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Automatic face detection using color based segmentation & eigen face-based facial recognition

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Abstract: This paper presents the procedures of Skin Detection and Segmentation of Human Face in Color Images through the establishment of skin model and the segmentation of skin region. Firstly, in order to reduce the effect of factors on the segmentation of face region, a method for compensating the Color of input images is used to alleviate the interferences from bad illuminating conditions. Secondly, Gaussian model about skin information is established which can be used to detect skin pixels in Color images and transform Color images to gray-scale images. Thirdly, a new algorithm of Otsu is used to find out the skin regions in binary images. Finally, mathematical morphology operator and prior knowledge are used to find out the face regions and discard regions that are similar to the skin in Color. This method can deal with various sizes of faces, different illumination conditions, diverse poses and changeable expressions. In particular, the scheme significantly increases the execution speed of the face segmentation algorithm in the case of complex backgrounds. The experiments show that this method reduces the computation of the procedure, and at the same time improves the detection speed and efficiency.

Keywords: color balance; space conversion; Gaussian model; gray-scale image enhancement; adaptive threshold Segmentation, PCA, Eigen faces.

Introduction

Face recognition (FR) As one of human's physiological features, skin information has broad applications such as face detection, gesture analysis, target tracking and image retrieval. Skin has the advantage of being non-sensitive to directions, so we can separate skin regions from other parts of the color images and segment face regions accurately through post-processing. The application of color can provide valuable candidate region when detecting stationary targets. The combination of information from moving-targets can enhance the accuracy of target tracking and the analysis of property when detecting moving targets. According to the needs of search and retrieval system requirements, skin color can be used in image classification and feature analysis when retrieving image. Many researches of skin detection have been proposed. An example study of skin colors is Soriano's work [1] which built a skin color model in normalized color coordinates (NCC). Soriano established the model based on an extensive collection of skin color pixels on images of different races of people under a variety of illuminating conditions. Garcia and Tziritas [2] also built their skin color models over and HSV color spaces to extract skin pixels as candidate regions of faces. Back incorporated a 2D Gaussian skin model associated with motion information to find candidate faces. But most have many restrictions, such as no compensation for varying illumination colors, no noisy defocus, which hinder researchers from developing successful face detection systems. So, we present an improved procedure of skin detection and segmentation which can find out arbitrarily tilted human faces in color images [3]. In this paper, we propose a skin-detection approach by using Gaussian model and skin-color information. Gaussian model about skin information is established to detect skin pixels in color images and transform color images to gray-scale images. Then a new algorithm of segmentation integrated histogram with Otsu is used to find out the skin regions in binary images. After that, mathematical morphology operator and prior knowledge are used to find out the face regions and discard regions that are similar to the skin in color [4].This paper are organized as follows. Skin model is introduced. A skin segmentation algorithm is proposed in fig 3.Experiments are conducted and discussed. Lastly, conclusions are given in Results.

Skin Model

For the segmentation of human faces based on skin color, the key is to select the color space and its cluster. In color images, skin color is very useful information for human face. Using skin-color information effectively can reduce the amount of searching time when it needs to make sure of the region of human face. However, skin color information is often influenced by some factors [5]. For instance, light environment and image acquisition equipment will lead to color offset. Before skin-color segmentation, we should do some pre-processing for images to alleviate the interferences from bad light. Taking account of the effects of light source and the high brightness region in images on skin detection, we use the assumptive method of Gray World in order to compensate the images with light interference [6]. In addition, considering the brightness information and chrominance that should be separated, we segment the skin of color image in the space of YCbCr and set up Gaussian model which can cluster the skin-color information in a regular range [7]. In color images, skin color is relatively concentrated in a stable region. Skin-color information can be used to separate human faces from the background of images. Studies have shown that for different race, age and gender, face color looks different, but they mainly concentrate in brightness. We know that the surface of objects appears the surface or interface reflection, so objects often send-off bright light. In color images, high-brightness region will be found. The surface reflection of objects mainly comes from the real color of light source when the light illuminates the objects, but not the color of the surface of objects. Based on these facts, the steps of determining whether the images have the light interference are as follows:

Step 1: The brightness of all the pixels in the image is put in order from top to low, taking the top 5% of the pixels. If the number of pixels is more than enough (such as more than 1000), then calculate the respective average of these pixels component (R; G; B) and record as AR, AG, AB;

Step 2: Calculate the value of max (AR; AG; and AB) =min (AR; AG; and AB).

If the value greatly deviates from 1, then determine the image has light interference. If the image has light interference, the light compensation pre-processing of the Gray World is proposed to alleviate the interferences from bad illuminating conditions. The steps are as follows:

Step 1: Calculate their respective average and total mean of these components(R; G; and B) and record as avgR, avgG, avgB, avgGray. The formula is as follow:

$$avgGray = (avgR+avgG+avgB) =3 \qquad (1)$$

Step 2: Calculate the adjustment factors of R, G and B, then record as aR, aG and aB, the formulas are as follow:

$$aR = avgGray=avgR,\ aG = avgGray=avgG,\ aB = avgGray=avgB \qquad (2)$$

Step 3: Adjust the values of R, G and B with the adjustment factors. The formulas are as follow:

$$R = RaR;\ G = GaG;\ B = BaB \qquad (3)$$

Step 4: If the value of R, G and B after adjustment is more than 255, then adjust it to 255. Fig.1 shows the compensation result for original images. The color of image is reddish, whose skin color is very close to the color of the background, which will lead to the error of skin-color segmentation.
Use the method which has been given in the previous part, we can alleviate the interferences from bad illuminating conditions in these images. Figure 2 shows the result of light compensation. Have been effectively used to segment color images in many applications. It is also well suited in this case to segment skin regions from non-skin regions. The Color distribution of skin colors of different people was found to be clustered in a small area of the chromatic Color space.

Fig.1 Original Images

Although skin colors of different people appear to vary over a wide range, they differ much less in color than in brightness. In other words, skin colors of different people are very close, but they differ mainly in intensities. With this finding, we could proceed to develop a skin-color model in the YCbCr color space [8]. YCbCr color space can be transformed from RGB, and the corresponding coordinate transformation matrix is as follows:

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 \\ -0.1687 & -0.3313 & 0.5000 \\ 0.5000 & -0.4187 & -0.0813 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (4)$$

Generally speaking, the result is much better when the luminance and color separate completely. Actually, there are certain of non-linear relations between them to some extent which will impact the image detection. So, it is needed to reduce these non-linear relations, and eliminating the relations between luminance and color. The transformation formulas that are used to change YCbCr color space to other space which has non-linear relations are as follows:

$$C_i(Y) = \begin{cases} (C_i(Y) - \overline{C_i(Y)}) \times \frac{W_{C_i}}{W_{C_i}(Y)} + \overline{C_i(Y)} \\ \quad if(Y < K_i) or (K_h < Y) \\ C_i(Y) \quad if (Y \in [K_i, K_h]) \end{cases} \quad (5)$$

Where i represent b or r (b and r are the value of the rgb image), $C_i(Y)$ denotes the axis of skin-color regions, K_i and K_h are sub-threshold of non-linear transformation, and WCi(Y) is the width of the skin-color regions.
Fig.3 shows the images in YCbCr color space, which is different from the RGB space.

Fig. 2: YCbCr Color Space Image

Gaussian model

Although skin colors of different people appear to vary over a wide range, they are very close in color and have huge differences in luminance. The color distribution of skin color of different people was found to be clustered in a small area of the color space and a skin color distribution can be represented by a Gaussian model. According to the Gaussian distribution in the color space of images [9], a color image with skin-color regions can be transformed into a gray scale image so that the gray value at each pixel shows the likelihood of the pixel belonging to the skin. The likelihood of skin for this pixel can then be computed as follows:

$$m = E\{x\} \quad (6)$$

$$x = (Cb; Cr)^T \quad (7)$$

$$\mathbf{C} = E\{(x-m)(x-m)^T\} \quad (8)$$

$$P(Cb;Cr) = \exp\{-0.5(x-m)^T C^{-1} (x-m)\} \quad (9)$$

Where m is the mean of x, C is the covariance matrix. We can obtain m and C through the sample statistics. This skin model is based on the statistical characteristics [10], which needs to commutate the likelihood of each pixel belonging to the skin, so the speed is not fast. Of course, when doing the practical application of skin detection, you can directly use the formula of in order to improve the detection speed. A total of 500 images of human faces were used to determine the color distribution of human skin in YCbCr color space. Our samples were taken from people of different ethnicities, different conditions and different ages. Fig.4 and Fig.5 have shown the statistical characteristics of skin information and Gaussian model.

$$-0.5(x-m)^T C^{-1}(x-m) \quad (10)$$

Through Gaussian Model, the image in YCbCr Space can be transformed to a gray scale image which has the obvious skin regions. With appropriate threshold, the gray scale images can then be further transformed to a binary image showing skin regions and non-skin regions.

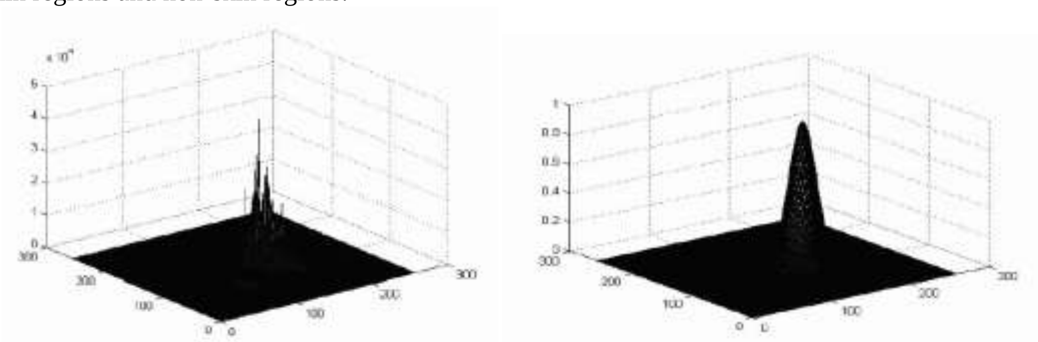

Fig.4, 5: Skin Distribution in YCbCr Space Gaussian Model

Skin Segmentation

Image segmentation is the key step of image processing to image analysis, and the foundation of identification and understanding, which mainly uses the differences between the target objects and its background segmenting the target regions which are wanted in need. There are many segmentation algorithms proposed by scholars, including threshold method, boundary detection, matching method and so on. In this paper, we use facial characteristics to separate the skin-color region from the images and get the binary image of human face regions, which is called threshold segmentation algorithm [11]. This method can segment the wanted objects from background by choosing a suitable threshold, which is based on the different characteristics in gray-scale between the target and background. The most representative methods are histogram threshold, Otsu, the best entropy method, moment invariant method, and fuzzy clustering method, a very small error of law and co-occurrence matrix method. With the advantages of small amount of calculation, simple theory and easy implementation, Otsu is generally used in real-time image processing system. Therefore, Otsu is used in this paper to segment the gray-scale image transformed from RGB in order to get the binary image. Then, process the binary image to obtain the accurate face region shown in fig 6.

Fig.6 Skin-likelihood Image

The method of Otsu

Otsu was proposed in Japan, which is derived on the principles of discrimination and the theory of least Square [12]. There is a image with the gray-scale between one to m, the number of pixels with the value of i is n_i, then the total number of image pixels is:

$$N = \sum_{i=1}^{m} n_i \quad (11)$$

The probability of appearing gray-scale pixel with the value of i is:

$$p_i = \frac{n_i}{N} \quad (12)$$

Then, use T to split the gray scale into two groups, C_0= {1-T} and C_1= {T+1-m}. The formulas of the average and probability generated by each group are as follows:

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$$\begin{cases} \omega_0 = \sum_{i=1}^{T} p_i = \omega(T) \\ \mu_0 = \sum_{i=1}^{T} \frac{ip}{\omega} = \frac{\mu(T)}{\omega(T)} \end{cases} \quad (13)$$

And

$$\begin{cases} \omega_1 = \sum_{i=T+1}^{m} p = 1 - \omega \\ \mu_1 = \sum_{i=T+1}^{m} \frac{ip}{\omega} = \frac{\mu - \mu(T)}{1 - \omega(T)} \end{cases} \quad (14)$$

Where,

$\mu = \sum_{i=1}^{m} ip_i$ Is the formula for calculating the mean of the whole image.

$\mu(T) = \sum_{i=1}^{T} ip_i$Is the formula for calculating the average of the image when the threshold value is T so the formula of the gray sample average is$\mu = \omega_0\mu_0 + \omega_1\mu_1$.The formula for calculating the variance between the two groups is as follows:

$$\begin{aligned} \delta^2(T) &= \omega_0(\mu_0 - \mu)^2 + \omega_1(\mu_1 - \mu_0)^2 \\ &= \omega_0\omega_1(\mu_1 - \mu_0)^2 = \frac{[\mu\omega(T) - \mu(T)]^2}{\omega(T)[1 - \omega(T)]} \end{aligned} \quad (15)$$

Seek the maximum value of the formula, when T is changing from one to m. Then T is the threshold and ∂^2(T) is the selecting function of ∂^2(T) [9].

3.2 Improved segment method

Based on the principle of threshold segmentation, we will segment the skin-likelihood images. With the original images affected by non-face regions, light, rotation angle of face and many other factors, the skin likelihood image can't reflect good differences between background and the objects, which thus affect the results of a follow-up partition. Different from the previous procedure, this article does not directly deal with the similar gray-scale images, but first needs to determine whether the skin-likelihood images should be adjusted. This can improve the accuracy of segmentation to a large extent, although it will be affected by the factors such as light. Specific methods are as follows [13]:

Step 1: Get the histogram of the similar gray-scale image histogram, and determine the brightness and contrast of the image according to the distribution of pixel images in histogram. If the pixels are in the low-end of the histogram, they are illustrated in dark images; if the pixels are in the high-end of the histogram, they are illustrated in brightness images; if the pixels are in the centre of the histogram, they are illustrated in the images with poor contrast; only when the gray histogram is more evenly distributed throughout the gray-scale range, is the image contrast relatively good.

Step 2: According to the above conditions, compare the histogram of the similar gray-scale images with the conditions one by one, and then the treatment is necessary to enhance the needed image.

Step 3: Get the histogram of the new gray-scale image and set the value which is in the trough of the histogram as the threshold A. The gray space will be divided into two parts, part a and part b, by this threshold. Then get the variance of this two parts, and determine the values in the troughs of histograms in part a and part b separately [14]. And make these two values as the boundaries which is the range of A moving, thus obtain the best threshold. Experiments show that the improved method of segmentation not only accelerates the speed of segmentation, but also ameliorates the accuracy of skin segmentation. As shown in Fig.6 is the skin-likelihood image and the binary image.

Determination of human faces

Determination of human faces it is important to note that the detected regions may not necessarily correspond to skin. It is only reliable to conclude that the detected regions have the same color as that of the skin. The important point here is that this process can reliably point out regions that do not have the color of the skin and such regions would not need to be considered anymore in the face finding process. In this paper, mathematical morphology operator of open computing is used to deal with the binary image [15]. Use the following methods to deal with the non-face region.

Fig.7 Binary Image

Step 1: Calculate the number of holes in each skin region, if there are no holes, and then discard the skin region. Use Euler's formula to calculate the number of holes.

Step 2: Find the width and the height in external rectangular of skin region, then compute the ratio of wide and high. After that, give up the skin region whose proportion is not demanded, and the range of ratio is between 0.8 with 2.0. If the value is more than 2.0, use the lesser part of the ratio of 2.0 to match, and minimize the occurrence of undetected face, instead of discarding it [16].

Step 3: Calculate the ratio of skin area and its external rectangular, and discard the non-human face region with color characteristics; its ratio should be more than or equal to 0 [17].

Fig.8 Facial Skin Region

Step 4: Remove the region whose area is less than 400. If the region of human faces is small, facial features will be lost during the pre-treatment.

Step 5: Discard skin region whose width or height is less than 20. According to this method, most of the non-face region can be removed, which can segment face region accurately, as is shown in Fig (8).

Fig.9 Face Detected in Box

Above find out the skin and non-skin region for different color spaces and all the faces are detected in the box. Then according to algorithm applying the Principal component analysis in these images. The purpose of this method is reducing the dimensionality of images and computing Eigen faces.

Eigen face-based facial recognition

An eigenvector of a matrix is a vector such that, if multiplied with the matrix, the result is always an integer multiple of that vector [18]. This integer value is the corresponding Eigen value of the eigenvector. This relationship can be described by the equation $M \times u = \lambda \times u$.

Where u is an eigenvector of the matrix M and λ is the corresponding Eigen value Eigenvectors possess following properties:

- They can be determined only for square matrices.
- There are n eigenvectors (and corresponding Eigen values) in an $n \times n$ matrix.
- All eigenvectors are perpendicular, i.e. at right angle with each other.

Calculation of Eigen faces with PCA

In this section, the original scheme for determination of the Eigen faces using PCA will be presented. The algorithm described in scope of this paper is a variation of the one outlined here. A detailed (and more theoretical) description of PCA can be found in [19].

Step 1: Prepare the data; In this step, the faces constituting the training set (Γ_i) should be prepared for processing.
Step 2: Subtract the mean; The average matrix ψ has to be calculated, and then subtracted from the original faces (Γ_i) and the result stored in the variable Φ_i :

$$\psi = \frac{1}{M}\sum_{n=1}^{m} \Gamma n \qquad (16)$$

$$\Phi_i = \Gamma i - \Psi$$

Step 3: Calculate the covariance matrix; In the next step the covariance matrix C is calculated according to

$$C = \frac{1}{M}\sum_{n=1}^{M} \emptyset n \emptyset nT \qquad (17)$$

Step 4: Calculate the eigenvectors and Eigen values of the covariance Matrix In this step, the eigenvectors (eigenfaces) u_i and the corresponding eigenvalue λi should be calculated [20]. The eigenvectors (Eigen faces) must be normalized so that they are unit vectors, i.e. of length 1. The description of the exact algorithm for determination of eigenvectors and Eigen values is omitted here, as it belongs to the standard arsenal of most math programming libraries shown fig 10.

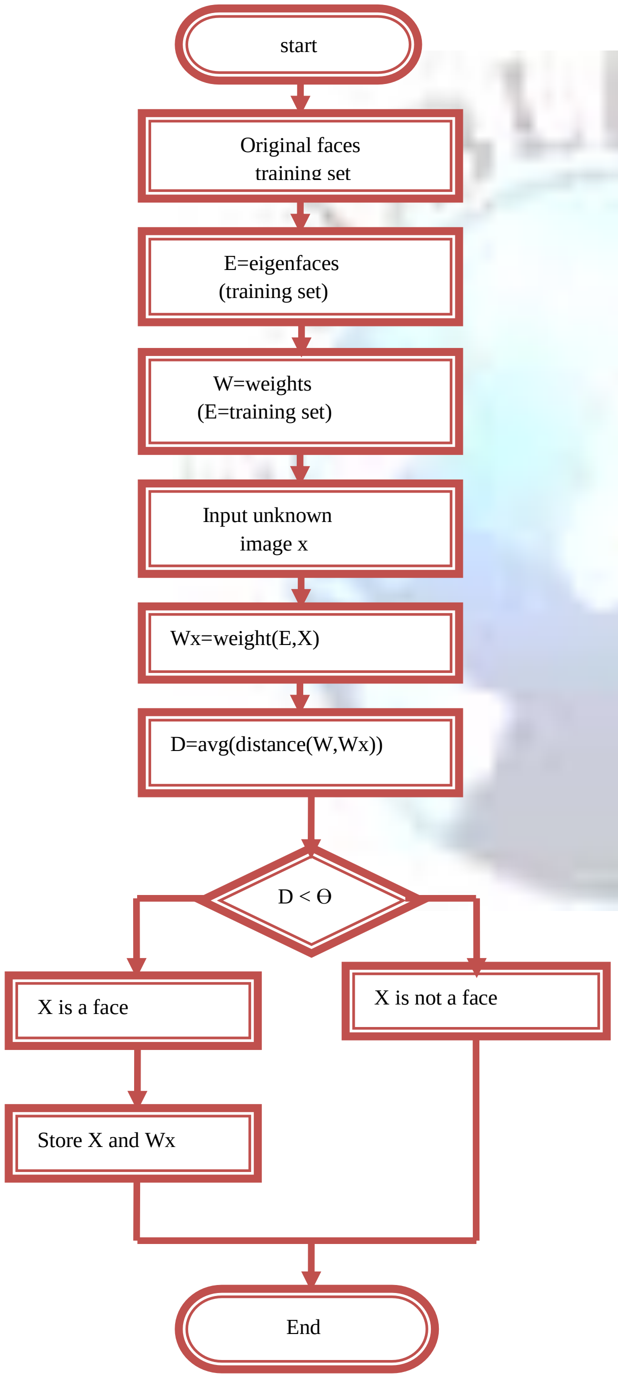
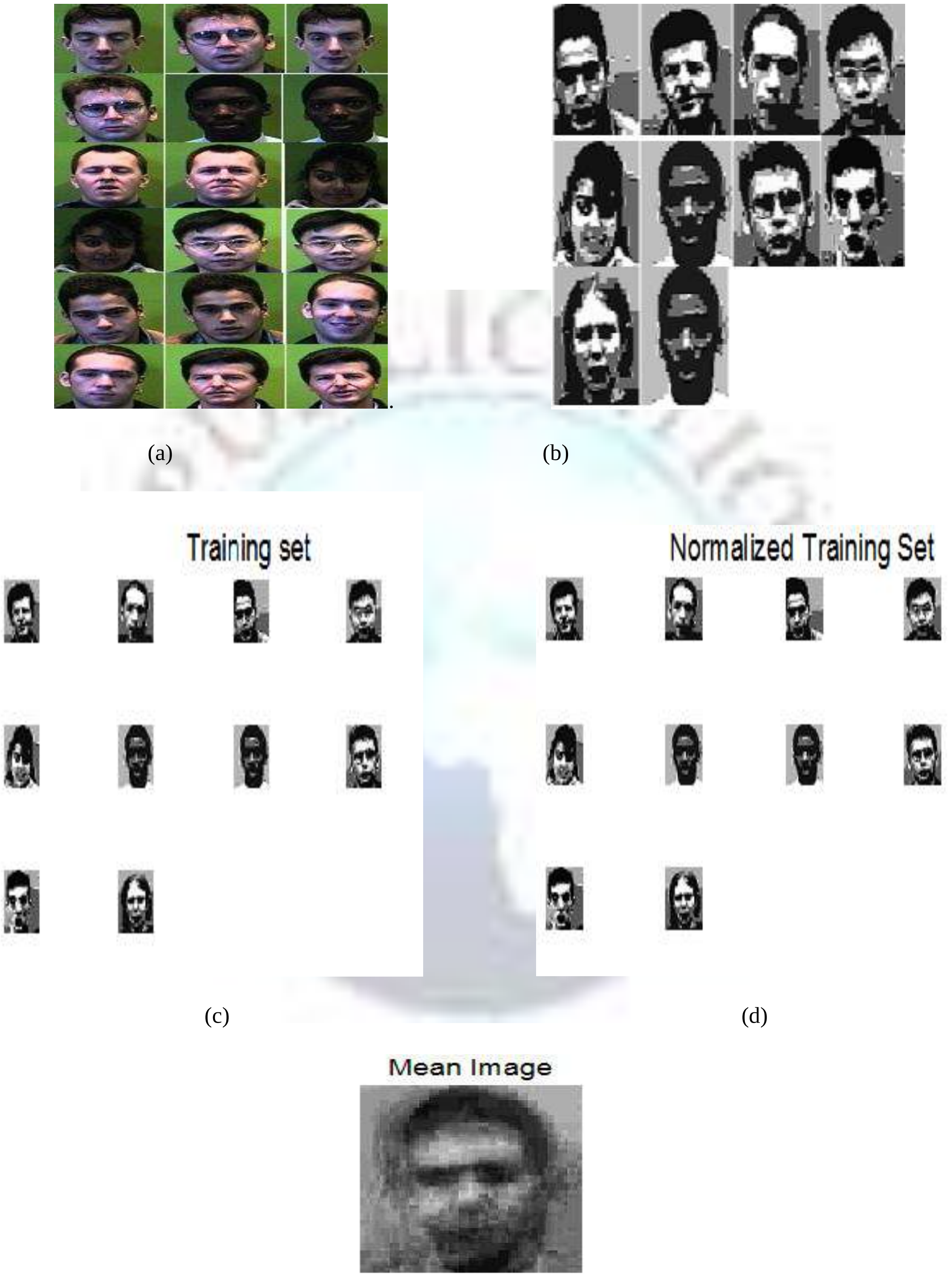


Fig 10: Eigen face-based facial recognition Algorithm

Step 5: Select the principal components: From M eigenvectors (eigenfaces) ui, only should be chosen, which have the highest eigen value. The higher the Eigen value, the more characteristic features of a face does the particular eigenvector describe. Eigenfaces with low eigen values can be omitted, as they explain only a small part of characteristic features of the faces[21]. After M eigenfaces ui are determined, the "training" phase of the algorithm is finished and databases collected from the FERET face database.



(a) (b)

(c) (d)

(e)

Fig: 11 (a) RGB Image database with different condition and illumination, (b) Gray size database of Original Image, (c) Training Set of original Image, (d) Normalized Training Set (e) Mean Image of normalized Training Set.

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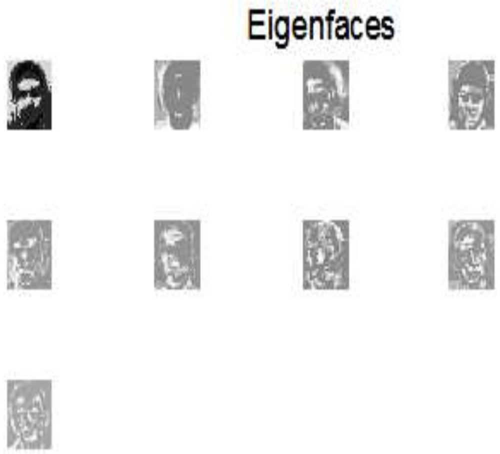

Fig:12: Eigen-faces of Training Sets

Results and Conclusion

The proposed algorithm based on HSV are show in table 1. It is observed that the proposed algorithm is giving better results than the existing one in terms of accuracy.

Parameters of Implemented algorithm based on HSV

Training Images	Faces	Correct	False Positive	False Negative	Accuracy (in %)
Training Image1	21	21	1	0	100
Training Image2	23	21	3	2	91
Training Image3	23	22	0	1	96
Training Image4	24	22	0	2	92
Training Image5	24	23	0	1	96
Training Image6	24	23	0	1	96
Training Image7	22	19	1	3	86
Total	**161**	**151**	**7**	**10**	**95**

Table no 1

The Comparative analysis of proposed Eigen-face based algorithm with respect to various algorithms like (2D-PCA) 2-dimensional principle component analysis, (DTM) Deformable Template Matching and (ACRT) Adaptive Concentric Ring Template is done and Table 2 shows that better results are achieved.

Comparison of various existing algorithms and proposed Eigen-face algorithm

Methods	Rotation angle (in degree)	Matching Rate	Matching Time (in sec.)
2DPCA	0	88	2.35
DTM	0	91	1.98
ACRT	0	86	3.48
Eigen-face	**0**	**100**	**2.01**

Table 2

Conclusion

This paper proposes an algorithm with good accuracy and running time for face detection based on HSV skin color segmentation. Though there are some cases of false positives, the overall performance of the proposed algorithm is quite satisfactory. The training images on which the algorithm is tested are natural images taken under uncontrolled conditions. The efficiency of the face detection was found to be 95%. In addition, HSV color model is chosen because it is fast and compatible with human color perception. Hence it can be concluded that the present algorithm demonstrates better performance with respect to speed, low false positive rate and high accuracy. In case of Face recognition, we compared the parameters of face recognition with existing one like 2D-PCA, DTM, and ACRT techniques and the matching rate as well as matching time of our proposed algorithm is good with respect to existing one and achieved better results. We compared the few techniques used in face recognition and some pros and cons of those techniques are achieved. In this paper, we proposed an Eigen face based recognition and based on this recognition, we also proposed a detection technique using HSV component, and these techniques are successful in detection as well as recognition.

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