



A Robust and Efficient System to Detect Human Faces Based on Facial Features

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAA designed the study, performed the statistical analysis and wrote the protocol. Authors TAEH and YKM managed the analyses of the study, managed the literature searches and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Face detection is considered as a one of the most important issues in the identification and authentication systems which use biometric features. Face detection is not straightforward as long as it has lots of dissimilarity of image appearance. Some challenges are required to be resolved to improve the detection process. These challenges include environmental constraints, device specific constraints and the facial feature constraints. Here in our paper we present a modified method to enrich face detection by using combination of Haar cascade files using skin detection, eye detection and nose detection. Our proposed system has been evaluated using Wild database. The experimental results have shown that the proposed system can achieve accuracy of detection up to 96%. Also, here we compared the proposed system with the other face detection systems and the success rate of the proposed system is better than the considered systems.

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1. INTRODUCTION

Face detection is a computer technology that getting used in differences systems that identifies human faces on digital images. We could attribute most of challenges which associated with face detection to the following factors:

- Pose: Face image verify due to the relative camera-face pose ex (direct, with angle, diagonal, up or down).
- Facial features like mustaches, beards, and glasses may or may not be present and there is a great deal of variety of these components.
- Finding Structural components or not effects in detecting process.
- The expressions of the face: the appearance of faces is immediately affected by expressions of people like sadness or Laughing.
- Obstruction: faces may be partially obstructed by other objects. For example if we have an image with a group of faces, some people faces may partially occlude another.
- Orientation: face images directly vary for different rotations about the optical axis of the camera.
- Imaging conditions: the condition in which the picture has captured like the amount of light as it verses at morning than night, also camera accuracy is one of the most influential factors [1].

Face detection and recognition [2] are challenging problem in image analysis and computer vision. It has received a great attention in the last years because there are a lot of systems based on various methods, in different fields such as law enforcement, security and so on. We could divide face detection into three categories based on the face data acquisition methodology using well known, Viola Jones with AdaBoost classifier, SMQT features with split up SNoW classifier and color based method [3]. For face recognition using methods based on principles component analysis, support vector machine (SVM) and others [4].

The structure of the paper is as follows: Section 1 gives a brief overview of some face detection methods. In Section 2 Skin Detection technique using HSV color system is introduced. In Section 3 face detection technique is presented. In

Section 4 eye detection technique is explained. In section 5 nose detection technique is explained. The proposed method for face detection technique is introduced in section 6. Section 7 presents the experimental results. We presented the conclusion and future work in section 8.

2. METHODOLOGY

2.1 Face Detection Techniques

Face detection is one of the most important computer technologies which was used to determine the size and location of a human face in the digital image. We can detect the facial features, and any other objects like cars, trees, animals, buildings and bodies are ignored from the tested digital image. Face detection can be considered as a certain case of object-class detection that used to find the location and sizes of all objects in an image that related to the same class. It can be considered as a more general case of face localization. In face localization, the main goal is to identify the locations and sizes of a known number of faces. Basically, facial part in the given digital image can be detected by two types of approaches i.e. feature based and image based approach. In feature based approach, features have been extracted from the image and have been matched against the knowledge of the facial features. On the other side image based approach, the best match between training and testing images can be obtained from it. We can use the following methods commonly to detect the faces from a still image or a video sequence.

Fig. 1 shows different Face detection Techniques [5].

2.2 Skin Detection

Skin color detection is a process of separating between skin and non-skin pixels; the objective of the skin detection is finding out skin regions in an image. Color tone of human skin is varied radically for people from one region to another [6].

We don't prefer RGB color space for color based detection and color analysis because of blinding of color (chrominance) and intensity (luminance) information and its non-uniform characteristics [7].

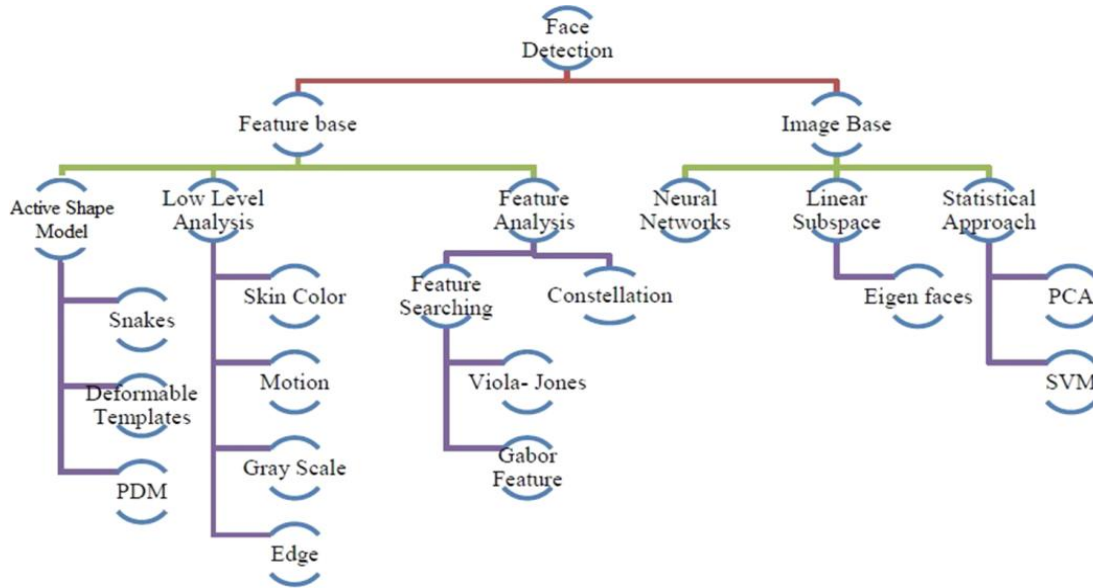


Fig. 1. Face detection techniques [5]

Here we show the process of normalization which explains the transformation of RGB to normalized RGB

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

$$g = \frac{G}{R+G+B} \quad (2)$$

$$b = \frac{B}{R+G+B} \quad (3)$$

$$r+g+b=1 \quad (4)$$

Given a color (R,G,B) where R, G, B = intensity of red, green and blue, this can be converted to color (r,g,b) where r, g, b imply the proportion of red, green and blue in the original color [8]. The transformation of Color images in RGB color space is transformed into HSV color space using [5,6,7].

$$H = \arccos \frac{\frac{1}{2}(2R-G-B)}{\sqrt{(R-G)^2 - (R-B)(G-B)}} \quad (5)$$

$$S = \frac{\max(R,G,B) - \min(R,G,B)}{\max(R,G,B)} \quad (6)$$

$$V = \max(R, G, B) \quad (7)$$

2.3 Skin Detection Using HSV Color Space

The explanation of the algorithm of the detection of human skin color in color images is as follows:

1. From the image database which is the collection of 30 color images, we could get the input image.
2. By using transformation we could convert the Input image in RGB color space into HSV color space. HSV image is a combination of three different images as hue, saturation and value.
3. We computed Histogram for all three components, so we could determine threshold value for three components from the histogram.
4. Then we applied Masking for skin pixels in the test image.
5. After that we applied Threshold to the masked image.
6. Threshold image is smoothed and filtered.
7. Finally get the output image which contains only skin pixels [8].

Fig. 2(b)-2(d) show the three different components (hue, saturation and value) based on color (chrominance) and intensity information as we transformed the input image in RGB color space into HSV and their corresponding histogram was shown in Fig. 3. We could determine the corresponding threshold value

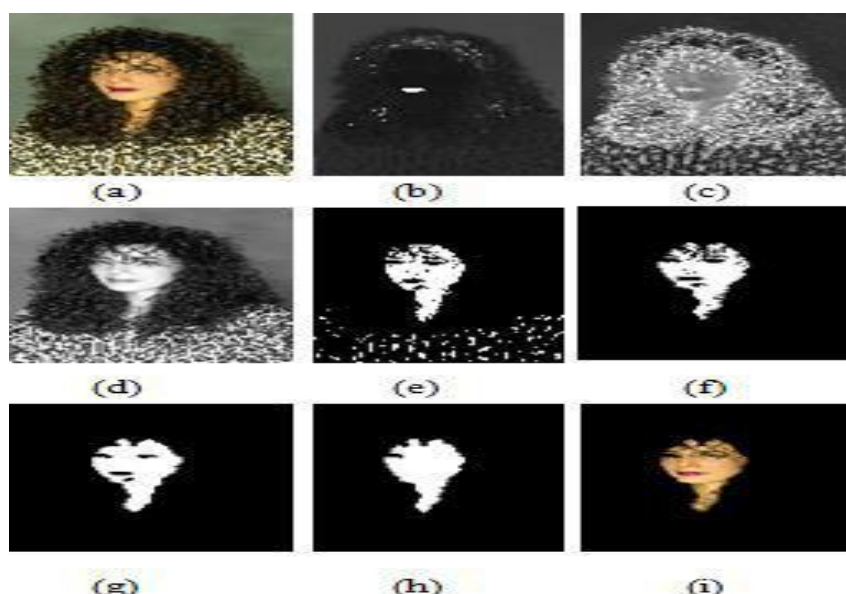


Fig. 2. Skin detection using HSV color space (a) test image1 (b) hue image (c) saturation image (d) value image (e) masking of skin pixels(f) threshold image (g) smoothened image (h) regions filled image (i) output image

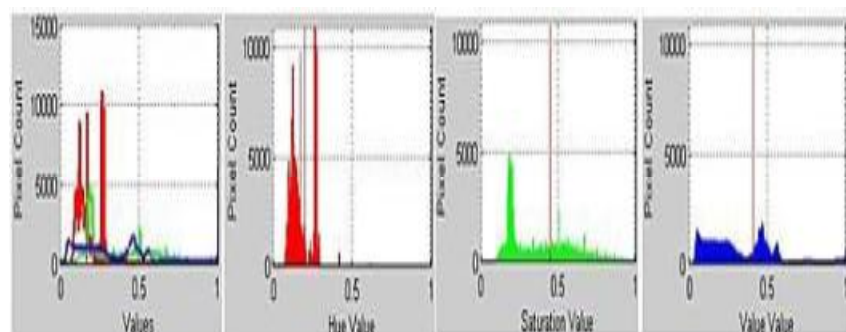


Fig. 3. Histogram and threshold value for hue, saturation and value. The vertical red line indicates threshold value

from the histogram. Masking of skin pixels is shown in Fig. 2(e). Threshold is applied for the masked image. Here the threshold value for this image was determined as 150. The pixels' values which are less than threshold are removed simply. Finally we get the output image after smoothening and filtering [9].

2.4 Face Detection Technique

There are many techniques to detect faces, with the help of these techniques; we can identify faces with higher accuracy. These techniques have an almost same procedure for Face Detection such as OpenCV, Neural Networks, Matlab, etc. The face detection work as to detect

multiple faces in an image. Here we work on OpenCV for Face Detection, and there are some steps that how face detection operate, which are as follows:

Firstly the image is imported by providing the location of the image. Then the picture is transformed from RGB to Gray scale because it is easy to detect faces in the gray scale as shown in Fig. 4 [10].

After this step, the image manipulation used, in which the resizing, cropping, blurring and sharpening of the images done if needed. The next step is image segmentation, which is used for contour detection or segments the multiple

objects in a single image so that the classifier can quickly detect the objects and faces in the picture. The next step is to use Haar-Like features algorithm, which is proposed by Viola and Jones for face detection. This algorithm used for finding the location of the human faces in a frame or image. All human faces shares some universal properties of the human face like the eyes region is darker than its neighbour pixels and nose region is brighter than eye region [11].

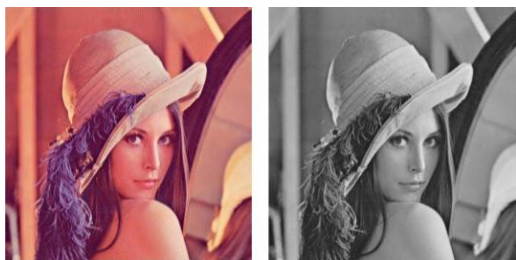


Fig. 4. The results of converting RGB image to gray scale

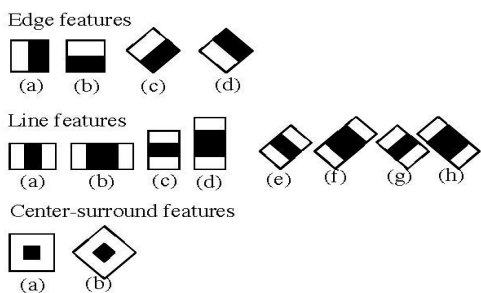
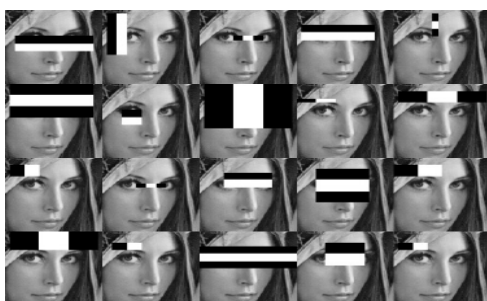


Fig. 5. Haar-Like features which are proposed by Viola and Jones for face detection [11]

2.5 Haar-Like Features for Face Detection

The haar-like algorithm is also used for feature selection or feature extraction for an object in an image, with the help of edge detection, line detection, centre detection for detecting eyes,

nose, mouth, etc. in the picture. It is used to select the essential features in an image and extract these features for face detection. The next step is to give the coordinates of x, y, w, h which makes a rectangle box in the picture to show the location of the face or we can say that to show the region of interest in the image. After this, it can make a rectangle box in the area of interest where it detects the face. There are also many other detection techniques that are used together for detection such as smile detection, eye detection, blink detection, etc. [12].



Fig. 6. The successfully detected face in an image with a rectangle box [12]

2.6 Zahra Face Detection Method

Zahra et al. [13] face detection method is a hybrid face detection method. It first makes skin detection to the input image, then apply the face detection method suggested by Viola and Jones. The method uses RGB skin color classifier and classify pixel as a skin pixel if the following constraints are satisfied:

$$\begin{aligned}
 &R > 95 \text{ and } G > 40 \text{ and } B > 20 \text{ and} \\
 &\text{Max}\{R, G, B\} - \text{Min}\{R, G, B\} > 15 \text{ and} \\
 &|R - G| > 15 \text{ and } R > G \text{ and } R > B
 \end{aligned}
 \tag{8}$$

This helps face detection algorithm to quickly identify non-faces which include majority pixels of each image. Also this method efficiently reduces false positive rate. Zahra experimental result shows that it improves viola and Jones face accuracy. However, false negative rate in this method is a little bit increased because using skin detection before face detection may cause distortion is some faces and the detection algorithm does not detect it [14].

2.7 Eye Detection

It is the process of human eye localization by using edge projections. A human eye localization algorithm in images and video is presented for faces with frontal pose and upright orientation. A

high pass filter of wavelet transform can be used to filter a given face region. Here edges of the region are focused and caricature-like representation is gained. After analyzing horizontal projections and profiles of edge regions in the high-pass filtered image, the candidate points for each eye are detected. Then by using a support vector machine (SVM) based classifier, all the candidate points are classified according to the most probable ones among the candidate points, locations of each eye are estimated. It is experimentally observed that this eye localization method provides acceptable results for both image and video processing applications [15].

2.8 Nose Detection

For nose three different local characteristics are used as follows:

- (i) Both sides' similarities: both of right and left sides of nose are similar in a front-view face as shown in Fig. (7a). By using Euclidean distance we can measure this property of similarity between both sides.
- (ii) Dark-White-Dark (DWD) property: Also, The reflection of light on the nose makes the lower part of nose region characterized by two dark nostrils and a light sub region as shown in Fig. (7b). The average of gray intensity in each sub region could identify DWD property, where the average in the two nostrils regions is less than the average of middle lighter sub region containing nose tip.
- (iii) The variation in lower/upper parts property: The two previous properties are despaired when the face is rotated so the variation between lower part and upper part will be the only clear property as shown in Fig. (7c). We can measure this variation by the variance in each part. According to this analysis, we search for a certain region among the ten highest regions detected by ICA method which satisfies the properties (i)-(iii) [16].

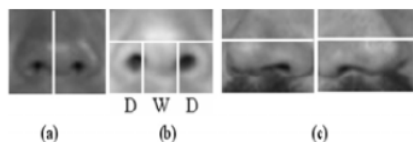


Fig. 7. The nose detection steps [16]

2.9 The Proposed Method

After we describe the different techniques, here we could explain the proposed method to improve the face detection accuracy. The proposed system can be briefed as follows:

1. We use skin detection technique using HSV color system to reduce the space of search.
2. Then apply face detection by using Viola Method.
3. To detect missed faces that weren't detected by Viola face detection method we apply the eye detection technique.
4. Finally, we apply nose detection technique to detect faces that weren't detected by Viola face detection method and eye detection.

Fig. 8 shows the flow chart that describes the proposed system steps.

Fig. 9 shows how our system works. In Fig. (9a) is the input image to be tested. Fig. (9b, 9c) show the image after skin detection is applied. Fig. (9d) is the image after the Viola face detection algorithm applied and as shown the Viola method fails to detect 50% of faces in the image, then we apply the eye detection technique in Fig. (9e) but 25% of faces are not detected. Finally we apply the nose detection on the (9e) image; hence all faces are detected successfully.

2.10 Experimental Results

This section presents the results of the experiments, which were carried out to evaluate the effectiveness of the proposed system in detecting faces in the images. The implementation of the proposed system is based on Python. We used image database contains 500 color images gathered from various sources such as Internet, video frames, etc. The used image database contains images with variation of illumination and images having background similar to skin color and non-frontal faces and images that contain glasses. The overall performance of the proposed system is compared with both Viola & Jones and Zahra algorithms; in terms of detection rate, false negative and false positive rates. Table 1 shows some of the output images obtaining by applying Viola & Jones, Zahra, and the proposed methods. Table 2 gives the total number of detected regions, false negative and false positive for each method.

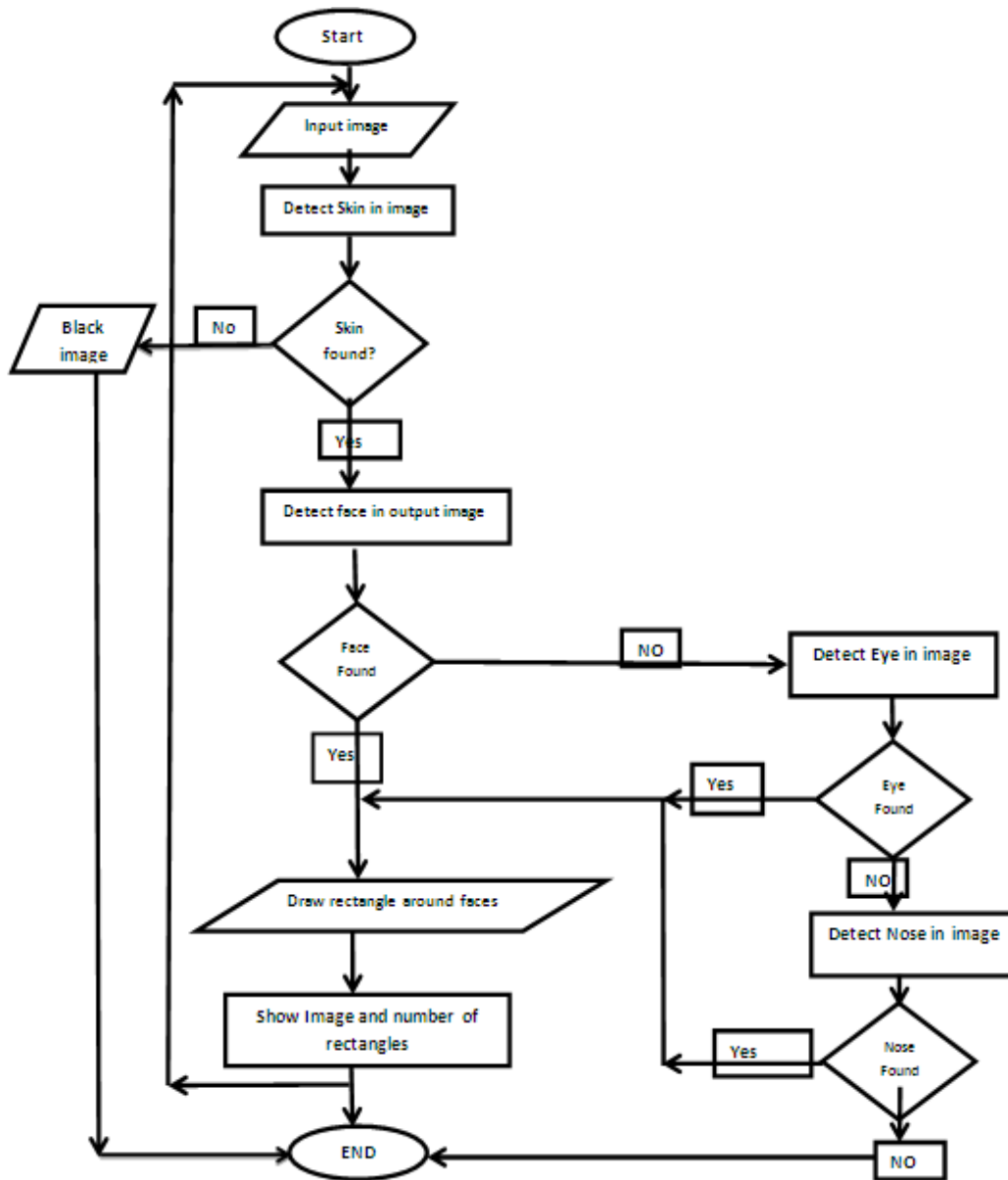
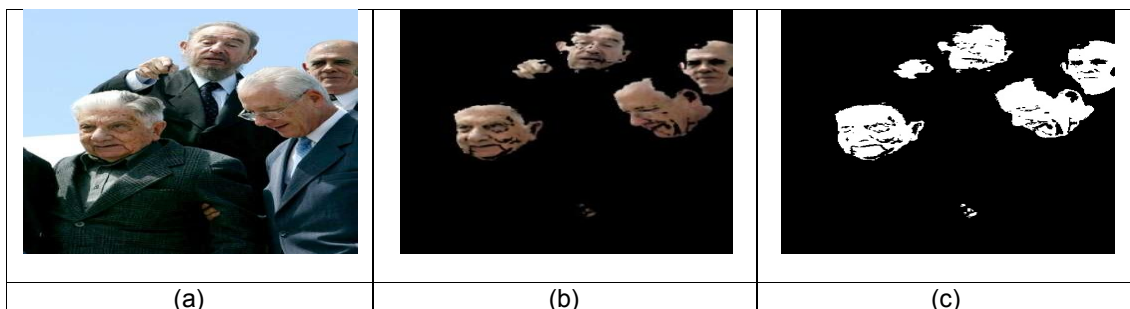


Fig. 8. The flow chart of the proposed system



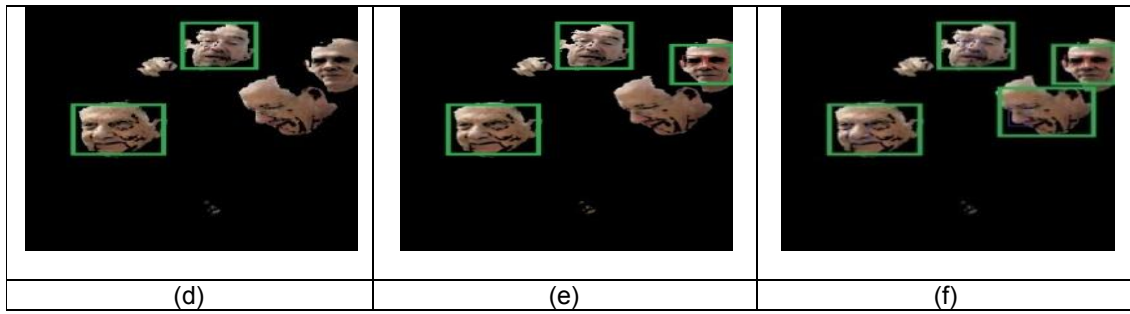


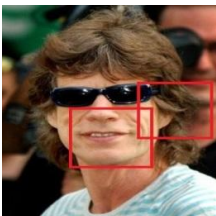
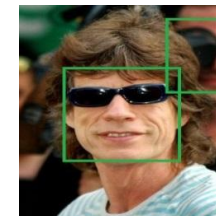




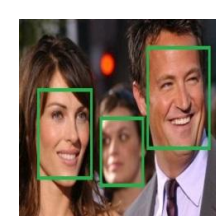


Fig. 9(9a). Original Image, (9b)Image after skin detection area, (9c)Image after converting to black and white, (9d) Image after apply Viola method, (9e) Image after apply eye detection, (9f) Image after apply nose detection

Table 1. Detected regions after applying the three methods

#	Original image	VIOLA	ZAHRA	Proposed
1				
2				
3				
4				

5				
6				
7				
8				
9				
10				

11				
12				
13				
14				
15				

Table 2 shows the experimental results of 150 sample images from Labeled Faces in the Wild database and Internet images. We choose the images that may contain some challenges such as pose sided, contrast, illumination, brightness, complex background and eye glasses. Here is apart from the result using 15 images for example which have 100 faces totally.

The proposed system has defects in images 3, 8 and 10 because the following reasons:

In Image 3, it has 9 faces varies between frontal and non-frontal faces the missing face is non-

frontal and the nose in this face isn't complete so it couldn't detect it. In Image 8, because of large amount of skin in this image the system has defect in only 1 false positive face. In image 10, it has many partial faces so the proposed system couldn't detect a complete nose in the two missed faces.

As can be seen in Tables 1 and 2, the face detection performance of the proposed method is better than both Viola & Jones and Zahra methods. The detection, false negative, false positive and average error rates for the considered methods are given in Table 3.

Table 2. Some detection results

Sample	No.of.faces	All Detection			False Negative			False Positive		
		Viola	zahra	Proposed	Viola	zahra	Proposed	Viola	zahra	Proposed
1	3	4	2	3	1	1	0	2	0	0
2	2	3	2	2	0	1	0	2	0	0
3	10	7	7	8	4	3	2	1	0	0
4	3	4	3	3	1	1	0	2	1	0
5	4	2	2	4	2	2	0	0	0	0
6	2	3	2	2	2	2	0	2	2	0
7	23	26	24	23	0	0	0	3	1	0
8	3	3	3	4	1	1	0	1	1	1
9	3	4	2	3	1	1	0	2	0	0
10	7	8	6	6	1	1	1	2	0	0
11	5	6	5	5	0	0	0	1	0	0
12	3	3	2	3	0	1	0	0	0	0
13	3	3	2	3	1	1	0	1	0	0
14	4	5	4	4	0	0	0	1	0	0
15	25	25	23	25	1	2	0	1	0	0

Table 3. Detection, false negative and false positive rates for the considered methods

	Viola	Zahra	Proposed
Detection Rate	64%	78%	96%
False Negative	15%	17%	3%
False Positive	21%	5%	1%
Average Error Rate	36%	22%	4%

As can be seen in this Table, it is clear that the face detection rate of the proposed method is better than the other considered methods. The proposed method could detect 96% of the faces correctly and the average of errors (false positive and false negative) is 4%. Generally, combining Viola& Jones with skin detection technique improve the performance detection rate. Eye and nose detection techniques are improved the Viola and Zahra methods and got more accurate results.

3. DISCUSSION

In recent years, face recognition has concerned much attention. It has numerous applications in computer vision Communication and regular access control system. Face detection is an important step towards automatic face recognition. However, face detection is not clear-cut because it has lots of variations of image look, such as pose variation (front, non-front), occlusion, image orientation, illuminating situation and facial appearance. Face detection is the middle of all facial analysis, e.g., face

localization, facial feature detection, face recognition, face verification and facial expression recognition. Moreover, it is a fundamental technique for other applications such as content-based image retrieval, video conferencing, and intelligent human computer interaction (*HCI*). The objective of face detection is to find out whether or not there are any faces in the image and, if present, return the location and the extent of each face. While face detection is a trivial task for human vision, it is a challenge for computer vision due to the variations in scale, location, orientation, pose, facial expression, light condition, and various appearance features (e.g., presence of glasses, facial hair, makeup, etc.).

4. CONCLUSION

Face detection is one of the most important issues in the identification and authentication systems that use biometric features. Face detection is not straightforward because it has lots of variations of image appearance. In this paper we present a modified method to enhance face detection by using combination of Haar

cascade files using skin detection, eye detection and nose detection. The proposed system has been evaluated using Wild database. The experimental results have revealed that the proposed system can achieve detection accuracy up to 96%. Also, the performance of the proposed system is compared to the performance of Viola et al. and Zahra face detection systems and the success rate of the proposed system is better than the considered systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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