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A Human Face Recognition Software Development Applying PCA

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Abstract. A wide range of studies were researched to explore numerous image processing technologies. A human face recognition (HFR) system is without exception, and is an ever changing and evolving domain which had improved relentlessly. It is widely known that a HFR is increasingly being deployed in a wide range of real world applications. However, the application of HFR system is not commonly used as opposed to other biometric identifications such as fingerprint or smart card verifications. A HFR system is developed based on the Principal Component Analysis (PCA) algorithm. It is intended to be used for a library verification systems developed on a stand-alone computer. It was been designed to retrieve data of the recognized students resided in the training database. To test the system performance, the experiment is conducted on 50 different students' images. Finally, it concludes that although PCA approach is one of the legacy and well established feature extraction method, it can still deliver and produce high accuracy results.

Keywords: Face recognition, Eigenfaces, Principal Component Analysis, Biometric identification

INTRODUCTION

Human face recognition (HFR) system has been researched extensively for over two decades [7]. A HFR is defined as a biometric identification of a human's face and matched it against a library of faces [20]. Thus, it is a part of a biometric system which is based upon the verification of input data [12;13]. In the past, we have to bring our driving license for identification. Fortunately, this system does not require an individual to bring any individual identification in order to establish his or her identity. It uses images of a person's face for recognition and identification. This technology has emerged in the middle of the twentieth century and was first introduced commercially in the early 90s.

In this paper, a HFR is basically a task of identifying an already detected face of student as a known or unknown identity resided in a training database. The unknown face or test image will undergo through the face detection process in order to determine whether that image is a '*human face*' or not. Subsequently, this HFR recognition system will identify whether the detected image is someone known or unknown. This process is

achieved by comparing the test image to a database of known faces in the training images as depicted in Figure 1.

There are various HFR algorithms that were introduced. They all share similar functions to input all images into the algorithms. Among those are the Principal Component Analysis (PCA) by Kirby and Sirovich [10], Linear Discriminant Analysis (LDA) by Belhumeur, Hepanha and Kriegman [3] and Support Vector Machine (SVM) by Vapnik [22] among others. Initially, PCA which is commonly known as the Eigenfaces is used to represent faces [10]. Succeeding, Turk and Pentland [21] extended the PCA to recognize faces. This algorithm uses algebraic statistical measurement to extract and recognize facial images.

There are many practical reasons favoring the development of facial recognition systems. When security has become imperative for many organizations, security cameras are now commonly used in government complexes, shopping malls, banks, airports and universities among others. In order to overcome this problem, a new advanced technology has been introduced. This technology is the biometric identification that uses a person's physical features for identification for example, a face, fingerprints, an iris, and a retina.

The biometric method of identification has become an important means of human identification. By comparing biometric identification to other biometric techniques like fingerprints, voice recognition and iris, this face recognition system is more efficient especially when it is being implemented in public places. Nevertheless, using face recognition does not require close interaction between the person and the identification system. Thus, this is a time efficient approach compares to other approaches such as fingerprints whereby the person needs to put his or her thumb on a device recognizer

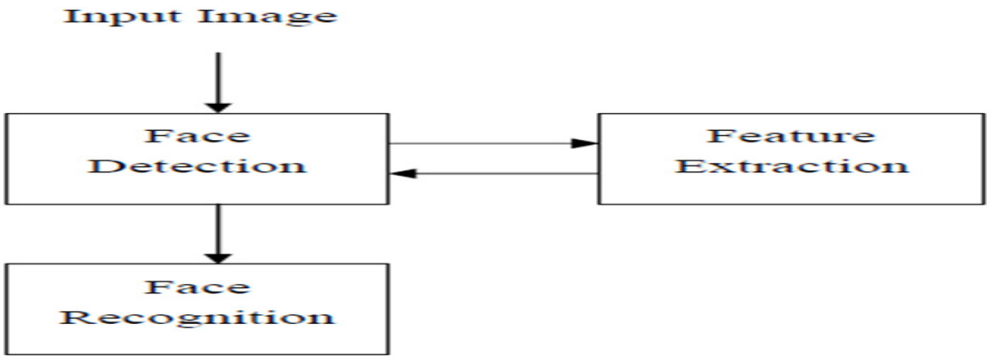

FIGURE 1. Face detection, extraction and recognition [1].

RELATED STUDIES

Efforts were undertaken among inter-disciplinarian researchers which include mathematicians, computer engineers, neuroscientists and psychophysicists to solve HFR problems [11]. Among the resolutions, the projecting approaches involved were PCA, Neural Network (NN), Discrete Cosine Transform (DCT), Template Matching using Correlation (TMUC), Partitioned Iterated Function System (PIFS) and Model Matching [14]. The TMUC face recognition uses a template consisting several masks enclosing the

mouth, eyes and the nose [4] whereas, the PIFS makes use of the similarity of human face to generate the PIFS code and matching them [6].

The HFR has gained a lot of interest from researchers and it has become one of the most popular discipline area of research in computer vision and biometrics. Historically, Bruner and Tagiuri [5] conducted the earliest work in this area in the field of psychology in the 50's. It has also been widely considered as a successful application of image processing. Other than facial recognition, there exists multiple methods of biometric identification such as fingerprints and iris scans.

PCA was first introduced in 1901 by Pearson [15] but was later proposed for pattern recognition in 1965 [23]. There are a series of algorithms pertaining to the feature extractions as shown in Table 1. Eigenfaces which is based on PCA was used extensively as compared to other methods applied by [16] and [17]. Following this, a bilinear model with a general framework was proposed by Freeman and Tenenbaum [9].

TABLE (1). Feature extraction algorithms [8].

Algorithm	Remark
Active Appearance Models (AAM)	Evolution of ASM, uses shape and texture
Active Shape Models (ASM)	Statistical method, searches boundaries
Discrete Cosine Transform (DCT)	Linear function, Fourier-related transform, usually used 2D-DCT
Independent Component Analysis (ICA)	Linear map, separates non-Gaussian distributed features
Kernal LDA	LDA-based, uses kernel methods
Kernel PCA	Eigenvector-based, non-linear map, uses kernel methods
Linear Discriminate Analysis (LDA)	Eigenvector-based, supervised linear map
Multidimensional Scaling (MDS)	Non-linear map, sample size limited, noise sensitive
Neural Network based methods	Diverse neural networks using PCA, etc.
Principal Component Analysis (PCA)	Eigenvector-based, linear map
Self-organizing map (SOM)	Non-linear, based on a grid of neurons in the feature space
Semi-supervised Discriminate Analysis (SDA)	Semi-supervised adaptation of LDA

RESEARCH APPROACH

PCA is the main focus of this paper. As discussed in the previous section, PCA is also known as Karhunen-Loeve expansion which is a feature extraction algorithm which is considered as one of the de facto standard in facial recognition. Kirby and Sirovich [10] applied PCA for faces representation, whilst Turk and Pentland [21] extended PCA for face recognition.

Traditionally, the computation for PCA consist of a set of N training facial images of $\{X_1, X_2, \ldots X_N\}$. The cardinal aim of applying PCA is to find an n X m matrix [8]. The n-dimensional vector is transformed to a m-dimensional vector where X_K ($1 \leq K \leq N$) representing the difference between two images vector Z_K, where $Z_K = P^T X_K$ (K=1,2 …N).

Consider *X*' as the average feature vector before performing the transformation, then *X'* is the average values of all training samples set. Therefore, the new average vector after transformation is illustrated in the equations below:

$$X' = \frac{1}{N}\sum_{K=1}^{N} X_K \tag{1}$$

The covariance matrix is employed to represent the scatter degree of all feature vectors that relate to the average vector. The image samples will be subtracted to the average vector *X'*. Before transformation, the covariance matrix is shown below:

$$S_x = \frac{1}{N}\sum_{K=1}^{N}(X_K - X')((X_K - X')^{\mathrm{T}} \tag{2}$$

The maximization of the scatter degree of Z_K, will lead to the transformation matrix which compose of eigen-vectors of S_x. The introduction of these equations lead to the formulation of other advanced PCA applications such as kernel principal component analysis (kernel (PCA), adaptive principal component analysis (APCA) and statistical principal component analysis (SPCA) among others.

A HFR device enables to view an image or a video of a person and later compares with one in the database's gallery by extracting features from an image of the person's face. As seen from Figure 1, face detection is the first stage in the recognition process where all faces are distinguished from non-faces. It is easy for human being to recognize faces even with different appearances such as different hairstyle, with and without glasses, contact lenses among others.

HFR is the second stage after face detection was carried out. One way to do this is by feature extractions. There are two approaches for feature extraction whether it is local or global. For local feature, it extracts eyes, nose and mouth information. The coordinates of a set of features from the photographs are extracted and then used by the computer for recognition. For a global feature, it extracts features from the whole image that is known as holistic methods. Turk and Pentland [9] discovered the residual error could be used to detect images of faces using eigenfaces.

A set of eigenfaces can be generated by performing a PCA on a large set of images that depicts various human faces. There are two stages in eigenfaces which involve learning and recognition. The learning stage involves the collection of images. These images are called the training images or training set. The recognition stage will identify whose face it belongs to.

The PCA will transform the training faces of M into a smallers set of K eigenfaces which evaluates into K < M. Each image is denoted in terms of these eigenfaces with assigned weightages. This transformation is defined wherein the first principal component or eigenface always presents the most important features of the training set. Each consecutive components would display the next dominant features. For example, assume the training set consists of 200 face images. Therefore M will be 200, meanwhile, PCA will transform M into a small set of K by removing eigenfaces that contain awful data.

PCA will only select the first 50 eigenfaces which carry useful information and discard the rest of the eigenfaces that are not very important to the image that carry more noises. To recognize the test image, the difference between it and each training images must be

calculated. Each image is actually made up of proportions of all K "features". It is also possible to rebuild each face image from the training set by combining the eigenfaces.

PCA performs some complex calculations on the images to get the covariance matrix. It calculates the eigenvectors and eigenvalues decomposition of a data covariance matrix. Hence, it obtains the dimensionality reduction. Finally PCA will select the most relevant eigenfaces, whereas the rest of the last principal components will be discarded. This is how the PCA generate K, the best eigenfaces with significant features.

There are also several face databases that can be used to experiment the HFR such as Olivetti Research Laboratory (ORL), Yale, AR, UMIST, FERET database, AT&T, Rice database to name a few. These databases provide a set of face images with different poses, and are used specifically to test face recognition. Many researchers had conducted using the available faces found in the existing databases. In this project, a customized training database is used.

This particular project is to experiment the face recognition for student verification in a library system. Therefore, the training set is a set of students' images. An individual image has been taken to be recognized, such as a passport size photograph of each student. In addition, each face image that was collected for the training set contained some information about the student particulars such as faceID, faceName, rollNumber, course and department. All this information is stored in the database which has perceived benefits [20].

The current library system uses student ID card for verification to borrow books. It is essential for student who wishes to borrow books to bring their ID card. The system uses bar code reader to retrieve the details of students from the ID. This current system can be considered as inefficient, lacking and imperfect as it only reads the bar code but it could not verify if the student is the real ID owner. Some of these drawbacks of using this traditional method are stated below. Hence, an urgent needs to implement face recognition system.

A group of students from the university are the main subjects for this experiment. These students must be verified through the HFR system. The system will capture the faces and then compare the image with the training image in the database (the passport-size photo of the student) during his or her enrolment to the university. This experiment is for the library verification purposes. For a student to borrow books, he or she will just scan his or her face via the biometric face recognition reader without having to bring the student ID card. Nevertheless for this project, the HFR system is experimented using a static photo or face image taken from the webcam.

The test image captured will then be compared to the training set images for recognition. The features of the detected test image will be extracted for matching process. The system will determine if the features extracted from the test image is identical or not. If the system detects match found or identical images, the student's identity will be verified. The system will show the student's name and other details such as roll number, enrolment date, faculty, course and intake.

The HFR system could work in two ways, verification mode as well as identification mode [13] as depicted in Figure 2. For the verification mode, first the student claims his or her identity. Subsequently, before accepting or rejecting, the system will first verify by comparing the test images. For example, a face captured from webcam to match against a training image that has been stored in the database.

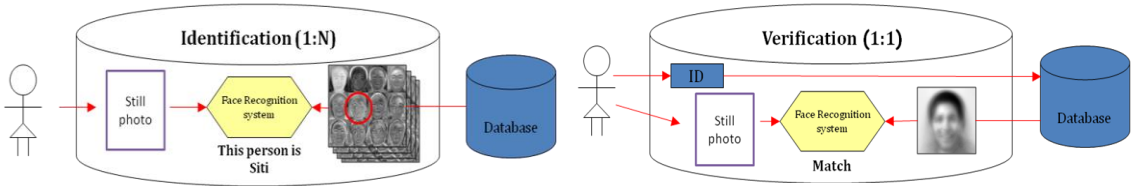

FIGURE 2. Identification and verification process.

For identification mode, once the student has been verified, the system will recognize that particular student by matching the test image with the training images stored in the database. In other words, face verification is a one-to-one (1:1) match that confirms whether the student is just as whom he or she claims to be. Whereas, face identification involves a one-to-many (1: N) comparisons that determine whether the student is someone known from the database or not. If the system recognizes the student, his or her details will be shown. The images are stored in a database as depicted in Figure 3.

FIGURE 3. Process of storing the training face to the database

EXPERIMENTAL RESULT AND ANALYSIS

This section will discuss the outcome of the HFR system based on the testing conducted. This is the most essential part of the report that measures the project's success. After implementing, it is important to test the system thoroughly, by measuring the accuracy on both, detection and recognition.

The computer used in this experiment is a PC with 8GB RAM, running on Intel Core i-7 with a 3.40GHz, 32 bits operating system with a webcam and a Tb of hard disk space. The database package used is a MS Access DBMS which was proven to be beneficial in storing data [18]. The programming languages used are C, C# and C++ which provide excellent programming skills [19]. An OpenCV which is an open source image processing library is included in the development of the application.

For the physical design, only two interfaces are required in this project. One is for training and another is for testing as shown in Figure 4 and Figure 5. The windows form is designed based on the logical design, with the User Interface (UI) control such as image box, button, picture box, label, textbox etc. These UI control will handle and will be responsible for the function.

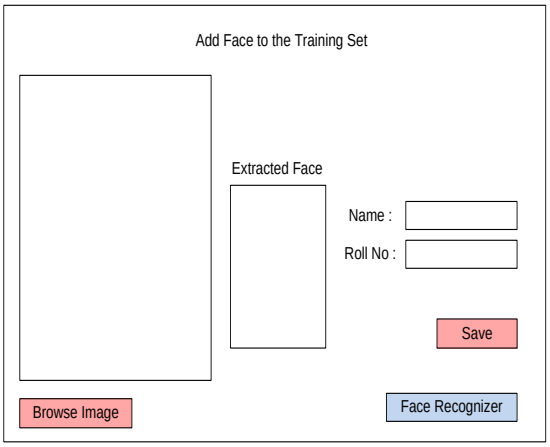

FIGURE 4. User interface design (Training).

The database contains a collection of faces of students (training set) where the system is built to recognize. The training database contains 86 images of 50 individual students, consisting of students from the computing programmes of the university. For testing, 50 images of 40 known and 10 unknown students were used. To test the recognition performances in real environments, test images of the students were taken using a webcam.

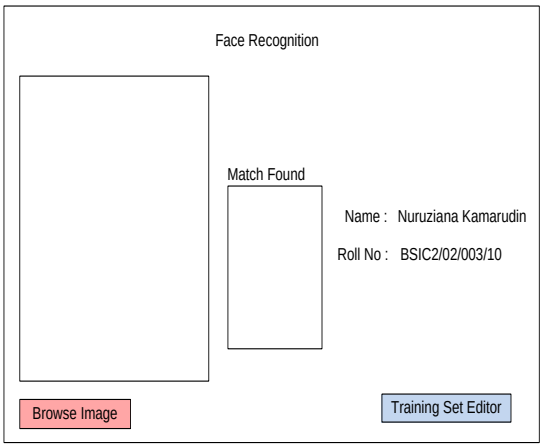

FIGURE 5. User interface design (Testing)

Upon further testing, 21 face images were successfully recognized, while 3 faces were not detected, and 6 faces were able to be detected but not recognized by the system. In the original and testing images, it can be seen that the students have different postures and facial expressions therefore the system failed to successfully match both images

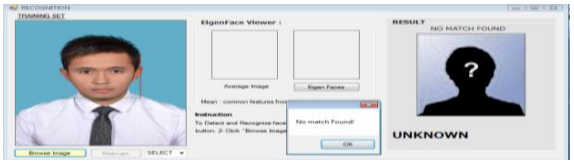

FIGURE 6. Image of unknown face result

In a case where an unknown image is detected, the system will not be able to recognize the fixtures that are stored in the database as shown in Figure 6 above.

FIGURE 7. Recognised test images taken from a webcam

DISCUSSION

The system is able to match and recognizes the image taken from a webcam with the images stored in the training database as depicted in Figure 8. From the test conducted, it can be observed that the system is also able to match and recognize both a known and an unknown person. Therefore here it can be seen that the system can obtain high success rate as long as there are no blatant differences and obstructions to the images. The detector can detect 9 ‘faces’, but only 7 out of that 9 detected ‘faces’ are the correct subjects. From the testing that has been conducted, the summarized result of success rate (SR) or accuracy can be predicted using the formula:

$$SR = (Matched / Test Images) * 100 \quad (3)$$

The detection success rate (DSR) is computed based on the formula:

$$DSR = (Matched / Test Images) * 100 \quad (4)$$

$= (45/50) * 100\%$

$= 90\%$

The recognition success rate (RSR) is computed based on the formula:

$$RSR = (Matched / Test Images) * 100 \quad (5)$$

$= (35/50) * 100\%$

= 70%

The DSR and RSR of 90% and 70% respectively clearly indicates that the HFR system has passed the minimum requirement to recognize genuine images with stored images in the database as compared to a study done previously [25].

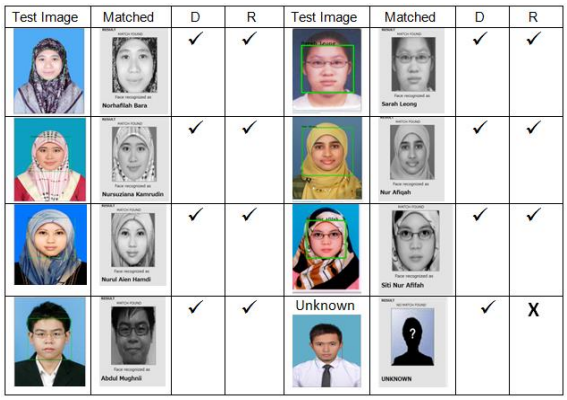

FIGURE 8. Matching and un-matching faces

CONCLUSION

This study has fulfilled its objective of constructing a HFR system by introducing a brief description about PCA and later applied it to the development of a HFR. This system is based on the ability to recognize a face that belongs to one of the training images in the training dataset. The process is run by utilizing the algorithm that currently exist and compare the face in the test image with the training images in the database. The advantages of developing a face recognition using PCA over other approaches, is the fact that it is supported by the open source image processing library called OpenCV, which can performed the algorithm on each image. In fact, the library is now improved by programmers for both face detection and recognition to enhance the performance.

From the experiments conducted, the accuracy rate of HFR from a single image is very high. This proves that even though this technique has existed over the years, it could still work relatively well especially in a controlled environment; for example in images with the same lighting, position, and expression. From this, it can be deduced that the accuracy of HFR is up to 70% accurate on average. It is vital to include the full frontal face with less facial expression in order to ensure the successful rate of the PCA algorithm.

In the analysis stage of this project, initially many fields of student details are included. However, in the prototyping system, only six fields are included in the database. This is in order to emphasize on the face recognition part which focuses on the face recognition using PCA eigenfaces. Furthermore, the system is only able to retrieve limited information of the recognized students' full names.

However in some cases, particularly in group photographs, the system resulted in partial recognition and detection whereby these have affected the accuracy rate of students' verification. Perhaps this is because of the lengthy distance of the students from the camera which is not parallel to the distance of the images taken in the training images. In addition, the system detected incorrect images as facial features especially if the background contains multiple subjects (consisting of both objects and students).

Moreover, in dynamic images using a webcam, the detection and recognition is not consistent. Perhaps this is because the dynamic images are more difficult to control compared to the static images. This includes the constant change of angles, postures and lightings of the images taken from the webcam.

Future study will be extended to integrate this system with a manual guest log book to provide a complete security system at our university to prevent intrusion. Subsequently, it will be installed in the university's server for online and real-time recognition purposes with an additional facility to produce guest's identity card.

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