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# Realtime human face tracking and recognition system on uncontrolled environment

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**ABSTRACT**

Recently, one of the most important biometrics is that automatically recognized human faces are based on dynamic facial images with different rotations and backgrounds. This paper presents a real-time system for human face tracking and recognition with various expressions of the face, poses, and rotations in an uncontrolled environment (dynamic background). Many steps are achieved in this paper to enhance, detect, and recognize the faces from the image frame taken by web-camera. The system has three steps: the first is to detect the face, Viola-Jones algorithm is used to achieve this purpose for frontal and profile face detection. In the second step, the color space algorithm is used to track the detected face from the previous step. The third step, principal component analysis (eigenfaces) algorithm is used to recognize faces. The result shows the effectiveness and robustness depending on the training and testing results. The real-time system result is compared with the results of the previous papers and gives a success, effectiveness, and robustness recognition rate of 91.12% with a low execution time. However, the execution time is not fixed due depending on the frame background and specification of the web camera and computer.



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## 1. INTRODUCTION

In the last year, one of the most active topics and challenging problems in the field of computer vision is face tracking and recognition [1]. Furthermore, the images are analyzed and process, the producers acquire extra information to create arithmetic or symbolic data [2]. Supervised learning has been used in image classification and pattern recognition by providing the data set to be used in similarity comparison; the dataset can be containing features of the image (such as faces image) [3]. Human face detection, tracking, and recognizing system play an important role in our day-to-day life that has been developed and used in such notebooks, personal computer (PC) cameras, digital monitoring, 3G cell phones, intelligent robots, digital cameras [4]. There are three modules usually used in video-based face tracking and recognition systems; the first module, face detecting, the second is tracking detected face and the third is recognized module [5]. The art of the human face recognition system is completely difficult as it shows the features like the variations in facial expressions, poses, or even occlusion that affected on feature extraction step in the face recognition system [6], [7]. While, the face recognition (FR) system is described the examination of the face and is robust for challenging doing from alteration in expressions of facial, poses, and the lighting and imaging situation [8]. In identification, built automated face recognition system's ability to recognize a face is a true challenge [9]. Faces could be displayed in dissimilar angles (diverse rotations); where the hair and their expressions can modify the facial; the comparison between various faces can be detected [10]. In general system of face recognition has three main steps: detection of face; extract the features; and recognize the face [11], [12]. The detection of face procedure is utilized as a significant feature in a lot of applications of the analysis of image and systems of biometric [13]. In insecurity systems, facial recognition is widely used test data and training a person's [14]. Holistic methods are used in [15]–[17]. Moreover, the research of detection is using image data for training and testing, also the techniques of feature extraction are used in [18], [19]. On the other hand, researchers can be used one division of the face; therefore the technology of research recognition is developed [20]. This paper presents the face detected, tracked, and recognized with various angles and rotations in real-time is discussed. The front and profile face with different rotations are detected by the Viola-Jones method. The facial features are tracking like as mouth, nose, eyes, and eyebrows. The color-Space method is applied to track faces detected by the available algorithm depending on the color of the face. The moving frame in real-time is used face image recognition as the data test; principal component analysis (PCA) is used to recognize tracked faces. Euclidean distance between the results of features from data trained and data tested is compared to get the similarity measurement level.

## 2. CONTRIBUTION

This paper aims to build a fast face tracking and recognition system with 180 degrees rotation and increasing the recognition rate with different rotations below various surrounded cases for a number of the facial impressions. Our proposed contains of three phases. First of all, detecting a face from the capture frame from web camera with different rotation; that means the faces are detected from the right to left direction. The second phase is starting after rectangle bounding of the image face and it is tracking the detected face by using a color space algorithm. The third phase is the recognition phase to recognize the face that appeared in a real-time system by comparing it with face images in the database using the PCA algorithm that returns the face image which has the nearest distance with its details.

## 3. REALTIME FACE RECOGNITION SYSTEM

To get automatic realtime recognition of the face, a database of the face image is fundamental to makeup. The features are stocked and extracted in the database for every human being from several images. After that, perform a detected of the face for each frame captured from the camera and feature extraction by Viola-Jones, its features compared with face stocked in the database for recognizing the face. Figure 1 describes the realtime face recognition system.

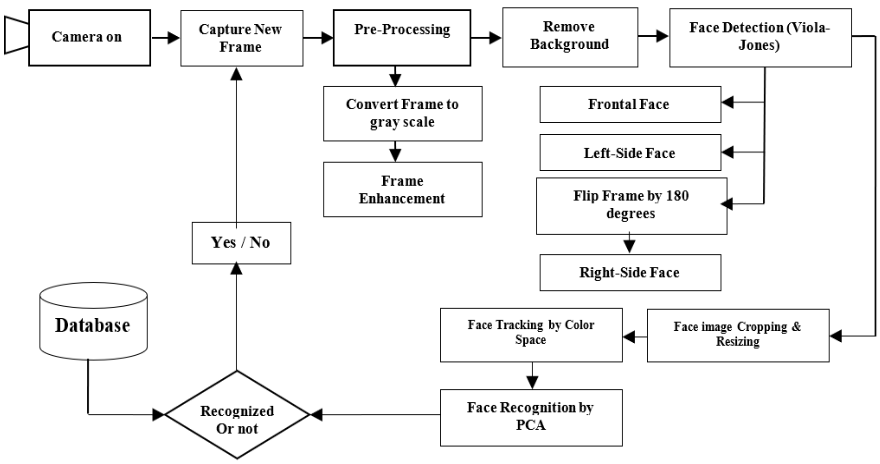



Figure 1. Realtimes face recognition system diagram

### 3.1. Preprocessing

A preprocessing is used to enhance the visual frame appearance [21], [22]. The frame is transformed to the level of grey band by converting the three bands of the color captured frame red, green, and blue (RGB) into single gray band which refers to the intensity band using the (1) [23]–[28].

$$Y(i,j) = 0.2989 \times R(i,j) + 0.5870 \times G(i,j) + 0.1140 \times B(i,j) \quad (1)$$

where, $Y$ refers to the grey level that refers to the intensity part of the image color and $I$, $j$ indicates the indices of image pixels. The three estimated bands $R$, $G$, and $B$ refer to the components of color that matched to the bands of the image as red, green, and blue bands [29], [30]. The intensity resulted of image includes the whole features of image that might be helpful for the process of detection [31].

### 3.2. Remove the background

Real-time systems have a dynamic background called an uncontrolled environment [31]. The background of the frame is removed to get reliable results and reduce processing time in real-time systems [29]. Video in real-time demands great resources to be treated so, this stage aims to minimize the number of resources used and avoid any other needless processes. To achieve the removing background, XOR has been used to the difference between two frames successive to get binary image [31].

### 3.3. Face detection

In this paper, the best Gamma-correction value used is 0.5 before going on with the basic processing to enhance the image and provides faster and enhanced results. The detectives of faces are used for phases of tracking and recognition. A real-time system can detect the presence or absence of faces in the captured frame from the camera with various rotations (profile and frontal faces) by the algorithm of Viola-Jones. Frames possessed from the camera might not be fully appropriate for the detection of face phases of working. The goal of the face detection phase in a real-time system is to finding every face in a specified frame and, if present, the area of each face and the frame location are returned [10]. Figure 2 shows the four components: Haar features, the integral image, AdaBoost, and cascading. To start evaluating features in the algorithm, of Viola-Jones the window base range taken is a 24×24 window in every specified image, additional details in [2], [10]. The face detected is rectangular as simple features with specified colors in real-time with a different rotation, a variety of facial expressions, poses, and time execution is low.

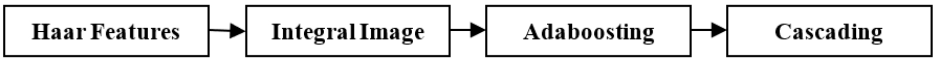



Figure 2. Flowchart of Viola-Jones algorithm [10]

### 3.4. Face cropping and resizing

The size of the captured image from the camera is 640×480. The detected face with different rotations and on the uncontrolled environment (dynamic background) cropped and resized to 100×100 pixels as shown in Figure 3 that shows the outcomes of the image pre-processing with face detection in Figure 3(a) and after cropped and resizing the region of face in Figure 3(b).

(a) (b)

Figure 3. Face detected image on uncontrolled environment (a) detected face image and (b) cropped and resizing face region

### 3.5. Tracking face

In this phase, the algorithm of color space is utilized to track the face that was detected from the previous stage each detected face can be represented by one color value that mirrors the color values of the face detected. Some areas of the image will be established with similar color values by searching about color values in the image to be handled. All areas will represent the faces that will be tracked. The method of background removal presented in (3.2) will be used to check the difference between the previous and the current frames [31]. Color space algorithm described in the following steps:
- Exchange every face detected from RGB color space to Herpes simplex virus (HSV) color space by using algorithm 1.
- Compute the mean of the HSV pixels that compose up the image of the face.
- Save the mean for benefiting from it in the comparison process.
- Seek about the face in the next steps.

Algorithm 1. RGB to HSV convert
Input: R, G, B Color space for each face detected, Output: H, S, V Color space for each face detected, Procedure:
- $Set\ V = Max\ (R, G, B)$, $Set\ D = V - Min\ (R, G, B)$, $Set\ S = Select\ \left(V = 0, 0, D \times \frac{255}{V}\right)$
- If S=0 then Set H=0
- Else if R=V then Set $H_0$=(G-B)/D
- Else if G=V then Set $H_0$=2+(B-R)/D
- Else Set $H_0$=4+(R-G)/D End
- If $H_0$<0 then Set $H_0$+=6 End
- $Set\ H = H_0 \times 255/6$ End

### 3.6. PCA

PCA is applied as a multivariate analysis in a realtime face recognition system that converts many probably associated variables into a smallest number of unconnected mutable named principal components (PCs). The trouble of recognition is solved by PCA in an exemplification space of minimizing dimension than image space. PCA is an Eigenface process that aids in the reduction of the dimensionality of the space in new data and is used to simplify a dataset. Figure 4 illustrates the flowchart of the PCA algorithm [16]. The results of the steps below of PCA can be represented in Figure 5:

a. Keep the face images as training set be, $\Gamma 1\ \Gamma 2\ \ldots\ \Gamma N$ as shown in Figure 5(a).
b. Compute the mean of face images average as shown in Figure 5(b) by using (2).

$$\mu = \frac{1}{N} \sum_{n=1}^{N} R_i \tag{2}$$

c. Subtract the mean from each face image by using (3).

$$G_i = R_i - \mu \tag{3}$$

d. Determine the covariance matrix by the following relation:

$$C = \frac{1}{N} \sum_{n=1}^{N} G_i\, G_i^T = AA^T \tag{4}$$

e. Calculate the Eigenvalue and Eigenvectors of covariance matrix $B = [z1, z2, z3, \ldots\ldots, zn]$,

$$\Delta = \begin{bmatrix} \gamma_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \gamma_n \end{bmatrix} \tag{5}$$

f. Compute distance of Euclidian between the data examined and each another data training in the database. $Z$ mention to the test input data as the feature vector, $n$ is the digit of the feature utilized, and that of the database is $D$, then an equivalent is establish by reduce the distance of Euclidean.

$$Euclidean\ distance = \sqrt{\sum_{t=1}^{n} (D_t - V_t)^2} \tag{6}$$

where, the five-eigen face during the calculation of PCA fundamental shown in Figure 5(c) means the order of eigen faces from highest eigen values is listed from left to right and from upper to lower.

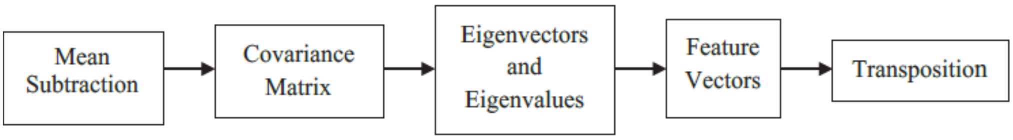
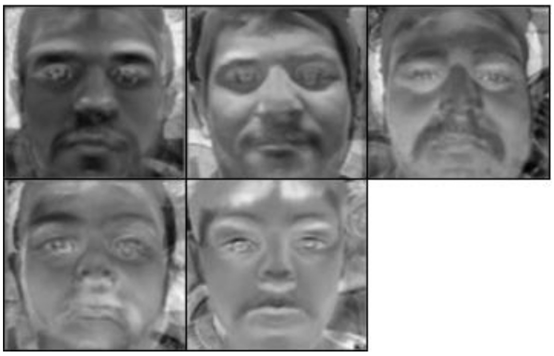



Figure 4. Flowchart of PCA algorithm [10]

(a) (b)



(c)

Figure 5. Applying PCA algorithm on some samples image database (a) samples of detected face images in database and each face size 100×100, (b) mean face through the computation of PCA basis, and (c) five-eigen face during the calculation of PCA fundamental (the order of eigen faces from highest eigen values is listed from left to right and from upper to lower)

## 4. RESULTS AND ANALYSIS

The complete realtime face recognition system displayed in Figure 6 is implemented on a laptop with Intel (R) Core (TM) i7- processor with 8.0 GB RAM. The operating system is Windows 10, visual studio C# programming language and the platform of MS-Windows is applied to build the use program. To evaluate and analyze the system training is conducted by using 10 persons where each person will be taken 10 images of a face from a different location, facial expressions, poses, and different rotations as train data. Then, testing data in real-time will use a web camera that has been linked with the system. Taken 100 frames of web camera with proper distance separated into three types, that is at a distance of (100, 150, and 200 cm) used for each one of 10 persons. The recognition rate of test images that succeeded (the better match case is the right match) to the total efforts as shown in (7).

$$Recognition\ Rate = \frac{\text{NO of image correct recognition}}{\text{Total number of test imeges}} \times 100\% \quad (7)$$

### 4.1. Results at 100 cm distance of face recognition

The distance utilized between the web camera and the object is around 100 centimeters for the result shown in Tables 1 and 2 respectively. That used uncontrolled environment with different variations in expressions of facial, poses, and illumination and Imaging states. Depending on the data in the Table 1 and Table 2, it can analyze that holistically. The results of the submitted using PCA process display recognition rate which is 100% with the time execution which is 0.266333 second.

### 4.2. Results at 150 cm distance of face recognition

The distance was increased to 150 cm and the results are display in Table 3 for the next face recognition test. To evaluate results in real-time of face recognition with different rotation and uncontrolled environments. Table 4 analyzed the previous table result obtained. Where it is found that the direction of the face if in the front view it gets the best rate of recognition and the leas average time. However, when the face movement to the right or left it record the lower rate of faces recognition and longer average time that the front view.

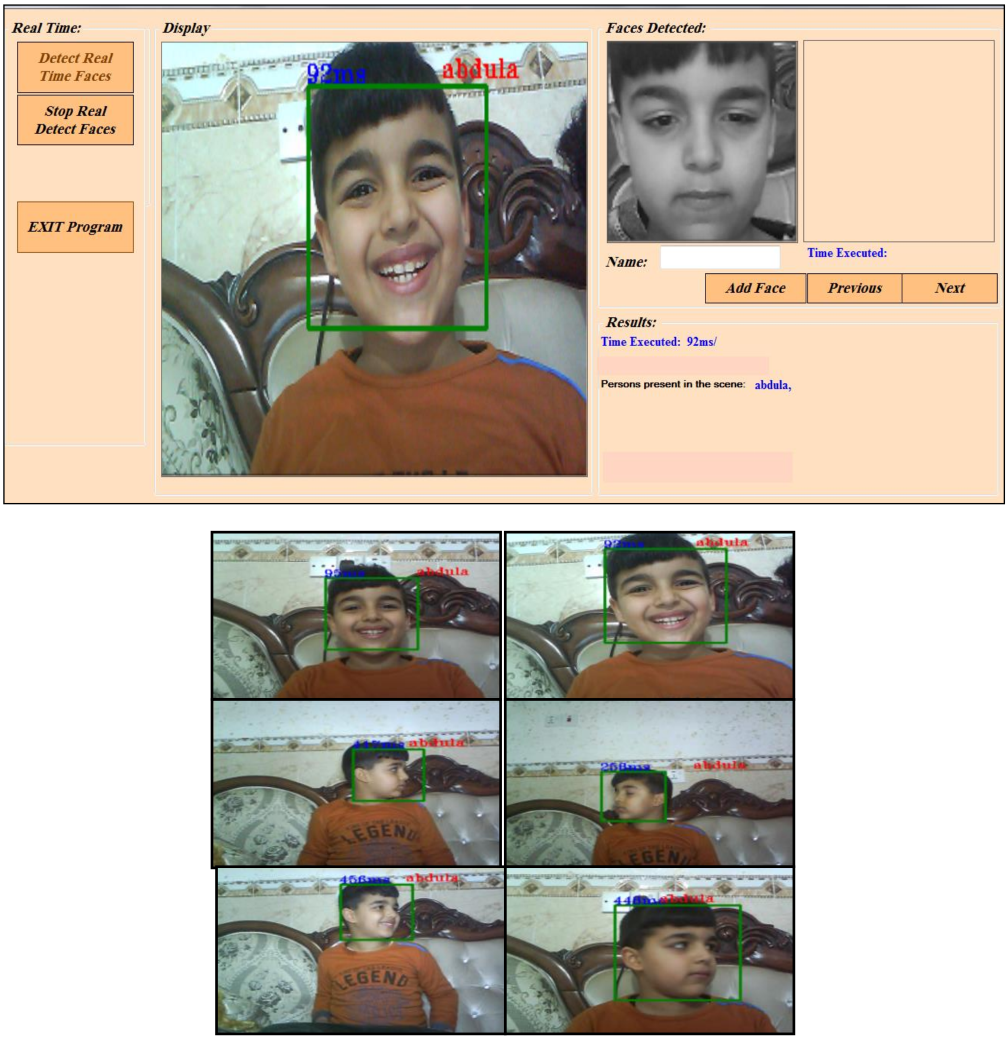



Figure 6. Test image in realtime face recognition on uncontrolled environment with different rotation, facial expressions, and poses

Table 1. Results at 100 cm distance of face recognition

| Name | Frontal Face | | Profile Face | | | |
|---|---|---|---|---|---|---|
| | | | Left | | Right | |
| | Results | Time (second) | Results | Time (second) | Results | Time (second) |
| Person 1 | Recognized | 0.074 | Recognized | 0.332 | Recognized | 0.675 |
| Person 2 | Recognized | 0.062 | Recognized | 0.266 | Recognized | 0.439 |
| Person 3 | Recognized | 0.054 | Recognized | 0.110 | Recognized | 0.475 |
| Person 4 | Recognized | 0.085 | Recognized | 0.061 | Recognized | 0.091. |
| Person 5 | Recognized | 0.093 | Recognized | 0.430 | Recognized | 0.449 |
| Person 6 | Recognized | 0.066 | Recognized | 0.287 | Recognized | 0.430 |
| Person 7 | Recognized | 0.084 | Recognized | 0.286 | Recognized | 0.460 |
| Person 8 | Recognized | 0.091 | Recognized | 0.244 | Recognized | 0.410 |
| Person 9 | Recognized | 0.200 | Recognized | 0.250 | Recognized | 0.450 |
| Person 10 | Recognized | 0.147 | Recognized | 0.323 | Recognized | 0.657 |

Table 2. Results of face recognition rate at 100 cm

| Face Position | Recognition Rate % | Average Time (seconds) |
|---|---|---|
| Frontal Face | 100 | 0.0956 |
| Left Side Face | 100 | 0.2589 |
| Right Side Face | 100 | 0.4445 |
| Average | 100 | 0.266333 |

Table 3. Face Recognition results at 150 cm distance

| Name | Frontal Face | | Profile Face | | | |
|---|---|---|---|---|---|---|
| | | | Left | | Right | |
| | Results | Time (second) | Results | Time (second) | Results | Time (s second) |
| Person 1 | Recognized | 0.076 | Recognized | 0.250 | Recognized | 0.436 |
| Person2 | Recognized | 0.082 | Recognized | 0.350 | Recognized | 0.650 |
| Person3 | Recognized | 0.115 | Not Recognized | 0 | Not Recognized | 0 |
| Person4 | Recognized | 0.067 | Recognized | 0.086 | Recognized | 0.096 |
| Person5 | Recognized | 0.093 | Recognized | 0.430 | Recognized | 0.449 |
| Person6 | Recognized | 0.086 | Recognized | 0.266 | Recognized | 0.433 |
| Person7 | Recognized | 0.096 | Recognized | 0.286 | Recognized | 0.466 |
| Person8 | Recognized | 0.095 | Recognized | 0.263 | Recognized | 0.410 |
| Person9 | Recognized | 0.098 | Recognized | 0.260 | Recognized | 0.463 |
| Person10 | Recognized | 0.088 | Recognized | 0.305 | Recognized | 0.605 |

Table 4. Results of face recognition rate at 150 cm

| Face Position | Recognition Rate % | Average Time (seconds) |
|---|---|---|
| Frontal Face | 100 | 0.0896 |
| Left Side Face | 90 | 0.277333 |
| Right Side Face | 90 | 0.445333 |
| Average | 93.33333 | 0.270755 |

### 4.3. Results at 200 cm distance of face recognition

Table 5 shows the test results when the distance is 200 cm. The results are analyzed in Table 6 for the previous test. When its front view face position, get the highest recognition rate up to 90% with leas time. Also find in the left side view has been obtained lowest percentage that front view and the time increased. As well as the lowest recognition rate was found the direction is to the right position it gets the lowest recognition rate with the longest time taken.

Table 5. Results at 200 cm distance of face recognition

| Name | Frontal Face | | Profile Face | | | |
|---|---|---|---|---|---|---|
| | | | Left | | Right | |
| | Results | Time (second) | Results | Time (second) | Results | Time (s second) |
| Person 1 | Recognized | 0.097 | Recognized | 0.302 | Recognized | 0.513 |
| Person2 | Recognized | 0.115 | Recognized | 0.205 | Recognized | 0.364 |
| Person3 | Not Recognized | 0 | Not Recognized | 0 | Not Recognized | 0 |
| Person4 | Recognized | 0.070 | Recognized | 0.100 | Recognized | 0.210 |
| Person5 | Recognized | 0.100 | Not Recognized | 0 | Not Recognized | 0 |
| Person6 | Recognized | 0.091 | Recognized | 0.271 | Recognized | 0.451 |
| Person7 | Recognized | 0.097 | Recognized | 0.290 | Recognized | 0.490 |
| Person8 | Recognized | 0.099 | Recognized | 0.286 | Not Recognized | 0 |
| Person9 | Recognized | 0.200 | Recognized | 0.260 | Recognized | 0.463 |
| Person10 | Recognized | 0.099 | Recognized | 0.405 | Recognized | 0.677 |

The experimental face recognition results are depending on several tests that have been done at 100, 150, and 200 cm distance. Every one of them has a various level of rate depending on several factors such as background lighting and distance. Also, things have been done in [31] where the recognition rates describe in a chart shown in Figure 7 for 100, 150, and 200 cm respectively. Table 7 shows overall analysis for all distances taken by the system design, its accuracy analysis, and realtime face recognition. Where it turns out that when the distance increases, the time increases, and the accuracy of face recognition decreases.

It can be concluded that the mean of face recognition in real-time has a rate of 91.12% with a calculation time of 0.270579 seconds, which represents an acceptable rate computed for different facial expressions and poses in real-time system of face recognition compared with previous papers. Table 8 describes a comparison between the results of the current paper with earlier papers. Also, the FR system can be designed as a website in the same website shown in [32] to be extra attractive by uploading a database made on the data center to reach from every region connected within the data center.

Table 6. Results of face recognition rate at 200 cm

| Face Position | Recognition Rate % | Average Time (seconds) |
|---|---|---|
| Frontal Face | 90 | 0.1065 |
| Left Side Face | 80 | 0.264875 |
| Right Side Face | 70 | 0.452571 |
| Average | 80 | 0.274649 |

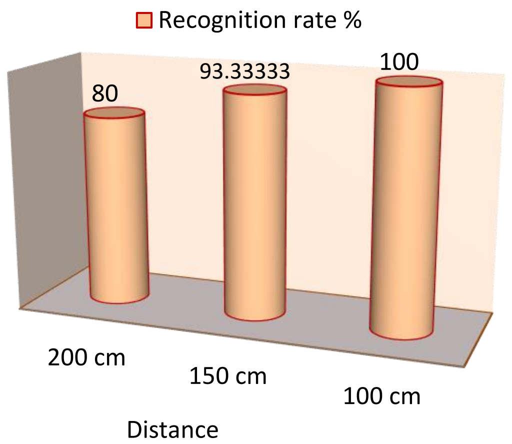



Figure 7. Chart of face recognition rate at 100, 150, 200 cm distance

Table 7. Gathering of face recognition rate

| Distance (cm) | Recognition rate % | Time (seconds) |
|---|---|---|
| 100 | 100 | 0.266333 |
| 150 | 93.33333 | 0.270755 |
| 200 | 80 | 0.274649 |
| Average | 91.12 | 0.270579 |

Table 8. Result comparison of face recognition

| Number | Research technique | Recognition Rate |
|---|---|---|
| 1 | PCA + GA + NN [33] | 81 |
| 2 | PCA + EmguCV [31] | 87 |
| 3 | Our Proposed | 91.12 |

## 5. CONCLUSION

Real-time facial images with different rotations and uncontrolled environments are some of the features of this system. This paper was developed to build a security-based system. The proposed realtime face recognition system detects the face image with various rotations from right to left. Different face expressions, poses using the Viola-Joens method, and color space algorithm are used for the tracking process, and the PCA algorithm is used for the recognition phase. The real-time system of face recognition result is compared with the results of the previous papers and gives a success, effectiveness, and robustness recognition rate of 91.12% with low execution time. However, the execution time is not fixed due depending on the frame background and specification of the web camera and computer specifications.

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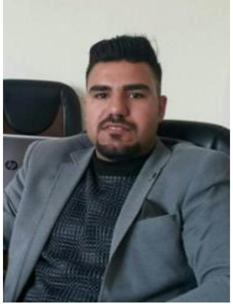

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