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A Secured Biometric Authentication with Hybrid Face Detection and Recognition Model

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Abstract: Now-a-days biometrics is used to recognize an individual, and is thought of a more secure way to authorize an individual. Face is the most important factor to recognize an individual. In order to enforce security features, many verification systems use face recognition to identify a person, such as - automobile security, security of home, smartphones owner recognition, attendance system, identification of criminals, etc. Face biometric works in two phases –face detection and face recognition. In this paper we are proposing a hybrid model that works in two phases, face detection is the first phase which includes two stages, in first stage it detects the face from the acquired image and then in the second stage acquired image is subjected to intensity equalization. The second phase is of Face recognition, where finally the individual is recognized as authenticated user or not. We are using Viola-Jones algorithm to detect the face, histogram stretching for intensity equalization and principal component analysis (PCA) algorithm for image recognition. The effectiveness of the suggested facial recognition system is shown through experimental findings using the face dataset constituting of 100 subjects using VTU-BEC-DB multimodal biometrics database with constraints of pose and illumination in the face images, without the intermediate step of intensity equalisation, we had a recognition rate of 93.60%. However, when the intermediate step of intensity equalisation was included, a novelty was added to the hybrid algorithm, and we achieved a recognition rate of 98.20%, which is higher recognition rate than the state-of-the-art methods.

Keywords: Biometric, Eigen face, Face detection, Face recognition, Haar features, Integral image, PCA.

1. Introduction

Biometrics is currently a booming technology, widely used in the field of security to authenticate an authorized user. An authorized user is identified by a variety of physiological or (/and) behavioral traits of that person [1]. The use of biometric systems for authentication and authorization of an individual or customer has the following benefits [2] - availability, robustness/ permanence, accessibility/ collectability and acceptability. Though it's beneficial to use the biometrics to authenticate an individual, the used variation and its trait(s) has its own challenges. Any biometric system can be categorized into two variations based on: Physiological traits and behavioral traits [3].

In this paper, we are using physiological trait of face and, developing a secured hybrid face detection and face recognition model to verify an individual for authentication purpose. We are using Viola-Jones algorithm to detect the face in the acquired image. In order to find a face, the algorithm outlines a bounding box and searches the face inside the box. The search is for the haar features. After traversing every tile in the image, the box advances one step to the right. Haar-like traits are detected by several boxes, and the data from all of those boxes together aids the algorithm in locating the face. Once the face in the image is detected from the source then the detected face is cropped and subjected to intensity

Table 1. Popular traits with their benefits and drawbacks

Sl. No	Trait	Benefits	Drawbacks
1	Fingerprint [4]	Low cost implementation High Mobility.	Due to its relationship with criminal identification, this method is probably the most criticized. Low social acceptability. Aged users or users with skin conditions may have a problem with population coverage. A filthy, damp, or dry finger can affect performance.
2	Face [5]	Ease of use. Low cost implementation. Commonly available cameras can be used.	Hair, glasses, caps, and other accessories might obscure the face. Perceptive to changes in lighting, expression, and posture. Different facial expressions.
3	Palm print [6]	palm area is substantially larger and can capture more distinguishing traits.	As they must capture a broader area, palm print scanners are typically larger. It is relatively expensive
4	Palm veins [7]	unique to every individual, even w.r.t. identical twins. No impact of age, cuts, bruises, scars, dirt, etc.,	The scanners are usually bulkier and expensive.
5	Hand Geometry [4]	Participant acceptability is high and the system is simple to use. Suitable for medium and low security application. Works in harsh environments.	Extraction of palm information is impacted by wearing watches, jewelries, etc. Data storage Large devices are needed. Less distinctive.
6	Iris [7]	The simplicity of use and adaptability of scanning technology have led to a surge in demand for this technique. Less prone to harm because it is a protected internal organ. Extremely steady over time.	Acquire a small target (1 cm) from a distance (1 m). Wearing glasses and eye lenses High cost of implementation. Eyelashes, eyelids, lenses, and corneal reflections partially block the view.
7	Retina [8]	Reliability is more A retina cannot be duplicated, as far as is known.	Medical factors such as high blood pressure can affect the accuracy also impacted by Wearing glasses and eye lenses Very expensive. Thoughts of consumers (The eye could be harmed by it.)
8	ECG [9]	The ECG is characterized by universality.	Complex setup Expensive in nature
9	DNA [10]	High Accuracy.	It is very expensive. Processing time of at-least 4 to 5hrs.
10	Gait [11]	Easily acquired without cooperation of the subject.	Can be acquired without consent of the subject. Prone to change in case of just in change of footwear to any accidents.
11	Signature [12]	Discovery of inconsistent users while enrolling. Training is quick and easy. Cheap Hardware.	Enrolling and verifying may be challenging for those whose signatures are inconsistent.
12	Handwriting [13]	Fast and simple training. Cheap hardware. Little storage requirement	Individual inconsistent handwriting.
13	Voice [14]	Public acceptance.	Not sufficiently distinctive for identification over large population. It can be mimicked.
14	Keystroke Dynamics [15]	Ease of use. Low cost of implementation	Tempo might change due to fatigues’

equalization for the purpose of enhancing the quality of image and thereby implementing PCA for face recognition. Face is afflicted by the "Curse of Dimensionality", hence processing a face takes a lot of memory and time. So only the important features must be found in order to increase accuracy and reduce image noise to solve the memory and time problem. To reduce the dimensionality, PCA is used. Images are then projected into eigen space following the reduction in dimensionality. All of the training dataset's images are projected onto eigen space by PCA method. The query image/test image is also projected onto eigen space. The Mahalanobis distance between the query image and each of the training images is calculated for the purpose of recognition. A threshold of image is also found with the Mahalanobis distance. If the value obtained is more than the threshold then the image is recognized, otherwise not. Experimental findings show that the suggested strategy offers a higher recognition rate than those mentioned in the literature.

2. Literature review

Any physiological and/or behavioural trait can be used to provide biometric-based security. The following Table 1 provides an insight on popular traits, their benefits, and their drawbacks based on the analysis of prior works.

Finger print technology is one the most popular technology used to provide biometric security, but it has its own set of disadvantages such as the social acceptability is medium, recognition widely depends on skin conditions of the user, and is hampered by finger plasticity or clay printing-related unauthorized access [16]. The accuracy of the Iris and Retina recognition is very high but the cost of implementation and the social acceptability is low. Gait as a biometric recognition has low implementation cost but the accuracy is medium and social acceptability is low. Even though, the voice recognition as a biometric recognition has high social acceptability but the accuracy is medium.

When face recognition is considered the accuracy rate was from high to medium but the social acceptability was high and the cost of implementation was medium and also "easy-to-collect" biometrics. These things triggered us to use face detection and recognition to authenticate a user.

The works of previous authors on face recognition are as follows:

Rama et al. [17] - Aiming to identify partially occluded face images; they have used three approaches Holistic PCA which is a eigen face approach; component based PCA (CPCA), a variation of the eigen features approach; and lophoscopic PCA (LPCA) with 11 lophoscopic subspaces which are created by masking different parts of the whole face. Their LPCA was most successful approach.

Table. 2 Comparison of various biometric traits [Accuracy – Acc, social acceptance – SA, medium – M, low – L, high – H]

Sl. No	Biometric Trait	Devices Used	Cost	Acc	SA
1	Fingerprint	Scanner	M	H	M
2	Face	Camera	M	H-M	H
3	Palm print	Scanner	L	M-L	H
4	Palm veins	Scanner	L	M-L	H
5	Hand Geometry	Scanner	L	M-L	H
6	Iris	Camera	H	H	L
7	Retina	Camera	H	H	L
8	ECG	ECG	H	M-L	L
9	DNA print	Laboratory Analysis	H	H	L
10	Gait	Sensor, camera	L	M	L
11	Signature	Touch Panel (TP), Optic Pen	M	L	H
12	Handwriting	TP, Optic Pen	M	L	M
13	Voice	Micro-phone	M	M	H
14	Keystroke Dynamics	Sensors and Keyboard	L	L	L

Jia et al. [18] - Aims at face (object) recognition using support vector machines (SVM) with partial occlusions, in their work they are allowing partial occlusions in both the training and testing sets. In order to achieve this, the authors introduce the SVM formulation that indicates the likely range of values for the missing data.

Siswanto et al. [19] - In their work they uses PCA, eigenface, fisherface, and haar cascade for face recognition, they first extracts the coordinates of features such as the width of the – eyes and mouth; and the pupil. Then compares the result of extracted features with the stored database values and returns the image with closest value as the recognized image.

Angadi et al. [20] - Their method begins by employing the Viola-Jones algorithm to extract the parts of face like mouth, nose and eyes from the source face image. The image is scaled to 64 x 64 pixel sizes and converted to gray scale. The Savitzky-Golay filter is used to compute the best set of features from each face portion. The retrieved features from the various facial components are used as symbolic data objects. In the recognition phase, a newly developed symbolic similarity measure is used to determine how similar test objects and trained objects of facial components are. The object is recognised as being a member of the class with the greatest similarity.

Elgarrai et al. [21] - Their work is based on a single, left-to-right dimension markov hidden models (1D-HMMs). They used Gabor wavelets to obtain face features. To retain only the most pertinent information, they had used Fisher's Discriminant Analysis and reduced the dimensionality of these features. In their work the features of interest are extracted without performing segmentation.

Borkar et al. [22] - In their approach, they have used PCA for dimensionality reduction. Eigen values and Eigen vectors are calculated using Jacobi method, then using linear discriminant analysi s (LDA) the image is projected onto eigen space. They have used euclidean distance for recognition purpose.

Kagawade et al. [23] - They have suggested a novel method based on a multi-directional local gradient descriptor (MLGD) that is created from local directional gradient characteristics and utilises edge/line information in different directions.

Sharmila et al. [24] - They have proposed a technique that applies eigenface, fisher face, and linear binary pattern histograms (LBPH) which utilises the haar cascade.

Angadi et al. [25] - Developed a technique for face recognition that makes use of graphs with symbolic representations that include texture information. They utilised the symmetric local binary pattern (CS-LBP) descriptor to extract the features from the facial image, which they represented as a collection of three completely linked graphs.

Ghrairi et al. [26] - In their work, they used the Viola-Jones algorithm to detect and extract the front and profile faces. They have used PCA for face recognition and depend on database models that have been generated and compared with test face images for the recognition process. They have used two sets of the file exchange interface (FEI) database's image sets to recognise the person during system training and testing.

Asha et al. [27] - Face feature extraction and face pattern matching are two steps that their proposed model uses to operate. Face identification uses the PCA-extracted features from face databases and the Haralick features. For the purpose of matching and searching facial traits, an artificial firefly swarm optimization technique is used.

The majority of automatic feature extraction techniques doesn't offer a high level of accuracy and demand a lot of processing power [28].

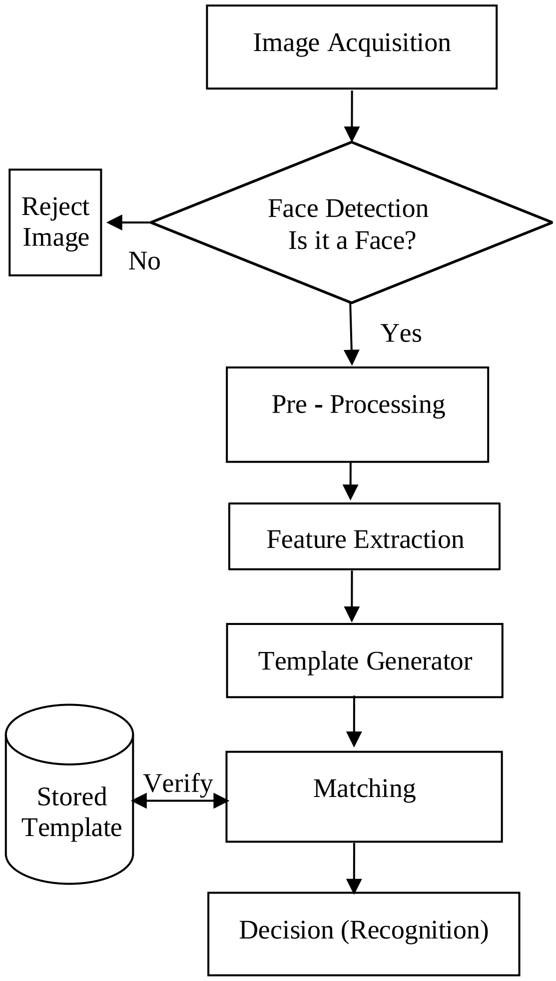

Figure. 1 Steps in facial detection and recognition

Consequently, there is more scope to investigate novel methods to advance the state-of-the-art in face recognition. In our work we are using Viola-Jones algorithm for face detection and PCA for face recognition; we are adding an additional step of intensity equalization to enhances the recognition rate.

3. Proposed system

The Facial recognition is generally carried out in the following steps and as depicted in Fig. 1.

1) Image acquisition: It is the first step of any biometric system. In this step the biometric image of the trait of interest is acquired or captured. It is a very critical and important step as processing of all the other step depends on this.

2) Preprocessing: In this step the acquired image in previous step is enhanced. The enhancement is attained by removing the unwanted noises present in the acquired image. It consists of set of operations on images at the lowest level of abstraction, the input image may be a true colour image but the

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output is always an intensity images. This step uses techniques like binarization, thresholding, resizing, normalization, localization, geometric transformations, image restoration, etc.

3) Feature extraction: It is a technique for identifying and extracting specific image features of interest for further processing. As a transition from an image representation to data representation occurs, it is a crucial stage in any image processing system (alphanumerical, usually quantitative).

4) Template generator: During enrollment phase – after the feature extraction, the information of biometric reference of an individual is persists in the system's database.

During authentication phase – after the feature extraction, the information of biometric reference of an individual is obtained, but not stored, the information is passed to the next step.

5) Matching: In this step, the stored template value i.e., the information stored in enrollment phase is matched with the reference value obtained in the previous step.

6) Decision: If, the stored template value, matches with reference value of the information obtained in template generator step, than the user is recognized as an authenticated user and allowed to access the system, otherwise the user cannot access the system.

At first the acquired image is applied with face detection algorithm to detect face in the acquired image, if face is detected, then the image is enhanced in the pre-processing step else the image is rejected, significant features are extracted than compared with the stored template, using the match score, it is determined whether the image belongs to an authenticated user (recognized) or not (unrecognized).

4. Methodology

The hybrid model algorithm is proposed and designed for the Authentication of the user, using face as biometric trait. It has two phases – first face detection with intensity equalization and second the face recognition.

4.1 Detection of face

The Viola-Jones algorithm is used for this purpose; the algorithm identifies the objects, in our case it is used to detect the face. It is pre-loaded with a number of pre-trained classifiers for detecting frontal faces. Viola-Jones algorithm [29] comprises of four stages to detect a face, they are - Haar-based features selection, integral image formation, adaptive boosting and cascading classifiers. We are supplementing the fifth stage of Intensity equalization to the regular Viola-Jones algorithm.

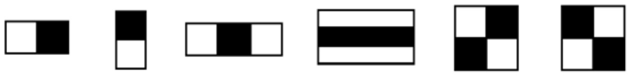


Figure. 2 Various Haar features: first two represent two-rectangle edges. The next two represent three-rectangle line features. The last pair represents four -rectangle features

4.1.1. Haar-based features selection

Haar based feature filters are used in this approach. The facial traits of all humans have certain similarities. These similarities can be matched using Haar features, for instance eyebrow region is darker than the forehead region, eye region is darker compared to the cheek region and the area around the nose bridge is whiter than the area around the eyes. Face features that can be matched are made up of a combination of traits based on location as well as on size, for example – eyebrows, eyes, nose bridge, mouth, etc. A Haar feature used by this algorithm is of three types - edge features, line-features and four-sided features.

Value of the features are obtained by the sum difference of pixels of low intensity (dark region) and sum difference of pixels of high intensity (light region) [29].

$$FV(h) = \sum_{LIP} - \sum_{HIP} \tag{1}$$

Where, $FV(h) = haar\ Feature\ Value$
$\Sigma_{LIP} = Sum\ of\ Low\ Intensity\ Pixels$
$\Sigma_{HIP} = Sum\ of\ High\ Intensity\ Pixels$

Let us consider we are applying the Haar rectangle feature for one of the regions and calculate the value of a feature. In this case we would sum up all the values that is covered by the feature, which is time-consuming to compute, hence we have the concept of integral image. By creating the integral image, the algorithm's efficiency can be greatly improved.

4.1.2. Integral image formation

In an integral image, each pixel reflects the total of the associated original pixel values. The pixels above and to the left of the pixel position (x, y) in the original picture $i(x', y')$, are added together to create $I(x, y)$, an integral image, given by [30, 31].

$$I(x, y) = \sum_{x' \leq x, y' \leq y} i(x', y') \tag{2}$$

	x^1_0	x^1_1	x^1_2	x^1_3
y^1_0	1	4	5	4
y^1_1	2	13	6	5
y^1_2	12	11	21	3
y^1_3	24	5	7	4

(a)

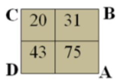
	x_0	x_1	x_2	x_3	x_4
y_0	0	0	0	0	0
y_1	0	1	5	10	14
y_2	0	3	**20**	31	40
y_3	0	15	43	**75**	91
y_4	0	39	72	111	127

(b)

Figure. 3 Construction of Integral image from original image: (a) Original image $i(x',y')$ and (b) Integral image $I(x,y)$

	x_0	x_1	x_2	x_3	x_4
y_0	0	0	0	0	0
y_1	0	1	5	10	14
y_2	0	3	20	31	40
y_3	0	15	43	75	91
y_4	0	39	72	111	127

(a)



(b)

	x^1_0	x^1_1	x^1_2	x^1_3
y^1_0	1	4	5	4
y^1_1	2	13	6	5
y^1_2	12	11	21	3
y^1_3	24	5	7	4

(c)

Figure. 4 Mapping of rectangular region of integral image to original image: (a) Rectangular feature (Integral image), (b) Rectangular (image), and (c) Mapping of feature (Original image)

In the original image, a pixel with coordinate (x,y) corresponds to a pixel with (x+1,y+1) in the integral image, as zero is padded to it. The pixel I(x,y) is formed from the four pixels. One pixel from the image i(x,y) the original image and the other three pixels that are currently calculated in the integral image [32].

$$I(x,y) = I(x,y-1) + I(x-1,y) + i(x'-1,y'-1) - \mathrm{I}(x-1,y-1) \quad (3)$$

For instance, $I(x_2,y_2)$ is formed from Eq. (3) as follows:

$$I(x_2,y_2) = I(x_2,y_{2-1}) + I(x_{2-1},y_2) + i(x^1_{2-1},y^1_{2-1}) - I(x_{2-1},y_{2-1})$$
$$= 5 + 3 + 13 - 1 = 20$$
$$I(x_2,y_2) = 20$$

Where, $I(x_2,y_{2-1}) = I(x_2,y_1) = 5$;
$I(x_{2-1},y_2) = I(x_1,y_2) = 3$;
$i(x^1_{2-1},y^1_{2-1}) = i(x^1_1,y^1_1) = 13$;
$I(x_{2-1},y_{2-1}) = I(x_1,y_1) = 1$
Similarly, $I(x_3,y_3) = 31 + 43 + 21 - 20 = 75$

A rectangular region is calculated using the integral image, for instance consider the following example where we have to find the rectangular feature

Let A,B,C,D be the integral image values at the four corners of a rectangle feature. Then, within the rectangle feature, the total of original image values can be calculated as [33]:

$$Sum = A - B + C - D \quad (4)$$

Where, $A = I(X_A,Y_A), B = I(X_B,Y_{B-1})$,
$C = I(X_{C-1},Y_{C-1})$ and $D = I(X_{D-1},Y_D)$

From the above example from Eq. (4),
When $A = 75, B = 10, C = 1$ and $D = 15$;
Then, $Sum = 75 - 10 + 1 - 15 = 51$

The sum value 51 obtained by processing integral image values is mapped to the region of original image that produces same sum, as shown in the Fig. 4, in original image the regions with value 13 + 6 + 11 + 21 gives 51, so this area is mapped.

4.1.3. Adaptive boosting (AdaBoost)

It selects the optimal subset of features from a large number of available features. This approach generates a classifier known as a strong classifier (also termed as ensemble). Strong classifier is nothing but the linear combination of weak classifiers (also termed as best features). It is because one weak classifier may not be as good, so we combine two or three weak classifiers to acquire a strong classifier. The AdaBoost algorithm's purpose is to extract the "m" weak classifiers from a set of "n" features.

Let $f_i(x)$ is various weak classifiers and a_i is the respective feature weights of the weak classifier $f_i(x)$, and then a strong classifier $S(x)$ is given by [34]

$$S(x) = a_1 f_1(x) + a_2 f_2(x) + \cdots + a_n f_n(x) \quad (5)$$

Weak classifiers are discovered by doing W iterations, where W is the desired number of weak classifiers, which is determined by the user. Each iteration, of the algorithm includes a calculation of the error rate for each feature. For that iteration, the algorithm selects the feature with the lowest error rate.

4.1.4. Cascading classifiers

It is a multi-stage classifier capable of speedy and precise identification. Begin by considering a sub-window of image, and then looking for the presence of most essential or best feature within that sub-window with the first classifier. Only upon the positive confirmation from the first classifier, the test for evaluation of second classifier is set and this continues till we reach n classifiers, in this sequence at any point of time any of the classifier gives

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negative confirmation then the sub-window will be rejected with immediate effect. In this approach the simple classifiers exclude non-face regions early in the process, which improves the speed of detection and it also reduces the number of false positives.

4.1.5. Intensity equalization

We are adding this stage to the Viola-Jones algorithm, where at first only the face detected in the bounding box is extracted. The extracted face image of dimension M x N is scaled to N x N dimension. Intensity equalization is applied to the newly formed image of dimension N x N. The contrast of the image is adjusted on the basis of histogram stretching. This technique results in image enhancement there by boost the recognition rate in the next Phase.

4.2 Recognition of face

The Face recognition is performed using principle component analysis (PCA) [35] in two stages:

Stage 1 – Training:
- Create a training set and load it.
- Normalize face vector:
  - Convert each of M images to vector $N^2 X$ 1.
  - Find the average face vector.
  - Find normalized face vector of each image.
- Calculate eigen vector:
  - Calculate covariance matrix C.
- Convert lower dimensionality K eigen vector to original face dimension.
- Represent each Face in the linear combination of the K eigen vectors.

Stage 2 – Testing:
- Input a query image.
- Create a face vector from the query image.
- Normalization of face vector.
- Find K eigen vector.
- Determine the input image's weight vector.
- Find the distance between each weight vector in the training set and the query image vector using the Mahalanobis distance formula. The image is identified if the distance exceeds the threshold, else it is not.

5. Implementation of hybrid face detection and recognition algorithm

Step 1: Pass the original image $f(x, y)$.

Figure. 5 Original image of $M\ X\ N$ dimension (640 X 480 pixels) for 5 Megapixel

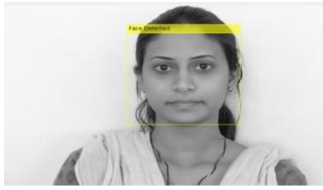

Figure. 6 Face detection - detected face enclosed within bounding box

Figure. 7 Face detection: Extraction of face

(a) (b)

Figure. 8 Scaling of image dimension of detected face: (a) $M\ X\ N\ Dimension$ and (b) $N\ X\ N\ Dimension$

Step 2: Transform original image $f(x, y)$ to gray scale $h(x, y)$.

Step 3: Detect the face in the transformed image $h(x, y)$ using Viola-Jones algorithm.

Step 4: If face is detected in $h(x, y)$

Extract only detected face $d(x, y)$ from $h(x, y)$

Else display message "Face not Detected"

Exit

Step 5: Let $f'(x, y)$be scaled image of dimension $N\ X\ N$ from $M\ X\ N$ (a pre-requisite of PCA)

Step 6: Apply intensity equalization to $f'(x, y)$

$$f'(x, y) = \sum_{i=1}^{n} f_1'(x, y), f_2'(x, y), \ldots, f_n'(x, y) = R \quad (6)$$

a) Image is decomposed into sub-regions such that

$$R = \sum_{i=1}^{n} R_1, R_2, R_3, \ldots \ldots \ldots, R_n \quad (7)$$

Where, $R_i = f_i'(x, y)$ a sub-region of $f'(x, y)$

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b) Evaluation of intensity equalization values. It can be evaluated for each region decomposed by above equation, as follows:

$$h_i = Ƕ(R_i) \quad (8)$$

Where, h is histogram equalization value,
Ƕ is the histogram function
R is the sub region of original image

c) Average histogram of entire image can be evaluated as follows

$$Avg(R_i) = \sum_{i=1}^{n} \frac{h_i}{n} \quad (9)$$

d) After equalizing the intensity of each sub-region R_i the image R is re-formed.

$$R = \bigcup_{i=1}^{n} R_1, R_2, R_3, \dots, R_n = f''(x,y) \quad (10)$$

Eventually, given M images of the dataset are transformed into intensity equalized grey image of dimension$N\ X\ N$, for training purpose.

Step 7: Face recognition using PCA

The Face recognition using PCA is performed in the two stages:

Stage 1 – Training:

a) Create a training set and load it - Given M images, each represented as $p(x,y)$. Let $f''(x,y)$ be the gray scale intensity equalized image generated from $f(x,y)$ of dimension $N\ X\ N$ [36].

$$p(x,y) = \sum_{i=1}^{n} f''(x,y) \quad (11)$$

b) Normalize face vector

(i) Convert each of M images to vector $N^2\ X\ 1$ [24], forming a face vector space Γ_i.

$$\Gamma = \frac{f''(x,y) - X_{min}}{X_{max} - X_{min}} \quad (12)$$

Where, X_{max} = max $(f'(x,y))$ and
X_{min} = min $(f''(x,y))$

(ii) Find the average face vector using [37]

$$\varphi = \frac{1}{m} \sum_{i=1}^{m} \Gamma_i \quad (13)$$

Where, m is total number of images

(iii) Find normalized face vector of each image [36]

$$\phi_i = \Gamma_i - \varphi \quad (14)$$

Figure. 9 Gray scale image versus enhanced gray scale image with Intensity equalization shown with their respective histograms (with same shape)

c) Calculate eigen vector - Calculate covariance matrix C [37]

$$C = A.A^T \quad (15)$$

The above equation results in ending up with huge number of Eigen vectors accounting with most of unwanted vectors. Our aim is to obtain, K – eigen vectors that should satisfy the condition $K \leq M$. Hence, the dimensionality reduction is applied to Eq. (15) as follows [37].

$$C = A^T.A \quad (16)$$

From Eq. (16), covariance matrix C returns M eigen vectors each of M X 1dimensionality, where $M << N^2$

d) Convert lower dimensionality K eigen vector to original face dimension - Now, convert lower dimensional K- eigen vector to original face dimensionality, as follows [37]

$$u_i = Av_i \quad (17)$$

e) Represent each face in the linear combination of the K eigen vectors

For each face from the training set, the K eigen face and the mean face may be combined and rendered as a-weighted sum [37].

$$\Omega_i = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ w_k \end{bmatrix} \quad (18)$$

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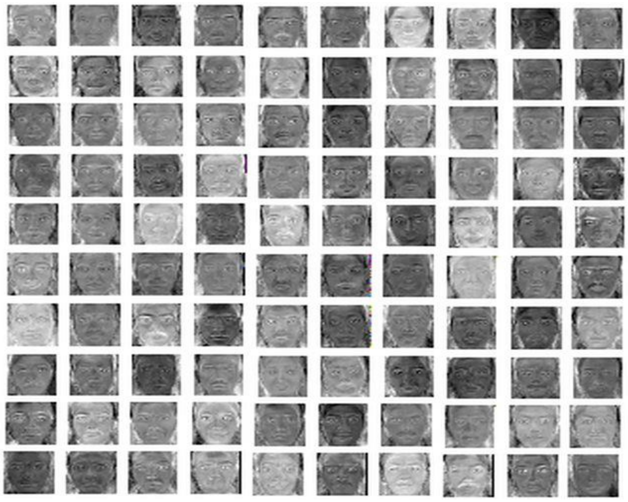

Figure. 10 Principal components (K = 100)

Where, $w_1, w_2, \dots \dots \dots, w_k$, is a proportion of Eigen face.

Now, find the weight of each image I as follows

$$\in = \sum_{i=1}^{k} [I.\phi] \quad (19)$$

Now find the average weight of the images (Fig. 10) as follows

$$w = \sum_{i=1}^{k} \frac{\in_i}{\max(\in).\phi} \quad (20)$$

Stage 2 – Testing:

Step 1: Input a query image
Step 2: Generate face vector from the input image.
Step 3: Normalizing the face vector.
Step 4: Find K eigen vector
Step 5: Find the weight vector of input image Eq. (18)
Step 6: Using Mahalanobis distance formula, find the distance between query image vector and each of the training set's weight vectors. Threshold of image is found using the following

$$\Delta i = \sum_{i=1}^{K} \omega[\Omega, w] \quad (21)$$

Where, ω - Mahalanobis distance.

Step 7 : If the distance is more than threshold then the image is recognized else not.

6. Results and analysis

The system is modeled using the standard dataset of face hosted by Visvesvaraya Technological University, for biometric research under VTU-BEC-DB multimodal biometrics database [38]. Using a digital camera, 100 respondents with ages ranging from 18 to 50 years old had their faces photographed. Of them, 64 were female and 36 were male. The resolution of images with face was set to 640 × 480 pixels for a 5 Megapixel image. The images were collected in a controlled environment by keeping the background white and by bringing up the differentiation in subjects pose and illumination. The images were captured with five variations in orientations, where subject looks front, left, right, up and down respectively as shown in Fig. 13, accounting for a total of 500. However, the subjects were free to express their facial expression.

The system was implemented on MATLAB R2016b running on Windows 7 64-bit Operating System platform, with the hardware specification of

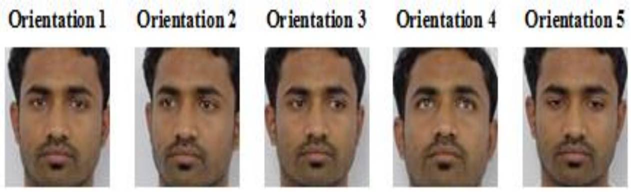

Figure. 11 Different orientation of one subject

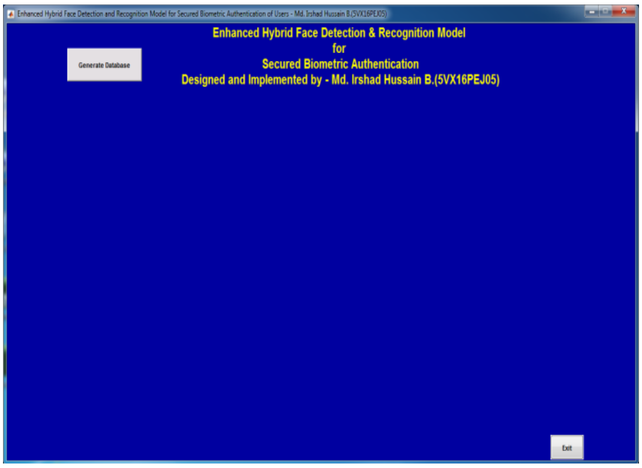

Figure. 12 Generate database

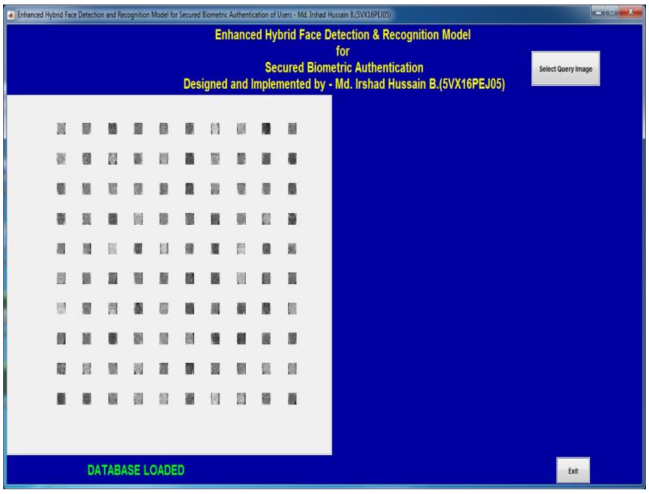

Figure. 13 Database with K principal components

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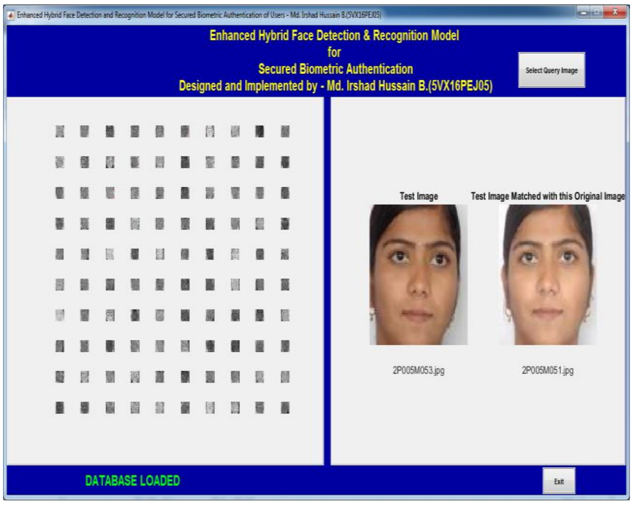

Figure. 14 Successful face recognition

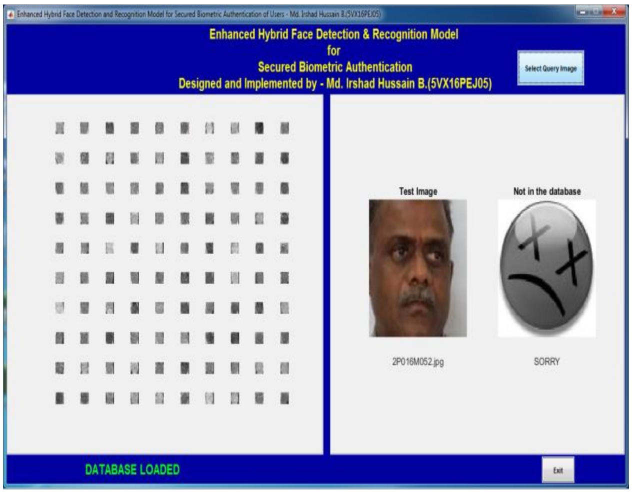

Figure. 15 Unsuccessful face recognition

Table 3. Face recognition based on orientation.

Orientation	**1 (Front)**	**2 (Left)**	**3 (Right)**	**4 (Up)**	**5 (Down)**
No. of Subjects/Trained Images – 100; Query Images - 100 Per Orientation (100 X 5= 500 images)					
Identified	100	94	98	99	100
Unidentified	00	06	02	01	00
Recognition rate	**100%**	**94%**	**98%**	**99%**	**100%**

Intel Core i5-2540M clocked at 2.60GHz with 4GB RAM.

On running the developed face recognition system application, in the first screen the clicking of “Generate Database” button will generate K principal components as shown in Fig. 12. It took on an average of 35.51 seconds to generate a database with K principal components (K=100), as shown in Fig. 13.

It took an average time of 1.2 seconds to identify an individual as authenticated user (Fig. 14) or not (Fig. 15).

Table. 4 Face recognition - sex of subject

Sex	Female	Male	All
Total Subjects	64	36	100
No. of Test images	320	180	500
Images Identified	318	173	491
Images Unidentified	02	07	09
Recognition rate	99.37	96.11	98.20

Table. 5 Face recognition with total images

Intensity Equalization	NO	YES
Total No. of Subjects	100	100
No. of Test images used	500	500
No. of Images Correctly Identified	468	491
No. of Images Not Identified	022	009
Recognition Rate (Percentage)	93.60%	98.20%

Table 3, represents the result of face recognition based on five different orientations – i.e., subjects looking front, left, right, up and down respectively, for orientation 1 and orientation 5 the recognition rate resulted in 100% accuracy, for orientation 2, 3 and 4 – the recognition rate resulted in 94%, 98% and 99% respectively.

The recognition rate (RR) is calculated by:

$$RR = \left(\Sigma_{IIC} \div \Sigma_{QI}\right) X\ 100\ \% \qquad (22)$$

Where, $\Sigma_{IIC} = Total\ Number\ of\ Images\ Identified\ Correctly$

$\Sigma_{QI} = Total\ Number\ of\ Query\ Images$

Table 4 represents the result of face recognition with respect to sex of subject. Out of 320 images of female subjects, 318 images were successfully identified resulting in a recognition rate of 99.37%. Out of 180 images of male subjects, 173 images were successfully identified with recognition rate of 96.11%.

Table 5, represents the recognition of 100 subjects with 500 images resulting in identification of 468 images with recognition rate of 93.60% without intensity equalization and identification of 491 images with a recognition rate of 98.20% with inclusion of intermediary step of intensity equalization (IE).

Table 6 compares our research to other cutting-edge techniques that have been reported in the literature. The earlier authors mentioned in the Table 6 have evaluated their proposed work by using various standard datasets and some also have

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Table. 6 Table. 6 Related Work Comparison - After Serial No. 9 instead of 10 we have Serial No. 13, if you can update the serial no. 13,14, 15 to 10,11,12 respectively

Sl. No	Authors	Face DB	No. of Subs	Method Adopted	RR in %
1	Rama et al., 2008. [17]	VISNET II	37	PCA	69.00
		AR	136		80.00
2	Jia et al., 2009. [18]	AR	100	SVM	90.80
3	Siswanto et al., 2014. [19]	P	NA*	PCA and LDA	90.00
4	Angadi et al., 2016. [20]	AR	120	SDM with SGFFDA	95.58
5	Elgarrai et al., 2016. [21]	AR	100	GFD with 1DHMM	94.35
6	Borkar et al., 2017. [22]	AT&T	40	PCA	91.00
				LDA	94.00
				PCA &LDA	97.00
7	Kagawade et al.,2019. [23]	AR	120	MDLGD	97.33
		LFW	80		97.25
8	Sharmila et al., 2019. [24]	P	NA*	PCA	70.00
				LDA	78.00
				LBPH	80.00
9	Angadi et al., 2019. [25]	AR	120	SDM with GSF and TF	95.97
		VTU BEC-DB	100		97.20
13	Ghrairi et al., 2022. [26]	EFI	35	PCA Algorithm	96.00
14	Asha et al., 2022. [27]	P	90	PCA	80.60
				AFSO	88.90
15	**Proposed Method**	**VTU BEC-DB**	**100**	**VJA with IE and PCA**	**98.20**

created their own proprietary dataset. These dataset are focused with varying background, illumination, orientations, size, occlusion, poses, etc. Different authors have proposed different methods for recognizing an individual on the basis of face trait such as PCA [17, 22, 24, 26, 27]; SVM [18]; Combination of PCA and LDA [19, 22]; Symbolic data modeling with Savitzky Golay filter features discriminant analysis (SDM with SGFFDA) [20]; gabor-fisher descriptors with 1D-hidden markov models (GFD with 1DHMM) [21]; LDA [22, 24]; Multi-directional local gradient descriptor (MDLGD) [23]; LBPH [24]; Symbolic data modeling with graph spectral features and texture features (SDM with GSF and TF) [25]; and artificial firefirefly swarm optimization algorithm (AFSO) [27].

For face detection [20, 23, 24, 26] have used Viola-Jones algorithm (VJA). Euclidean distance is used by [19, 22, 24, 25, 26] to obtain a feature vector of trained images and query images for recognition process where as in the present work we have used Mahalanobis distance, which is an effective distance metric on multivariate data. The outcome of various methods used for face recognition is shown in Table 6, the results discloses that the performance of the outcome is deeply impacted by the change in background, illumination, orientations, size and pose of the datasets used.

For comparison of our work with the previous authors we have concentrated on two things one the database should have at least 100 subjects embedded with constraints of at least pose and illumination; and/or have used PCA for Face recognition, as PCA efficiently removes correlated features and transform a high dimensional data to low dimensional data for easy visualization. In the present work, we have used the face images of 100 subjects of VTU-BEC-DB multimodal database with constraints of pose and illumination. We have used Viola-Jones algorithm for face detection and principal component analysis for face recognition, for this we have achieved a recognition rate of 93.60%. With the inclusion of intermediary step of intensity equalization, after face detection and before face recognition, we have achieved a recognition rate of 98.20%, which is comparably high compared to the state-of-art methods as depicted in Table 6 and the discussed literature.

7. Conclusion

In this paper, we have designed and developed a hybrid face biometric system that performs face detection and face recognition. We have used our own University - Visvesvaraya Technological University's face database VTU-BEC-DB multimodal biometrics database. The database consisted of 100 subjects with 5 different orientations – front, left, right, up and down. With respect to orientations, we have achieved a recognition rate of 100% for orientation 1 and 5; then for orientation 2, 3 and 4 the recognition rate was 94%, 98% and 99% respectively. With respect to sex of subject - female subject's recognition rate was 99.37% and male subject's recognition rate was 96.11%. The present face detection and recognition system, out of 500 images, has successfully recognized 491 images resulting in the recognition rate of 98.20% (with intensity equalization step and without it the recognition rate was 93.60%), which is comparably higher than the previous author's state-of-art methods. However as stated earlier the system's accuracy is susceptible to a small number of parameters, such as light intensity, capturing devices, pose variations, occlusion, etc.

With these experimental results we are of the opinion that our proposed work can be effectively used to enhance the security of the systems like online transaction system, secured automated teller machine transactions, E-commerce transactions, home security, automobile security and any other system that is critical to authenticate a user.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Md. Irshad Hussain B. was responsible for the paper's conceptualization, methodology, software, validation, formal analysis, inquiry, resources, data curation, writing-original draft preparation, writing-review and editing, and visualisation. The supervision and software administration have been done by Dr. Mohammed Rafi.

References

[1] M. I. B. Hussain and M. Rafi, "A Survey on Unimodal and Multimodal Biometric System for Enhancement of ATM Security", *International Journal of Research and Analytical Reviews*, Vol. 6, No. 1, pp. 1143-1148, 2019.

[2] D. T. Meva and C. K. Kumbharana, "Design and Evaluation of Multimodal Biometric System with Fingerprint and Face Recognition", *International Journal of Scientific and Research Publications*, Vol. 5, No. 4, pp. 1-4, 2015.

[3] S. Choudhary, "Design of Biometric Based Transaction System using Open Source Software Development Environment", *International Journal of Innovative Research in Computer and Communication Engineering*, Vol. 2, No. 2, pp. 37-42, 2014.

[4] Importance of Biometric Fingerprinting Technology: https://www.bayometric.com/importance-of-biometric-fingerprinting-technology/

[5] A. Anitha, O. Sumalatha, R. Hanisha, and C. Shashikala, "An Advanced ATM Crime Prevention System", *International Journal For Technological Research In Engineering*, Vol. 3, No. 9, pp. 2377-2380, 2016.

[6] M. Ahmadi and H. Soleimani, "Palmprint Image Registration using Convolutional Neural Networks and Hough transform", *ArXiv*, Vol. 2, pp. 1-8, 2019.

[7] Iris recognition Vs. Palm Vein Biometrics: http://www.m2sys.com/blog/scanning-and-efficien cy/iris-recognition-vs-palm-vein-biometrics-how-do-they-compare/

[8] J. B. Mazumdar and S. R. Nirmala, "Retina Based Biometric Authentication System: A Review", *International Journal of Advanced Research in Computer Science*, Vol. 9, No. 1, pp. 711-718, 2018.

[9] T. S. Lugovaya, "Biometric human identification based on electrocardiogram", [*Master's thesis*] *Faculty of Computing Technologies and Informatics, Electrotechnical University "LETI"*, Saint-Petersburg, Russian Federation, 2005.

[10] K. Mali and S. Bhattacharya, "Comparative Study of Different Biometric Features", *International Journal of Advanced Research in Computer and Communication Engineering*, Vol. 2, No. 7, pp. 2776-2784, 2013.

[11] J. E. Boyd and J. J. Little, "Biometric Gait Recognition", *Springer*, pp. 19–42, 2005.

[12] S. H. Khan, Z. Khan, and F. Shafait, "Can Signature Biometrics Address Both Identification and Verification Problems", In: *Proc. of International Conf. on Document Analysis and Recognition*, Washington DC, USA, pp. 981-985, 2013.

[13] How Biometrics Works: https://science. howstuffworks com/ biometrics.htm

[14] J. A. Markowitz, "Voice Biometrics", *Communications of the ACM*, Vol. 43, No. 9, pp. 66–73, 2000.

[15] F. Monrose and A. D. Rubin, "Keystroke Dynamics as a Biometric for Authentication", *Future Generation Computer Systems*, Vol.16, No.4, pp. 351–359, 2000.

[16] M. Kumar and Priyanka, "Fingerprint Recognition System: Issues and Challenges", *International Journal for Research in Applied Science and Engineering Technology*, Vol. 6,

No. 2, 2018.

[17] A. Rama, F. Tarres, L. Goldmann, and T. Sikora, "More Robust Face Recognition by Considering Occlusion Information", In: *Proc. of IEEE International Conf. on Automatic Face and Gesture Recognition*, Amsterdam, Netherlands, pp. 1- 6, 2008.

[18] H. Jia and A. M. Martinez, "Support Vector Machines in Face Recognition with Occlusions", In: *Proc. of IEEE Conf. on Computer Vision and Pattern Recognition*, Miami, USA, pp.136-141, 2009.

[19] A. R. S. Siswanto, A. S. Nugroho, and M. Galinium, "Implementation of Face Recognition Algorithm for Biometrics Based Time Attendance System", In: *Proc. of International Conf. on ICT for Smart Society*, Bandung, Indonesia, pp. 149-154, 2014.

[20] S. Angadi and V. Kagawade, "Face Recognition through Symbolic Modeling and Analysis of Segmented Face Images using Savitzky Golay Filter Features", *International Journal of Technology and Science*, Vol. 9, No. 1, pp. 50-55, 2016.

[21] Z. Elgarrai, O. Elmeslouhi, M. Kardouchi, H. Allali, and S. A. Selouani, "Offline Face Recognition System Based on GaborFisher Descriptors and Hidden Markov Models", *International Journal of Interactive Multimedia and Artificial Intelligence*, Vol. 4, No. 1, pp. 11-14, 2016.

[22] N. R. Borkar and S. Kuwelkar, "Real-Time Implementation of Face Recognition System", In: *Proc. of International Conf. on Computing Methodologies and Communication*, pp. 249-255, 2017.

[23] V. Kagawade and S. A. Angadi, "Multi-Directional Local Gradient Descriptor: A New Feature Descriptor for Face Recognition", *Image and Vision Computing*, pp. 39-50, 2019.

[24] Sharmila, R. Sharma, D. Kumar, V. Puranik, and K. Gautham, "Performance Analysis of Human Face Recognition Techniques", In: *Proc. of International Conf. on Internet of Things: Smart Innovation and Usages*, Ghaziabad, India, pp. 1-4, 2019.

[25] S. A. Angadi and S. M. Hatture, "Face Recognition through Symbolic Modelling of Face Graphs and Texture", *International Journal of Pattern Recognition and Artificial Intelligence*, Vol. 33, No. 12, pp. 1-25, 2019.

[26] A. H. T. A. Ghrairi, A. A. Mohammed, and E. Z. Sameen, "Face Detection and Recognition with 180 Degree Rotation Based on Principal Component Analysis Algorithm", *International Journal of Artificial Intelligence*, Vol. 11, No. 2, pp. 593-602, 2022.

[27] N. Asha, A. S. S. Fiaz, J. Jayashree, J. Vijayashree, and J. Indumathi, "Principal Component Analysis on Face Recognition using Artificial Firefirefly Swarm Optimization Algorithm", *Advances in Engineering Software*, Vol. 174, 2022.

[28] S. Lawrence, C. L. Giles, A. C. Tsoi, and A. D. Back, "Face Recognition: A Convolutional Neural Network Approach", *IEEE Transactions on Neural Networks*, pp. 1-24, 1997.

[29] P. Viola and M. Jones, "Rapid Object Detection Using a Boosted Cascade of Simple Features", In: *Proc. of IEEE Computer Society Conf. on Computer Vision and Pattern Recognition*, Kauai, USA, pp. 1-9, 2001.

[30] R. Bairagi, R. Ahmed, S. A. Tisha, M. S. Sarder, M. S. Islam, and M. A. Islam, "A Real-time Face Recognition Smart Attendance System with Haar Cascade Classifiers", In: *Proc. of International Conf. on Inventive Research in Computing Applications*, pp. 1417-1425, 2021.

[31] Understanding Face Detection with the Viola-Jones Object Detection Framework: https://towardsdatascience.com/understanding-face-detection-with-the-viola-jones-object-detection-framework-c55cc2a9da14

[32] R. Saveeth and S. U. Maheswari, "HCCD: Haar-Based Cascade Classifier for Crack Detection on a Propeller Blade", In: *Proc. of International Conf. on Sustainable Technologies for Computational Intelligence*, Singapore, Vol. 1045, 2020.

[33] P. S. Othman, R. B. Marqas, D. N. Abdulqader, and S. M. Almufti, "Effect of Mean Filter on Face Image from Video Frames", In: *Proc. of International Symposium on Digital Forensics and Security*, Beirut, Lebanon, pp. 1-7, 2020.

[34] S. Hazra, "Smart ATM Service, Devices for Integrated Circuit", In: *Proc. of Devices for Integrated Circuit*, Kalyani, India, pp. 226-230, 2019.

[35] M. A. Turk and A. P. Pentland, "Face Recognition Using Eigenfaces", In: *Proc. of Computer Society Conf. on Computer Vision and Pattern Recognition*, Maui, USA, pp. 586-591, 1991.

[36] A. Alkandari and S. J. Aljaber, "Principle Component Analysis Algorithm (PCA) for Image Recognition", In: *Proc. of International Conf. on Computing Technology and Information Management*, Johor, Malaysia, pp. 76-80, 2015.

Received: February 1, 2023. Revised: February 22, 2023.

[37] Y. V. Lata, C. K. B. Tungathurthi, H. R. M. Rao, A. Govardhan, and L. P. Reddy, “Facial Recognition using Eigenfaces by PCA”, *International Journal of Recent Trends in Engineering*, Vol. 1, No. 1, pp. 587– 590, 2009.
[38] S. A. Angadi and S. M. Hatture, “Multimodal Biometrics Database for Person Authentication: VTU-BEC-DB”, In: *Proc. of International Conf. on Intelligent Computing and Sustainable System*, Coimbatore, India, pp. 573-579, 2018.