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# Improving Accuracy in Face Recognition Proposal to Create a Hybrid Photo Indexing Algorithm, Consisting of Principal Component Analysis and a Triangular Algorithm (PCAaTA)

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Accurate face recognition is today vital, principally for reasons of security. Current methods employ algorithms that index (classify) important features of human faces. There are many current studies in this field but most current solutions have significant limitations. Principal Component Analysis (PCA) is one of the best facial recognition algorithms. However, there are some noises that could affect the accuracy of this algorithm. The PCA works well with the support of preprocessing steps such as illumination reduction, background removal and color conversion. Some current solutions have shown results when using a combination of PCA and preprocessing steps. This paper proposes a hybrid solution in face recognition using PCA as the main algorithm with the support of a triangular algorithm in face normalization in order to enhance indexing accuracy. To evaluate the accuracy of the proposed hybrid indexing algorithm, the PCAaTA is tested and the results are compared with current solutions.

*Keywords*: Face recognition; face detection; photo indexing; principal component analysis; triangular algorithm.

## 1. Introduction

With the rapid development of Information and Communication Technology (ICT), there has been a significant increase in the need for secure and convenient tools that can be used in real life to enhance accuracy in face recognition in areas of security, general human identification and education. At present, it is difficult to retrieve large numbers of images and videos from mobile devices and private computers. Therefore, there is a strong need to look for solutions from new and from among existing indexing algorithms.[24]

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One of the possible solutions is face recognition developed by Woodrow W. Bledsoe in the 1960s. The idea is to determine features, such as mouth, nose, eyes and ears on images before indexing, i.e. calculating ratios and distances to a common point that is used for comparison with reference data.[19]

The problem with Bledsoe's solution lay in measurement and location processes as these have to be performed manually. A significant number of studies have been carried to test if it is possible to automate those tasks by applying a variety of indexing algorithms namely, PCA, Linear Discriminant Analysis (LDA) and Elastic Bunch Graph Matching (EBGM).[7,24] Research showed that it was indeed possible to automate these processes. However, present solutions still have significant limitations.[24] Some features that can affect the accuracy are head rotation, light conditions, make up, background, emotions and others.[15,17] Although there is a new algorithm[19] that can detect multiple faces in a color image showing an accuracy of 93%,[17] this indicates that there is still a 7% margin for error.

This paper aims to use an enhanced face recognition algorithm to identify an individual in indexed photos and videos with the aim of bringing accuracy in detection closer to 100%. The proposed technique uses two triangles that are based on increasing the efficiency with which important features are detected in human faces. This technique can be managed in more cases than were considered possible in previous solutions and result in higher accuracy.

This paper is organized as follows: Sections 1 and 2 present the introduction and literature review, respectively. Section 3 presents the impact factors in this work, followed by proposed face recognition algorithm in Sec. 4. The results and discussion in proposed algorithms are detailed in Sec. 5. The conclusion can be found in Sec. 6 with possible future work Modelling Facial Shape and Appearance.

## 2. Review of Excising Literature

The first step in face recognition involves reducing noise affecting the human face image. Two main types of noise are "illumination" and "background", and sometimes "expression".

The negative effects of illumination on face detection are clear. Illumination leads to the creation of shadows, changes in highlights, shifts in location and reversal of contrast gradients.[8,21] Therefore, reducing illumination effects is very important to enhancement of the accuracy rate.[1] Thus, color can be considered as noise and RGB (Red–Green–Blue) images should be converted into YCbCr (grayscale). In order to reduce illumination, the image integral normalized gradient image algorithm (INGI)[10] can be considered as being illumination-insensitive. The current algorithm includes two steps. The first step is to employ gradient operation and normalize the gradient map. The second step involves reconstructing the image by employing features which are obtained from the training features of the database.

Face detection and recognition can be affected in terms of accuracy and is time-consuming due to the large scale of the background. For instance, an image where

90% consist of the human face and only 10% make up background is easier to analyze, compared to an image that has 90% background and a face that takes up only 10%. Color-based segmentation uses the color of the input image to differentiate the skin color region against areas not containing skin color.[2,23] The RGB input images are converted to HSV or YCbCr color space extraction, and the background is automatically subtracted; hence, the existence of the human face in the image is detected without background.

### 2.1. *Face detection*

Face detection is aimed at detecting and extracting facial features from a given image.[14] One of the most popular algorithms, which has been used for a long time, is the Viola and Jones algorithm.[26] This algorithm is used to classify whether an image contains a human face and if so, where it is located. However, this algorithm can only be applied to frontal images of faces and is highly sensitive to light conditions. Viola and Jones algorithm steps include face detection and the reduction of noise, extracting facial features and eliminating irrelevant features, for the purpose of face recognition, using PCA.[22] Figure 1 presents those steps.

Another existing algorithm is the Don-ju face detection algorithm which can detect facial features in unconstrained environments.[4] This algorithm can even be used in the detection of faces wearing glasses. This algorithm is known as a hybrid algorithm. It uses AdaBoost to detect the face region but uses Local Binary Pattern (LBP) to label the pixels of the image. The Local Directional Pattern (LDP) then uses information from intensity changes around pixels. The final element in this hybrid is PCA which is also used to extract the features of the human face. This algorithm, similar to the Viola–Jones algorithm, can only be used for frontal images of faces.

The steps carried out for the Don-ju algorithm include object detection, including face and eye regions from input images by applying AdaBoost algorithm based on Haar-like features, rotation of the image to measure the center between the eyes, the use of boundary information to crop the face and remove the background, and detection of the human face by using PCA. Figure 2 shows those steps related to this algorithm.

Another face detection method is the triangular approach.[6] This model first uses color segmentation to detect skin area, then regulation of eyes and mouth color to

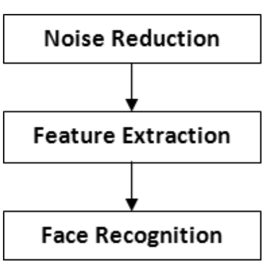



Fig. 1. Viola–Jones algorithm.

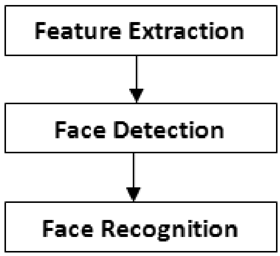



Fig. 2. Don-ju algorithm.



detect those features. When eyes and mouth create a triangle, it can be judged to be a human face.

In general, however, current face detection algorithms are hybrids with the purpose of improving accuracy and avoiding noise.

Most current face detection methods show good results. However, most of them have limitation. Taking the head pose and rotation into account, it is true that most human face images are not balanced and frontal, thus changing the human shape. To solve this problem, there are algorithm such as LBP, LDP and Viola–Jones. However, these algorithms have not considered the normalization process of the human face. This can be achieved through the use of triangular algorithm with good results.

Most current algorithms are hybrids requiring three general steps that are preprocessing, face detection and face recognition. These solutions can solve most problems that cause failure in the face detection process. However, there are some limitations, since errors can occur when images with large background are used. There is also the possibility of complete failure of the process when the image has too much complexity. Moreover, these algorithms do not focus on the normalization of input images which is considered advantageous when aiming to improve accuracy and reduce runtime.

### 2.2. *Face recognition*

As far as face recognition is concerned, considerable numbers of algorithms are used such as Independent Component Analysis (ICA), LDA PCA, and EBGM.[24] Research has compared these algorithms in terms of time-consumption, accuracy, and performance and has provided an evaluation of the usefulness of each. However, three important variables lead to different outcomes, namely experiment environments, experiment algorithms and face databases such as FERET, AT&T and Yale.[24] Moreover, every algorithm has advantages and disadvantages.

Other studies have also shown that it is possible to implement the advantages of those algorithms in combination with other algorithms. A hybrid algorithm that is based on Viola–Jones and PCA algorithms has been proposed in order to reduce the lighting sensitivity of PCA.[20] By using Viola–Jones algorithms, the accuracy rate increases to almost 99%. Furthermore, many other hybrid algorithms achieve good results such as F2DPCA, Fuzzy K-nearest neighbor and PCA in 2D images, and Manifold Configuration Algorithm (MCM)[9,27] with 98% and 89% respectively.

Face recognition algorithms can be classified into two groups, appearance-based algorithms and feature-based algorithms.[12,13] The first group is preferable because it results in high accuracy. There are a number of appearance-based algorithms such as ICA, LDA, PCA, EBGM, and Support Vector Machine (SVM).[24] However, this group is highly sensitive to noise and rotation of the target face. Therefore, preprocessing steps need be carried out to reduce noise and enhance effectiveness.

The second group, feature-based algorithms, uses geometric facial features such as, eyes, nose, mouth angle, cheek, and the relationship between them. This group of algorithms can cope with a change in the pose of the face and changes in light conditions by analyzing the relationship between facial feature data during the classification process. This algorithm is usually applied in video rather than image processing. However, this algorithm has drawbacks such as difficulties in allocating facial features automatically and time-consumption is high.

The reason for the high accuracy achieved by these hybrids is that they can transfer high-dimensional faces into low-dimensional equivalents. The core algorithm, PCA, is selected for the following reasons[3,11]:

- Compared to LDA, PCA algorithms can use multiple face images in the training phase, while LDA can only accept one single sample image. Therefore, the accuracy of PCA is higher.
- Compared to ICA, PCA requires less memory, while the others one require high storage capacity. In addition, the PCA process requires less time than that of the ICA.

Therefore, as far as the PCA is concerned, there are some features that reduce its accuracy, namely color, illumination and background. To overcome these problems, the preprocessing phase is required to reduce those kinds of noise.[5,16]

In addition robust human facial expression recognition (FER) system has been proposed by Siddiqi, capable of recognizing the face with high accuracy.[18] It uses an unsupervised algorithm based on the active contour framework for automatic face detection and extraction. Wento developed a system which can be used for both face detection and facial expression recognition. The system relies on an unsupervised feature selection scheme to enhance modeling performance and generalization capabilities. The expectation propagation (EP) inference approach has been used to identify the features.[25]

## 3. Impact Factors

There are many existing algorithms that have been used in image processing in face recognition. The question here is to find out what the factors that impact on the algorithms and which ones can be used to determine which algorithm is better than another. This paper only considers accuracy when evaluating algorithms. There are other factors such as image quality and cost, but among the current existing solutions, those factors do not play important roles. Therefore, they here will not be considered.

From the analysis of existing solutions, it is clear that high accuracy is due to the fact that an algorithm can transfer high-dimensional faces into low-dimensional equivalents. This is therefore a desirable feature for the proposed algorithm. The core algorithm, PCA, can be used to cause the following effects:

- It can use multiple face images in the training phase and it also requires less memory compared to LDA and PCA algorithms. Most other algorithms, such as LDA, can only accept one single sample image and they also require higher storage capacity. Therefore, the accuracy of the PCA is higher and requires less time than the ICA and others.

## 4. Proposed Face Recognition Algorithm

To overcome the accuracy problem that exists in current algorithms, a Hybrid PCA and Triangular Algorithm (PCAaTA) is proposed. The PCA has been used as main step in many current approaches for reasons outlined above. All these features make

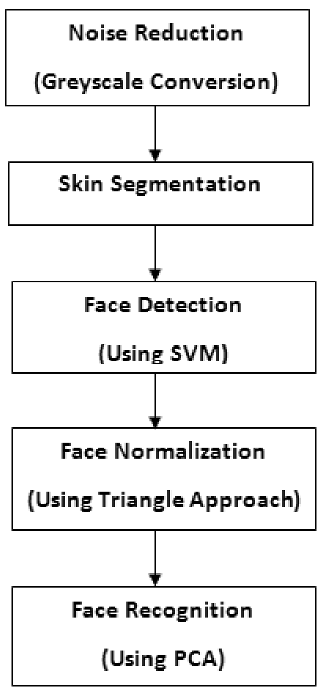



Fig. 3. PCAaTA face recognition algorithm steps.

the PCA suitable as a core component in the proposed algorithm. In addition, a normalization process of the human face based on triangle theory is used. The normalized images will affect some parameters used in the PCA algorithm. Furthermore, the noise reduction process must be carried out before the normalization for the best results. Figure 3 shows the flowchart for the proposed PCAaTA algorithm.



### 4.1. *PCAaTA algorithm*

The proposed PCAaTA algorithm is presented as follows:

**Algorithm 1.** Proposed PCAaTA

INPUT: Test image samples $(I) = \{I_1, I_2, \dots, I_i\}$
OUTPUT: Matching images $(I') = \{I'_1, I'_2, \dots, I'_i\} \in (I)$

BEGIN
Step 0: $I = 0; I' = 0$
Step 1: USE the Initial test image samples $(I)$ as input to PCAaTA
    Function PCAaTA$(I_i)$
Step 2: INPUT Test image samples $I$ with $N$ number of images
        $I = \{I_1, I_2, \dots, I_N\}$
Step 3: START nested loop
    FOR each Image $I_i$ belongs to $I$ DO
        $I_g$ = grayscaleImage$(I_i)$
        $I_g$ = skinSegmentation$(I_i)$
        $I_g$ = faceDetection$(I_i)$
IF the face $I_i$ is NOT balanced DO
    $I_i$ = faceRotation$(I_i)$
IF the face $I_i$ is NOT frontal DO
    $I_i$ = faceAdjustion$(I_i)$
    END FOR
Step 4: SELECT projected tested images $(T) = \{T_1, T_2, \dots, T_i\} \in (I)$
    $(I')$ = Function PCA$(T, I)$
    RETURN collection of matching images $(I')$
END

### 4.2. *Image color conversion for noise reduction*

Changing color is the first step in the proposed algorithm. It is used to eliminate the shape of shadows, and changes in highlights from contrast gradients.[1] In face detection algorithms, color information is not required; therefore it is considered as "noise" and has to be removed. As presented in Fig. 4, the image is converted form RGB into YCbCr grayscale by using the following steps.

**Algorithm 2.** Image color conversion for noise reduction

INPUT: Colored image ($I$) in $N * N'$ size
OUTPUT: Grayscale image ($I$) in $N * N'$ size

Begin
Step 0: $i = 0$
Step 1: FOR each pixel $i$ in ($I$) do
$\quad i \leftarrow (0.2126 \times \text{Red}^{2.2} + 0.7152 \times \text{Green}^{2.2} + 0.0722 \times \text{Blue}^{2.2})^{1/2.2}$
End

Fig. 4. Image color conversion.

### 4.3. *Skin color-based segmentation*

Skin segmentation is the second step of the PCAaTA. It is one of the best ways to identify skin and non-skin areas based on color components.[2] Skin color can be

**Algorithm 3.** Skin color-based segmentation[2]

INPUT: Colored image($I$) in $N * N'$ size
OUTPUT: Greyscale image ($I$) in $N * N'$ size

BEGIN
Step 0: $i = 0$
Step 1: For each pixel $i$ in ($I$) DO
$\quad \text{Y} \leftarrow 0.299\text{Red} + 0.587\text{Green} + 0.114\text{Blue}$
$\quad \text{Cb} \leftarrow -0.169\text{Red} - 0.331\text{Green} + 0.500\text{Blue} + 128$
$\quad \text{Cr} \leftarrow 0.500\text{Red} - 0.419\text{Green} - 0.082\text{Blue} + 128$
$\quad$ IF $90 < \text{Y} < 180$, $90 < \text{Cr} < 130$, $80 < \text{Cb} < 150$ THEN
$\qquad i$ is skin color
$\quad$ ELSE THEN
$\qquad i$ is not skin color
$\quad$ END IF
$\quad$ END FOR
$\quad$ Create a new image with removed background
END

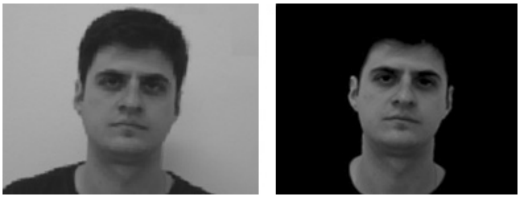


Fig. 5. Skin color-based segmentation.

identified by calculating the color components Y, Cb and Cr as the following formulas:

$$\begin{aligned} \mathrm{Y} &= 0.299\mathrm{Red} + 0.587\mathrm{Green} + 0.114\mathrm{Blue}, \\ \mathrm{Cb} &= -0.169\mathrm{Red} - 0.331\mathrm{Green} + 0.500\mathrm{Blue} + 128, \\ \mathrm{Cr} &= 0.500\mathrm{Red} - 0.419\mathrm{Green} - 0.082\mathrm{Blue} + 128. \end{aligned}$$

If the color components satisfy the condition $90 < \mathrm{Y} < 180$, $90 < \mathrm{Cr} < 130$, $80 < \mathrm{Cb} < 150$, then the pixel areas can be known as skin area (see Fig. 5). The skin color-based segmentation algorithm is presented as follows and the results of its implementation are shown in Fig. 5.

### 4.4. *Facial feature detection using a support vector machine*

The third step for this proposed work is detecting the face by using a support vector machine (SVM). The SVM is based on the use of a rectangle to scan the area containing the human facial features. With a conventional SVM, the rectangle has to scan the whole image. However, with the support of the skin segmentation algorithm, SVM does not need to scan the entire image, but the skin area only, reducing runtime. The Facial Feature Detection algorithm is presented as follows and the results of its implementation are shown in Fig. 6.

### 4.5. *Face normalization using a triangle approach*

Face normalization is the fourth step in the proposed algorithm. The purpose of using the triangle approach on human face images is to normalize the face into a standard position (frontal and balanced) as presented in Fig. 7. The normalized human face creates an isosceles triangle ABC as presented in Fig. 8.

Fig. 6. Facial feature detection.

**Algorithm 4.** Facial feature detection using SVM

INPUT: non-background greyscale image ($I$) size $N * N'$

OUTPUT: A$(x_a, y_a)$, B$(x_b, y_b)$: location of two eyes

C$(x_c, y_c)$: location of mouth

E$(x_e, y_e)$: location of nose

D$(x_d, y_d)$: midway of two eyes

BEGIN

Step 0: $A = B = C = D = 0$

Step 1: Construct eye map

$$\text{EMC} = \frac{1}{3}\left\{(\text{Cb})^2 + (255 - \text{Cb})^2 + \left(\frac{\text{Cb}}{\text{Cr}}\right)\right\}$$

$$\text{EML} = \frac{[Y(x,y) \oplus g(x,y)]}{[Y((x,y))g(x,y) + 1]}$$

$$\text{Eye Map} = (\text{EMC}) \text{ AND } (\text{EML})$$

Step 2: Construct mouth map

$$\text{Mouth Map} = \text{Cr}^2 \cdot (\text{Cr}^2 - \gamma \cdot (\text{Cr}/\text{Cb}))^2$$

Step 3: Construct nose map

$$\text{Nose Map} = 0.95 \times \frac{(1/N)\sum \text{Cr}^2}{(1N)\sum(\text{Cr}/\text{Cb})}$$

END

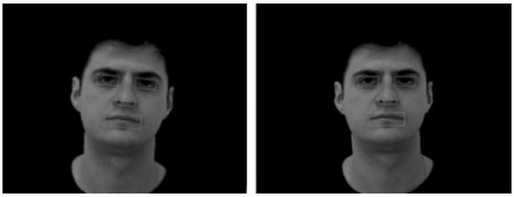


Fig. 7. Balanced face after normalization.

There are two cases when the face should be normalized:

- The face is rotated as shown in Fig. 9.
- The face is angled as shown in Fig. 10. This means that the human face is not frontal and the three point triangle C, E, D is not straight. Then, the distance from E to CD is calculated. To straighten the human face, the pixel needs to be moved to the left or right until the points C, E, D are straight.

The Euclid can be used to calculate angles and corners in the triangle.[5]

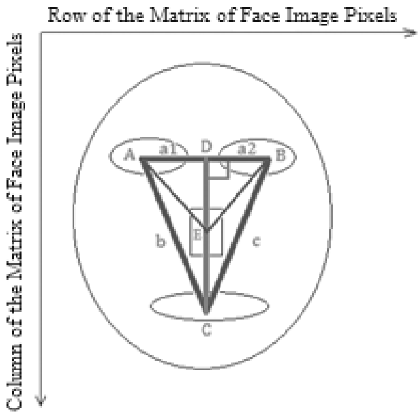



Fig. 8. Normalized face.


Fig. 9. Rotated face.

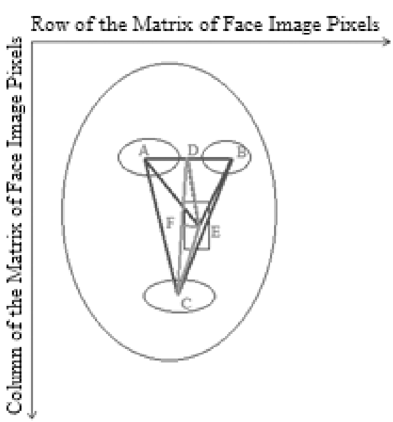



Fig. 10. Angled face.

**Algorithm 5** Face normalization using triangle approach

INPUT: $M$ unnormalized images $(I)$ in $N * N'$ size;
A$(x_a, y_a)$, B$(x_b, y_b)$: location of two eyes
C$(x_c, y_c)$: location of mouth
E$(x_e, y_e)$: location of nose
D$(x_d, y_d)$: midway between two eyes
OUTPUT: $M$ normalized images
BEGIN
Step 0: $M = 0$
Step 1: Construct linear equation
a1$\leftarrow y_{b-} y_a$
b1$\leftarrow -(x_{b-} x_a)$
c1$\leftarrow - y_b x_a + x_a x_b + x_b y_a + x_a y_a$
D $\leftarrow a_1 b_2 = a_2 b_1$
Step 2: Check whether the face is balanced or not
IF $a_1 b_2 = a_2 b_1$ AND $b_1 c_2 = b_2 c_1$ AND $D \neq 0$ THEN
AB parallel with 0x
ELSE: //If not balanced, rotate it
Cos $\alpha$□ BB′/A′B
END IF
Sin $\alpha \leftarrow$ A′B′/A′B
Step 3: FOR pixel $i(x, y) \in N * N'$DO
$x \leftarrow x * \text{Cos } \alpha - y * \text{Sin } \alpha$
$y \leftarrow x * \text{Sin } \alpha + y * \text{Cos } \alpha$
Check whether the face is frontal or not
Find the distance from E $(x_e, y_e)$ to CD by $a_2 x + b_2 y + c_2$
$a_2 \leftarrow y_d - y_c$
$b_2 \leftarrow -(x_d - x_c)$
$c_2 \leftarrow -y_d x_c + x_c x_d + x_d y_c + x_c y_d$
$d \leftarrow |a_2 x_e + b_2 y_e + c_2| / \text{abs}(a_2 a_2 + b_2 b_2)$
abs is function to calculate absolute value
IF $d \neq 0$ THEN
While $d \neq 0$ DO
FOR loop go through every pixels $P(x, y)$ in $(I)$
DO
IF $(x < x_d)$ THEN
$x \leftarrow x - 1$
ELSE IF $(x > x_d)$ THEN
$x \leftarrow x + 1$
END IF
IF $x_e > x_c$ AND $x_e > x_d$ THEN
$x_e \leftarrow x_e - 1$
END IF
ELSE IF $x_e < x_c$ AND $x_e < x_d$ THEN
$x_e \leftarrow x_e + 1$ END IF
END IF
END FOR
END WHILE
END

The triangular approach was proposed in face detection by Lin and Fan in 2000.[16] In this work, we have used the idea of double triangles in the face normalization process. After recognizing the location of both eyes, the nose tip and the center of the mouth, the image is scanned from top-left, point 0, by pixels. The $x$-axis; the horizontal axis, is the first row of the matrix of the face image pixels. The y-axis; the vertical axis, is the first column of the face image pixels.

### 4.6. *Face recognition using the PCA*

The PCA algorithm is used in face recognition as a last step in the proposed algorithm.[1] This is the core algorithm for face recognition. During the training phase for this algorithm, one or more images are needed, followed by the creation of vectors based on those images. The reason for the use of the PCA algorithm is it can

**Algorithm 6** Face recognition using PCA

INPUT: normalized images
OUTPUT: detected images
BEGIN
Step 0: Compute gradients of images. This has done by getting the images and train them to return an array of gradient vectors
Step 1: Decompose the image gradients (PCA)
Step 2: Compute the mean gradient vector of the set of image gradients
Step 3: Subtract the mean gradient vector from each gradient vector
Step 4: Perform Singular Value Decomposition (SVD) on the transformed gradient array that identify the desired number of principal components as an input to the SVD function
Step 5: Provide test images to find if there is match among them
Step 6: Project test Image Gradients onto the PCA basis and compute its coefficients
Step 7: Subtract the mean gradient vector from each gradient vector
Step 8: Find the coefficients for each test image by multiplying the test image gradient vector by transposing the U matrix that found in the PCA decomposition of the training images gradients
Step 9: Find the training image with the most similar coefficients. Define the coefficients of the training image by multiplying the S matrix times the V matrix found in performing singular value decomposition on the training images
Step 10: Compute the distance between the test image coefficients and each training image. Retain the training image associated with the minimum delta for each test image and mark it as match
Step 11: Show the output image and the corresponding test image

calculate the average mean value from the training images, test the images, and then compare those values with each other. If the comparison results are the same, the face will be detected.

The next step is to calculate the average value of the vector image using the following formula:

$$\Psi$$

- With $\Psi$ being the average vector image (size $N * N'$) of collection Ti.
- Ti is the vector image.
- $\Psi$ is known as the mean value of the training image vector.

The use of the triangle can normalize the image of the human face. Therefore, when the mean value is calculated, it will be more accurate and give better results. The proposed PCAaTA algorithm can optimize the PCA by reducing the sensitivity to illumination and background. Therefore, the algorithm can be applied in other conditions with high accuracy.

The proposed algorithm can optimize existing capabilities of the PCA to reduce the sensitivity to illumination and background. Therefore, it can be applied in other conditions with high accuracy.

## 5. Result and Discussion of the Proposed Algorithm

The FEI face database is used in doing experiments. The FEI is a Brazilian face database that contains a set of face images taken between June 2005 and March 2006 at the Artificial Intelligence Laboratory of FEI in São Bernardo do Campo, São Paulo, Brazil. There are four images for each of 200 individuals, a total of 800 images. All images are in multiple colors and the original size of each image is $640 \times 480$ pixels. All faces represent students and staff at FEI, between 19 and 40 years old with distinct appearance, hairstyle and make up.

Figures 11–13 below are three covariance matrices created by three different algorithms. These results compare the previous two solutions selected for comparison with the proposal. Those figures show covariance matrices extracted from a raw data matrix. The dimensionality of PCAaTA is smaller compared to the others, but still clear enough, because noises have been removed and the face has been normalized. Therefore, there is improved accuracy, in addition to reduced runtime.

The result obtained from the PCAaTA is better than the results from the two currently existing algorithms. Based on 10 experiments with examples from the given dataset, the average accuracy rate was 76.66%, 73.77% and 93.33% for Jones–Viola, Don–ju and the PCAaTA, respectively. Figure 14 shows two examples of the accuracy in detected faces using those three algorithms.

In order to enhance the accuracy, the quality of the images should be taken into account. Another issue is that the new algorithm uses steps to reduce noise as well as normalize the human face. Thus, it is time-consuming. This can be reduced by

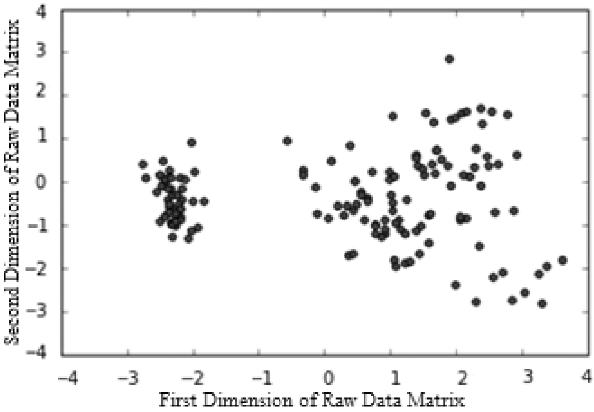



Fig. 11. Jones–Viola based on the covariance matrix of raw data.

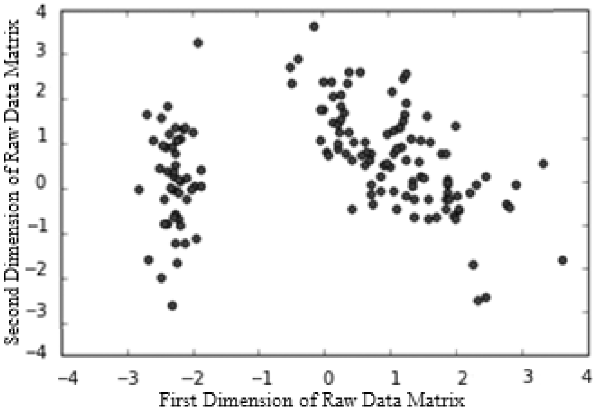



Fig. 12. Don-ju based on the covariance matrix of raw data.

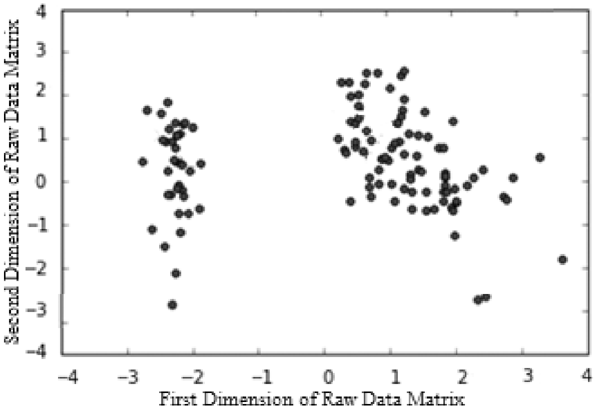
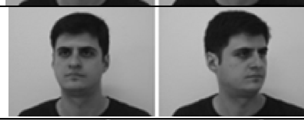
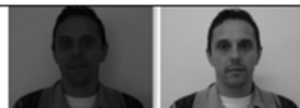
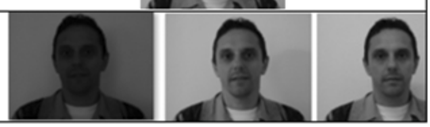


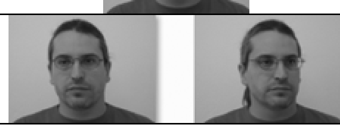

Fig. 13. PCAaTA based on the covariance matrix of raw data.

| **Sample 1** | **Face Recognition Algorithms** | **Accuracy** | **Detected Faces** |
|---|---|---|---|
|  | Viola-Jones | 66.66% |  |
| | Don-Ju | 66.66% |  |
| | Proposed PCAaTA | 100% |  |

(a)

| **Sample 2** | **Face Recognition Algorithms** | **Accuracy** | **Detected Faces** |
|---|---|---|---|
|  | Viola-Jones | 66.66% |  |
| | Don-Ju | 33.33% |  |
| | Proposed PCAaTA | 100% |  |

(b)

| **Sample 3** | **Face Recognition Algorithms** | **Accuracy** | **Detected Faces** |
|---|---|---|---|
|  | Viola-Jones | 66.66% |  |
| | Don-Ju | 33.33% |  |
| | Proposed PCAaTA | 66.66% |  |

(c)

Fig. 14. Samples at various stages for three algorithms.

creating some constraints for input data images. Specifically, the selected images should meet the standard of light; and the background should be white. Furthermore, when the selected images are already normalized, this step can be skipped. By using those constraints, time required can be cut down significantly.

Although PCAaTA can solve some problems identified in previous algorithms, namely illumination, background and face detection, it still depends on the facial features namely eyes, mouth and nose. When a certain feature cannot be detected, the triangles cannot be created. In other words, the normalization step will fail. Based on the resent experiment, the head pose should be within −45 to +45 degrees to ensure that all required facial features exist to apply the triangle. Appendix A shows the comparison between all three algorithms.

## 6. Conclusion

A variety of different algorithms have been used in order to improve the accuracy. This can be achieved in different ways, with the proposed PCAaTA algorithm focusing on how to turn a random face into one that is standardized, balanced and straight. The new algorithm is also known as a hybrid as it uses an illumination reduction algorithm, as well as background removal and feature detection. Moreover, to improve the accuracy, the triangular approach is applied to normalize the human face. Therefore, it impacts the mean value vector in the training and testing phases of the PCA, the core algorithm. The result shows that the proposed algorithm has higher accuracy compared to currently existing algorithms. This means that, although the proposed algorithm has limitations, it can solve the problem found in current solutions. In the future, the accuracy can be enhanced by creating input image constraints. For instance, the algorithm can skip the normalization step, if the input images are already normalized. Thus, accuracy can be enhanced while reducing the time required for processing. This algorithm shows a result that may be acceptable in some fields such as security, human identification and education.

Singular Value Decomposition (SVD) will be an element of future works for image de-noising, space reduction, stability, scaling property and rotation invariant which represent algebric and geometric invariant features of an image.

## Appendix A

| Face Recognition Algorithms in Photo Indexing | Samiksha, A., Pallavi, K. (2015) | Don-ju, K., Sang-Heon, L., Myoung-Kyu, S., Buyngmin, K., Huy-duk, K. (2013) | PCA and Triangular Algorithm (PCAaTA) |
|---|---|---|---|
| Work Goal | Detecting face in images | Detecting faces in images | Reduce noise in human face images |
| Features | • Preprocessing<br>• Extract the shape of the eyes, nose, mouth and chin<br>• Direction, background, and lighting condition<br>• Noise from the image is removed Edge Size<br>• Reduction: Image edges are detected and marked<br>• PCA | • Measurement of eye distance<br>• Does not require color change<br>• PCA | • Does not require color change<br>• Illumination<br>• Eye, mouth<br>• PCA |
| Advantages | • Illumination is removed<br>• Saving time — because the training phase is short. | • Simple algorithm but gives good results especially when the image contains a direct face.<br>• Works well even the human face has accessory such eyes glasses | • Illumination is removed<br>• Background is removed<br>• Faces are normalized |
| Limitations | Some images with complex backgrounds have drawbacks in terms of detection rate, accuracy or timing | This algorithm should be used for a direct image; an image taken from a different angle may cause faulty results | Can only be used for faces taken at small angles. That means that if faces are shown with accessories, it may cause failure |
| Accuracy | 76.66% | 73.77% | 93.33% |

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