Face Recognition using Principle Component Analysis (PCA) and Linear Discriminant Analysis (LDA)

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***Abstract*— Image Recognition is one of the computer vision applications in recent years. Commercially, security and law applications require the use of face recognition technology. Human face can be regarded as the most obvious human identifier. Apparently the face is the most visible part of human anatomy and serves as the first distinguishing factor of a human being. It helps a person to distinguish an individual from one to another. Each individual has his own uniqueness and this could be one of the most transparent and unique feature of a human being. Face recognition involves comparing an image with a database of stored faces in order to identify the individual in that input image. The images can be analyzed and faces can then be identified, before they can be recognized. There are different methods of face recognition which involve a series of steps that serve to capturing, analyzing and comparing a face to a database of stored images. This project covered comparative study of image recognition between Linear Discriminant analysis (LDA) and Principal Component Analysis (PCA). In this study, the result of PCA and LDA will be analyzed in term of its accuracy, percentage of correct recognition, time execution and database used.**

***Index Term*— PCA, LDA, feature extraction.**

I. INTRODUCTION

Nowadays, image recognition has become a popular topic among the researchers because of its broad usage in many applications such as digital cameras, surveillance camera, image editing software, Facebook and many more. In Facebook, it implements facial recognition technology that allows all users to semi-automating the photo-tagging process. In this comparative study, face recognition was chosen because it is the most significant human identifier. The face is the most visible part of human anatomy and serves as the first distinguishing factor of a human being. It helps a person to distinguish an individual from one to another. Every individual has his own uniqueness and this could be one of the most transparent and unique feature of a human being.

Face recognition involves comparing an image with a database of stored faces in order to identify the individual of that input image. The image will first be analyzed and faces can then be identified, before it can be recognized. While this process may be a trivial task for the human brain, it has proved to be extremely difficult for the artificial technology to imitate. It is commonly used in applications such as human-machine interfaces and automatic access control systems.

The need of face recognition application in many areas such as in Law Enforcement help the government to stay one step ahead of the world's ever-advancing terrorists, in Airport Security where it is use to enhance security efforts that already underway at most airports and other major transportation hubs (seaports, train stations, etc.), in Access Control to enhance security efforts considerably, in Driver's Licenses & Passports that can leverage the existing identification infrastructure, Homeland Defense, Customs & Immigration and Scene Analysis. All of this makes face recognition become more important nowadays. Other potential applications include ATM and cash-checking security. The software is able to quickly verify a customer's face. After a customer's consent, the ATM or check-cashing kiosk captures a digital image of him.

II. LITERATURE REVIEW

A. Face recognition

A facial recognition system is a computer application to automatically identifying a person from a digital image or a video frame. One way to achieve this is by comparing selected facial features from the image to a facial database [2]. It is typically used in security systems and can be compared to other biometrics such as fingerprint or human iris [1].

Currently, developers came up with the design that is capable of extracting and picking up faces from the crowd and have it compared to an image source - database. The software has the ability to know how the basic human face looks like in order

for it to work accordingly. Thus, developers designed these programs (by storing commands) to pinpoint a face and measure its features.

There are different methods of facial recognition which involve a series of steps that serve to capturing, analyzing and comparing a face to a database of stored images. Some related software was designed to recognize similarities through pattern recognition. Pattern recognition is often used under the names of diagnosis and clarifications. Each of this software varies on how it is designed to work yet the function and concept is still the same that is identifying on facial landmarks. Because of these, facial recognition is hard to fool since it compares specific proportions and angles of the defined facial features.

Facial recognition software falls into a larger group of technologies known as biometrics. Biometrics uses biological information to verify identity. The basic idea behind biometrics is that our body contains unique properties that can be used to distinguish us from other persons.

Face recognition has a number of advantages over other biometrics. Firstly, it is non-intrusive. While many biometrics require the subject's co-operation and awareness in order to perform identification, such as looking into an eye scanner or placing their hand on a fingerprint reader, face recognition could be performed even without the subject's knowledge. Secondly, the biometric data used to perform recognition is in a format that is readable and understood by humans. This means that a potential face recognition system can always be backed up and verified by a human. For example, supposing a person was falsely denied access to a site by a face recognition system. That decision could easily be corrected by a security guard that would compare the subject's face with the stored image, whereas this would not be possible with other biometrics such as iris. Other advantages are that there is no association with crime as with fingerprints (few people would object to looking at a camera) and many existing systems already store face images (such as police mug shots).

B. Principle Component Analysis

Principal component analysis (PCA) method used for global feature extraction is a powerful technique for extracting global structures from high-dimensional data set and has been widely used to reduce dimensionality and extract abstract features of faces for face recognition (Turk and Pentland, 1991; Zhao et al., 2000). It can also be used to identify patterns in data, and expressing the data in such a way as to highlight their similarities and differences. This provides an effective technique for dimensionality reduction.

The PCA method has been extensively applied for the task of face recognition. Approximate reconstruction of faces in the ensemble was performed using a weighted combination of eigenvectors (Eigen pictures), obtained from that ensemble (Sirovich and Kirby, 1987). The weights that characterize the expansion of the given image in terms of Eigen pictures are seen as global facial features. In an extension of that work, Kirby and Sirovich (1990) included the inherent symmetry of faces in the Eigen pictures. All images in face image in database are representing in matrix as a very long vector.

There are five steps involved in the system developed by Turk and Pentland. First, the system needs to be initialized by feeding it a set of training images of faces. This is used these to define the face space which is set of images that are face like. Next, when a face is encountered it calculates an eigenface for it. By comparing it with known faces and using some statistical analysis it can be determined whether the image presented is a face or not a face at all. Then, if an image is determined to be a face the system will determine whether it knows the identity of the face or not. The optional final step is that if an unknown face is seen repeatedly, the system can learn to recognize it.

The eigenface technique is simple, efficient, and yields generally good results in controlled circumstances [1]. The system was even tested to track faces on film. There are also some limitations of eigenfaces. There is limited robustness to changes in lighting, angle, and distance [6]. 2D recognition systems do not capture the actual size of the face, which is a fundamental problem [4]. These limits affected the technique's application in security cameras because frontal shots and consistent lighting cannot be relied upon.

C. Linear Discriminant Analysis

Linear Discriminant is a "classical" technique in pattern recognition [4], where it is used to find a linear combination of features which characterize or separate two or more classes of objects or events. The resulting combination may be used as a linear classifier or, more commonly, for dimensionality reduction before it can be classified.

In computerized face recognition, each face is represented by a large number of pixel values. Linear discriminant analysis is primarily used here to reduce the number of features to a more manageable number before classification. Each of the new dimensions is a linear combination of pixel values, which form a template. The linear combinations obtained using Fisher's linear discriminant are called Fisher faces, while those obtained using the related principal component analysis are called eigenfaces.

Linear Discriminant Analysis easily handles the case where the within-class frequencies are unequal and their performance has been examined on randomly generated test data. This method maximizes the ratio between-class variance to the within-class variance in any particular data set thereby guaranteeing maximal separability. The prime difference between LDA and PCA is that PCA does more of feature classification and LDA does data classification. In PCA, the shape and location of the original data sets changes when transformed to a different space whereas LDA doesn't change the location but only tries to provide more class separability and draw a decision region between the given classes [5].

Data sets can be transformed and test vectors can be classified in the transformed space by two different approaches.

(i) Class-dependent transformation: This type of approach involves maximizing the ratio of between class variance to within class variance. The main objective is to maximize this ratio so that adequate class separability is obtained. The class-specific type approach involves using two optimizing criteria for transforming the data sets independently.

(ii) Class-independent transformation: This approach involves maximizing the ratio of overall variance to within class variance. This approach uses only one optimizing criterion to transform the data sets and hence all data points irrespective of their class identity are transformed using this transform. In this type of LDA, each class is considered as a separate class against all other classes.

The goal of the Linear Discriminant Analysis (LDA) is to find an efficient way to represent the face vector space. PCA constructs the face space using the whole face training data as a whole, and not using the face class information. On the other hand, LDA uses class specific information which best discriminates among classes. LDA produces an optimal linear discriminant function which maps the input into the classification space in which the class identification of this sample is decided based on some metric such as Euclidean distance. LDA takes into account the different variables of an object and works out which group the object most likely belongs to [3].

III. RESULT

A. Database

There are two types of database that has been used which is ATT Face Database [7] and Indian Face Database (IFD) [8]. The used of these two databases is for performance comparison. The different between these two databases is the angle of which the image was captured where ATT database has a very small change of angle for every dataset but IFD has a significance change of angle for every image. The dimensionality of ATT database is 92x112 pixels while IFD is 64 x48 pixels.

ATT face database contains ten different images for 40 distinct subjects. For some subjects, the images were taken at different times, varying the lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses). All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position (with tolerance for some side movement).

IFD contains images of 40 distinct subjects with eleven different poses for each individual. All of the images have a bright homogeneous background and the subjects are in an upright, frontal position. For each individual, the following pose for the face is included: looking front, looking left, looking right, looking up, looking up towards left, looking up towards right, looking down. In addition to the variation in pose, images with four emotions - neutral, smile, laughter, sad/disgust - are also included for every individual. These two databases provide a comprehensive dataset for testing the performance of the algorithms chosen.

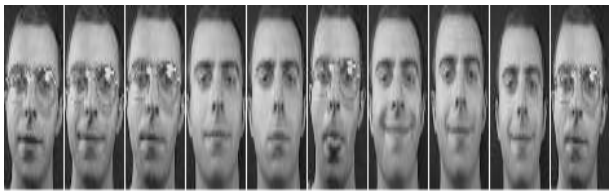

Fig. 1. One of ATT face database with ten different expressions.

Fig. 2. Images corresponding to one individual.

B. ATT face database

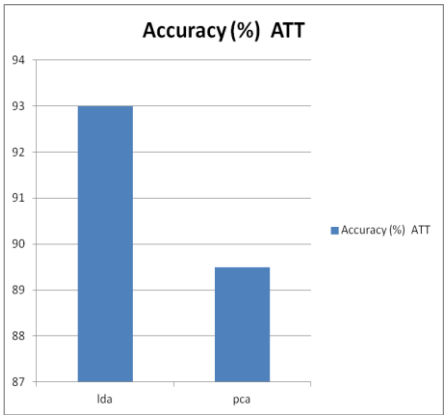

Fig. 3. Accuracy PCA and LDA using ATT database

Based on the fig. 3, we can see LDA is more accurate than PCA. LDA accuracy is 93% while PCA is 89.5%. This accuracy is based on separating 50% of the images in the database to be train image and the remaining 50% to be test image.

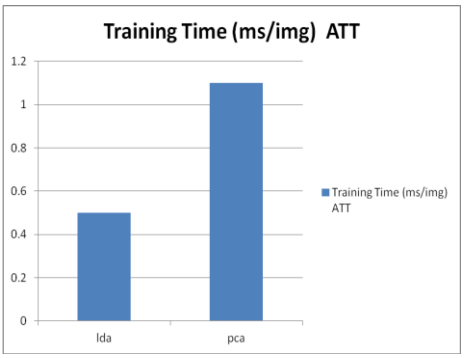

Fig. 4. Training time taken in millisecond for each image(ATT)

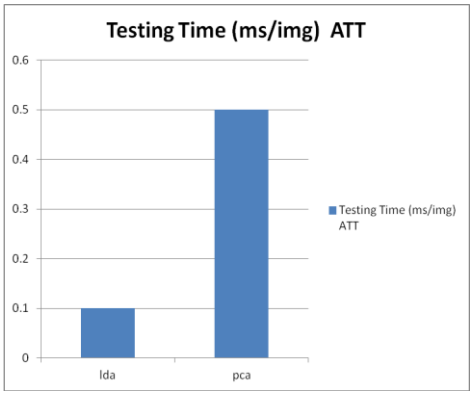

Fig. 5. Testing time taken in millisecond for each image(ATT)

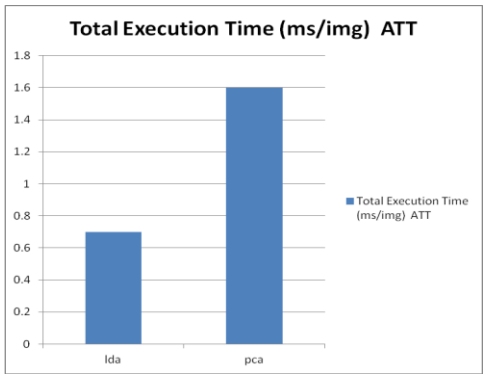

Fig. 6. Total execution time taken in millisecond for each image(ATT)

Based on the result above, LDA is proved to be better than PCA. The accuracy for LDA is more than PCA. Moreover, LDA is faster than PCA in testing and training the image and of course LDA beat PCA for total execution of time taken.

C. Indian Face Database (IFD)

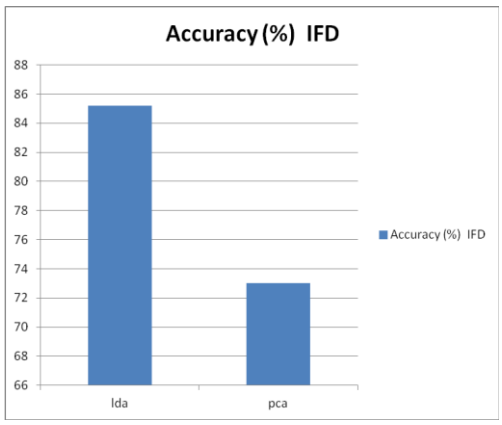

Fig. 7. Accuracy LDA and PCA (IFD)

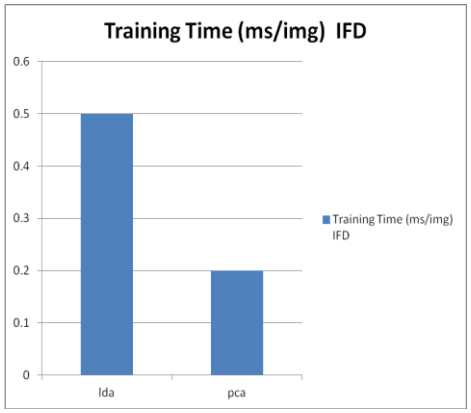

Fig. 8. Training time taken LDA and PCA (IFD)

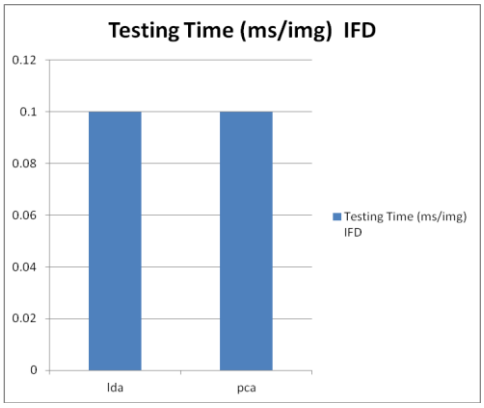

Fig. 9. Testing time taken LDA and PCA (IFD)

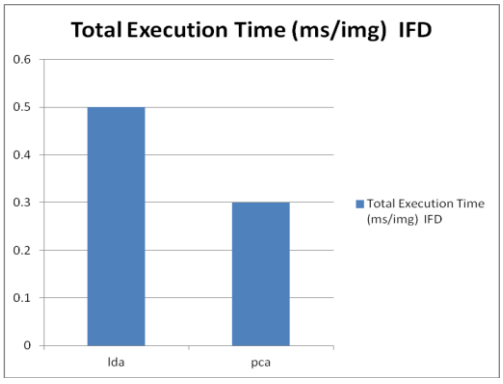

Fig. 10. Total execution time taken LDA and PCA (IFD)

By using IFD, the accuracy for LDA is more than PCA. But the time taken for execution, train and test the image of LDA is more than PCA for IFD dataset.

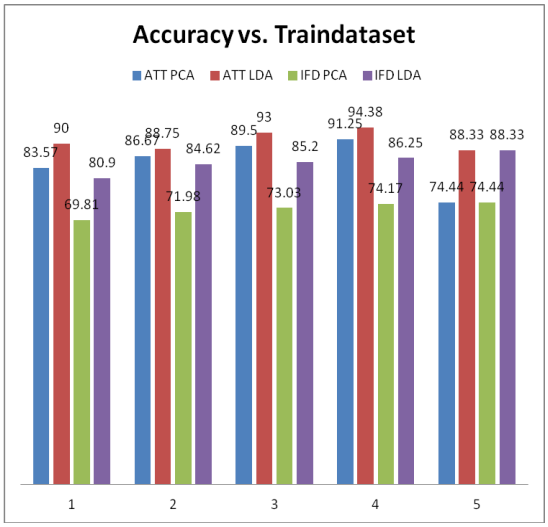

Fig. 11. Accuracy vs. %train dataset

The figure shows that overall result for two dataset that had been used which has been testing for each percentage form 30% to 70% on PCA and LDA technique. Based on the result, it clearly shows that LDA is a more accurate technique and it will be even more accurate when it being tested using ATT database.

IV. Discussion

The performance of the two algorithms for the two databases has been compared considerably which showed a distinctive performance. It is observed that the recognition rate is higher in the ATT database than the IFD. This observation is due to the nature of images encompassed in the IFD. The IFD database has images where each subject is portrayed with highly varying orientation angles. Also, the IFD has images with a larger background region that the ATT images.

In terms of accuracy the LDA shows a higher recognition rate. This is because of the use of discrete classes to group the images and perform a covariance minimization within the same class. The use of this distinct class information increases then feature space used for classification.

In term of training set used, it's not always when the training set is small, PCA can outperform LDA, it's also depend on the database which is type of image had been used. It is also the same when the number of samples is large and representative for each class, LDA outperforms PCA, because based from the result the LDA is always outperform than PCA even the training set is small.

Result shows a classic shortcoming of the recognition function which is seen to be heavily dependent upon the number of images the algorithm is trained upon. Although this project considers only closed loop recognition where the images to be tested are also from the same database the choice of a higher number of faces for training can lead to a higher accuracy.

However, the improved performance of the class based LDA is evident from the results. Another noticeable property is that the execution time varies inversely with the percentage of images the algorithms are trained upon. This is because the recognition process is simplified with a larger trained weight set.

V. Conclusion

In this project two type of feature extraction for face recognition algorithms, PCA and LDA were studied. The PCA and LDA were implemented using MATLAB and the performance was determined in terms of the recognition accuracy and the execution time taken. Experiments were performed under different conditions; by varying the input face image dataset and also by varying the parameters of the individual algorithms. The study showed that the LDA performs better than PCA in terms of the accuracy of recognition. For the future enhancement, method of finding and identifying faces accurately can maximize control of subject's pose and maximize control of environment. By controlling a person's facial expression, as well as his distance from the camera, camera angle, the scene's lighting, a posed image can minimize the number of variables in photograph. This control allows the facial recognition software to operate under near ideal conditions greatly enhancing its accuracy.

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