSED FACE DETECTION ALGORITHM

In the current section we have proposed a new algorithm based on the integration of RGB, HSV, YCgCr color space and edge information. Our proposed method will give improved performance in locating the face region in images containing both both single and multiple faces in complex background and constrained lighting environments.
During the implementation of the proposed algorithm there are eight main steps whose flow chart is given in fig (4). The main steps in our proposed algorithm is image pre-processing, skin segmentation, color space transformation, feature extraction, morphological operations, connected component analysis, facial detection and accurate face localization.

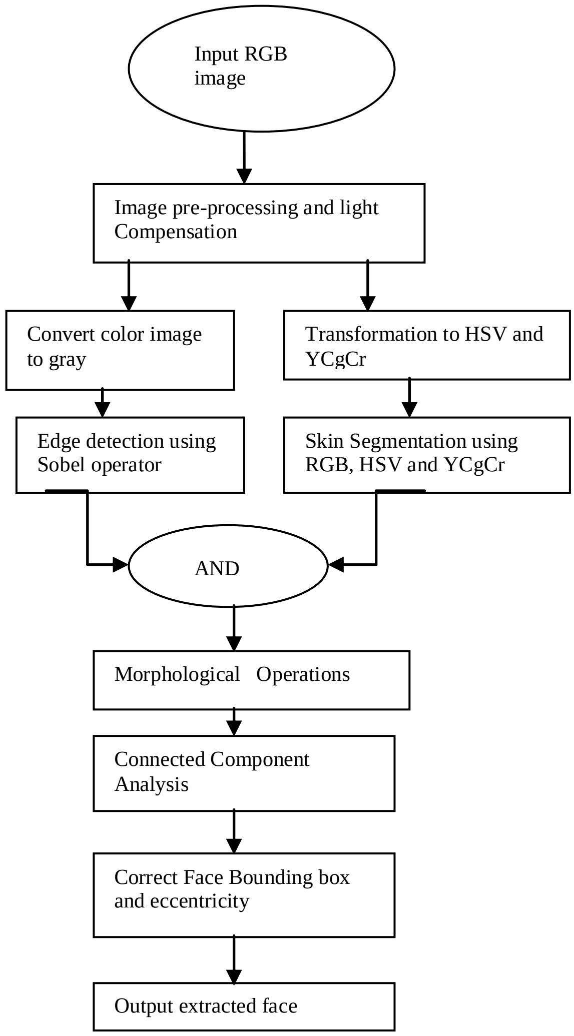


Fig 4: Flow chart of the proposed algorithm

IV. PROPOSED FACE RECOGNITION ALGORITHM

A-Extraction Of Facial Feature Using Gabor Filter
Gabor wavelets, capturing the properties of orientation and spatial localization is a type of sampled Short Time Fourier Transform (STFT)[7].The main concept of Gabor transform is that we can express any signal as a combination of mutually orthogonal time-shifted and frequency-shifted Gaussian functions. Gabor filters are complex exponentials having a Gaussian envelope, or Gaussian signals modulated by the complex harmonics [7][9].
The Gabor kernel function is represented as:

$$\varphi_{r,s}(z) = \frac{||k_{r,s}||^2}{\sigma^2} e^{\left(\frac{-||k_{r,s}||^2 ||z||^2}{2\sigma^2}\right)} [\, e^{ik_{u,v}z} - e^{\frac{-\sigma^2}{2}}] \quad (10)$$

Where $z = (x \;\; y)$ and $e^{ik_{u,v}z}$ represents function of oscillation and $e^{\left(\frac{-||k_{r,s}||^2 ||z||^2}{2\sigma^2}\right)}$ represents Gaussian function. The Gaussian window represents the localization of the Gabor filter both in the time domain and frequency domain and reduces the range of the oscillation functions. Gabor filters can tolerate considerable distortion in brightness variations using the Gaussian window.

$e^{\frac{-\sigma^2}{2}}$ term stands for the DC component and by we can see that the filter is devoid of any DC component from equation(). $k_{r,s}$ represents the wave vector of the Gabor filter having orientation r and scale s. We can construct a Gabor filter set by selecting a set of values for $k_{r,s}$. $\sigma = 2\pi$ is a constant which along with $k_{r,s}$ represents the wavelength of the Gaussian window.

$$k_{r,s} = k_s e^{i\emptyset_r} \quad (11)$$

Where

$$k_s = k_{max} / f^s \quad (12)$$

$$\emptyset_r = \pi r/8 \quad (13)$$

Here k_{max} reflects the maximum frequency and f represents frequency spacing between kernels. Different s value is chosen for describing various wavelength of the Gaussian window, and controlling the scale of sampling. Various r values are chosen for describing the oscillation function having different directions, and then controlling the direction of sampling. Six different scales and ten orientations can create 60 filters.

A face image is described by the Gabor wavelet transform, which describes the spatial frequency structure and spatial relations. Convolving the given image with complex Gabor filters with 6 spatial frequency (s = 0,…, 5) and 10 orientation (r = 0,…,9) encapsulates the entire frequency spectrum, both amplitude and phase. After convolving the face image with Gabor filter bank, we get 60 convolved outputs consisting of essential features at various resolutions [2][9].

B-PCA and LDA Analysis

In case of several applications, the number of variable in the classification dataset must be minimized because of the presence of noisy, redundant and irrelevant data that has been proved to be the destructive component which leads to inaccurate and inefficient classification performance. Furthermore, due to the increase in number of features used in classification, the number of training samples needed for statistical modeling and learning process increases extensively. PCA and LDA are two most robust tools used for reducing dimensions and extraction of features in majority pattern recognition applications which performs transformation of data and project it to a lower dimensional subspace in such a way that most of the useful data is preserved and the irrelevant information is discarded [10]. For reduction of the dimensionality of features, we have used the fusion of PCA and LDA on Gabor features. The main concept behind PCA is to select the vectors which best account for the distribution of the face images within the entire image space and choosing dominant features for efficient class representation. LDA searches directions for maximum discrimination of classes in addition to dimension reduction and determine features that are most efficient for separability of classes. Thus, first PCA is applied on Gabor features resulting in images with lower dimensions which are ready for extraction of LDA features.

C-SVM Based Classification

After facial feature extraction, the samples are classified with help of the classifier. In machine learning, classical approaches like the K-nearest neighbor classifier (KNN), artificial neural networks (ANN) etc. having its own benefits and drawbacks have been used extensively for multi-class classification. Experimental results prove that the performance of SVM classification method used in binary classification and pattern recognition is superior compared to existing classification methods [8]. The typical method for extending the SVM to multi-class scenario is done by decomposition of an M-class problem into a sequence of binary class problems and construction of a no. of binary classification modules like one-against-all and one-against-one classifiers.

For several usages, the one-against-one approach is computationally more efficient because the outputs of more SVM pairs should be calculated. From the training effort point of view, we prefer the one-against-all method as only K SVMs need to be trained compared to [K(K - 1)]/2 SVMs in case of the one-against-one method. In the one -against-all method the computation of K SVMs is required, whereas the one-against -one method needs the computation of only (K – 1) SVMs. Due to the above reason, as the total number of classes in facial recognition is very large, we have used the one against all method where the no. of SVMs is linear with the no. of classes.

V. RESULTS AND DISCUSSION

A-Experimental Result of Proposed Facial Detection Algorithm

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

The proposed facial detection system was executed by makin use of 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.

For the purpose of evaluating the face detection performance, we have used two performance parameters: Correct Detection count (CDC) and False Detection Count (FDC).

We have defined FDC as the number of faces wrongly detected over the total number of detections.

FDC= (no of false detection/total no of detection)*100 (14)

We have defined Correct Detection Count (CDC) as the number of faces correctly detected over the total number of faces present in the image.

CDC =(no of correct detection/total no of faces)*100 (15)

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

Detection Method	Total Faces	Hits	False Alarms	CDC (%)	FDC (%)
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	CDC (%)	FDC (%)
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 COMPLEX BACKGROUN FACE IMAGE

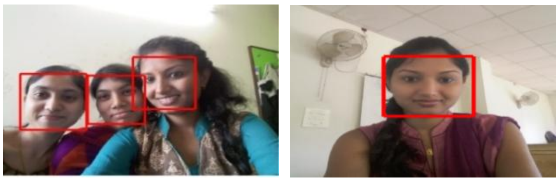
Detection Method	Total Faces	Hits	False Alarms	CDC (%)	FDC (%)
Proposed Algorithm	100	88	9	88	9.27
RGB	100	79	18	79	18.55
HSV	100	75	12	75	13.79
YCbCr	100	83	15	83	15.3

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 face detection 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 our proposed detection scheme can be utilized for real-life applications.

(a) (b)

(c) (d)

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

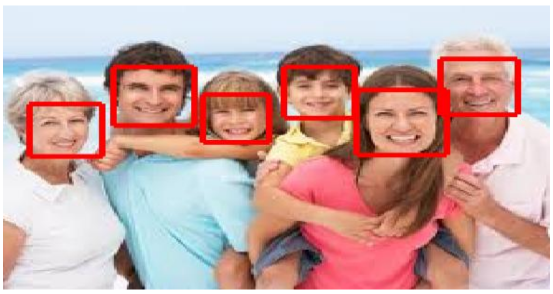


(a) (b)

(c) (d)

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

(a)



(b)

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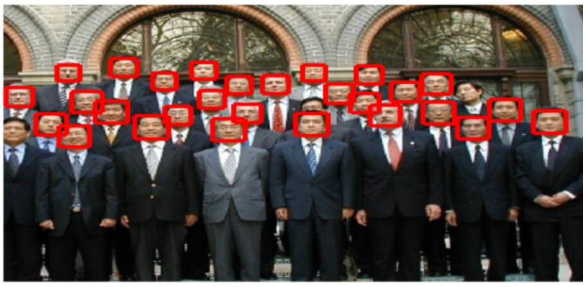

(c)

Fig 7(a, b, c): Bao face database result

Fig 5 depicts, the results of our proposed face detection algorithm on LFW face database, which contains single images with different poses, orientations and images with occlusions. Fig 6 shows, the face detection results for real life images, captured under different lighting conditions having varying orientations. Fig 7, represents the results of the suggested method on Bao face database containing multiple face images having different orientations. From the above figures, we can see that the proposed algorithm can detect both single and multiple face images.

B-Results of Proposed Facial Recognition Algorithm

We have verified the recognition stage of the proposed algorithm with the help of ORL database. The ORL database consists of 400 images which correspond to 40 persons. The ORL database consists of images having variations in posture, size, facial expressions and facial detailing. Every image contains 112×92 pixels and has 256 gray levels.

Fig. 7 Group of Face Images of the ORL Database

We have divided ten images of every person in the database into two teams and chosen seven images of every person as the training sample and the rest three images as the testing sample of every person. So, Overally training set contains 280 images and testing set contains 120 images.

TABLE IV RESULTS OF VARIOUS FACIAL RECOGNITION SCHEMES

Classifier	**Rate of face recognition (%)**			
	PCA	**LDA**	**PCA+ LDA**	**Gabor feature+ PCA+ LDA**
KNN	86.6	92.1	93.00	96.2
SVM	91.8	94.2	94.8	98.3

Simulation results depict that with the use of Gabor filter in conjunction with LDA and PCA for extracting the facial feature and the application of multiple class based SVM classification having the one-against-all scheme and the radial basis function (RBF) kernel, gives the recognition rate of approximately 98.3% which outperforms existing methods.

C- Results of Overall System

TABLE V RESULTS OF OVERALL SYSTEM

Classi -fier	**Rate of face detection and recognition (%)**			
	PCA	**LDA**	**PCA + LDA**	**Gabor feature + PCA + LDA**
KNN	82.5	86.3	87.5	90.5
SVM	85.8	88.5	90.5	95.2

We have applied two steps of our proposed facial detection and recognition method on real life videos having several illumination situations and complex background and the results are demonstrated in table V.

VI. CONCLUSIONS

We have presented a robust method for facial detection and recognition in this paper. For detection of faces we have used a hybrid approach of combining three skin color models with region properties for making a considerable trade off between the accuracy and time complexity and developing a facial detection system having superior performance. This causes significant minimization of the false positive rate and increase in the true positive rate and processor speed simultaneously. We have developed the facial recognition stage as an amalagamation of four steps: Extraction of Gabor features, dimensionality minimization utilizing PCA, LDA based feature selection, and classification using SVM. We have made use of the above methods to build a robust facial recognition system with very high recognition rate. Simulations results depict that the suggested algorithm is fast, efficient and can detect faces irrespective of scale and pose variation, in presence of occlusion, complex background, reduces computational complexity and has the ability to extract features optimally and efficiently classifies the faces. The overall performance of our suggested method is quite satisfactory as it achieves a face recognition rate of approximately 95% and it can be applied in real-life situations with varying environments and for advanced applications like virtual reality, terrorist screening, forensic investigations etc.

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