COMPARATIVE ANALYSIS OF FACE RECOGNITION ALGORITHMS

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ABSTRACT

Biometric system provides automatic identification of an individual based on a unique feature or characteristics possessed by the individual. There are various types of biometric technology like face, iris, voice, signature, DNA etc. The ability of recognizing a person solely from his face is known as face recognition. Face recognition comprises of four distinct blocks data acquisition, data preprocessing, feature extraction and face recognition. Data acquisition means detection of face in image. In data preprocessing stage reducing the variation of face obtained during the acquisition. Feature extraction is used for extraction the geometrical features of images. There are many types of algorithms used for extraction. This paper contains the review of various face recognition algorithm, parameters used for recognition and the problems encounter during recognition. Then we define the problem statement and explain how solve it.

Keywords: *Face Recognition, Eigenface, Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), Face Recognition Technology (FERET).*

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1. INTRODUCTION

Face recognition has gained much attention in recent years and has become one of the most successful applications of image analysis and understanding. Face recognition technology involve analyzing certain facial characteristics, storing them in a database and using them to identify users accessing systems [9]. A general statement of the problem can be formulated as follows [6]: Given still or video images of a scene, identify or verify one or more persons in the scene using a stored database of faces. Currently, image based face recognition techniques can be divided into two groups based on the face representation which they use: 1) *appearance-based* [11] which use holistic texture features and are applied to either whole-face or specific regions in a face image, and 2) *feature-based* which use geometric facial features (mouth, eyes, brows, cheeks etc.) and geometric relationships between them. The goal of this paper is to present an independent, comparative study of three most popular appearance-based face recognition algorithms in completely equal working conditions. They are: Principal Component Analysis (PCA), Independent Component Analysis (ICA), and Linear Discriminant Analysis (LDA). PCA [1], [4] finds a set of the most representative projection vectors such that the projected samples retain the most information about original samples. ICA [2], [4] captures both second and higher-order statistics and projects the input data onto the basis vectors that are as statistically independent as possible. LDA [3], [10] uses the class information and finds a set of vectors that maximize the between-class scatter while minimizing the within-class scatter. Comparison will be done using the FERET data set [12] for consistency with other studies.

The rest of this paper is organized as follows: Section 2 gives a brief description of the algorithms to be compared, Section 3 reports the details of findings draw from the literature, Section 4 the problem statement and methodology for solve it, Section 5 describe experiments results and discussion and Section 6 concludes the paper.

2. ALGORITHMS

2.1 Principal Component Analysis

PCA is a technique that effectively and efficiently represents pictures of faces into its eigenface components. It reduces data dimensionality by performing a covariance analysis between factors [4], [11].

1. Method of finding Principal components

- First of all we need to find the linear combination of the original variables with large variance.
- The covariance matrix C or the correlation matrix R is then calculated.
- The eigen values and eigenvectors of C or R is found
- The eigen values are computed in descending order (from largest to smallest) $e_1, e_2, e_3....., e_p$.
- Finally the corresponding eigenvectors

  $a_1, a_2, a_3, ...a_p$ are found, where $a_i^{'} a_i = 1$ and $a_i^{'} a_i = 0$ thus

  $y_1 = a_1^{'} x = a_{11} x_1 + a_{12} x_2 + ... + a_{1p} x_p$ is the first principal component

  $y_2 = a_2^{'} x = a_{21} x_1 + a_{22} x_2 + ... + a_{2p} x_p$ is the second principal component

  .....

  $y_p = a_p^{'} x = a_{p1} x_1 + a_{p2} x_2 + ... + a_{pp} x_p$ is the p'th principal component.

2. Choosing the principal components

To choose the value of K this is the number of principal components, the following criterion to be followed.

$$\frac{\sum_{i=1}^{K} \lambda i}{\sum_{i=1}^{M} \lambda i} \rangle Threshold(e.g., 0.9 or 0.5)$$

By using this criterion the requirement of the number of principal components can be determined.

3. Mathematical representation of PCA

PCA generates a set of orthonormal basis vectors, known as principal components that maximize the scatter of all projected samples. Let $X = X_1, X_2, ...X_n$ be the sample set of original images. After normalizing the images to unity norm and subtracting the grand mean a new image set $Y = Y_1, Y_2, ...Y_n$ is obtained. Each Yi represents a normalized image with dimensionality $N, Y_i = y_{i1}, y_{i2}, ...y_{iN}{}^{t}$, $i = 1, 2, ..., n$ .The covariance matrix of normalized image set is defined as

$$\sum y = \frac{1}{n} \sum Y_i Y_j^t = \frac{1}{n} YY^t$$

and the eigenvector and eigenvalue matrices U,λ are computes as

$$\sum YU = U\lambda$$

2.2 Linear Discriminate Analysis

Linear discriminate analysis tries to differentiate between classes rather than trying to present the data. Therefore, LDA cares about getting features vectors for class discrimination. We define two scatter matrices [10].

$$S_w = \sum_{j=1}^{R} \sum_{i=1}^{M_j} x_i^j - \mu_j \quad x_i^j - \mu_j \;^T$$

$$S_b = \sum_{j=1}^{R} \mu_j - \mu \quad \mu_j - \mu \;^T$$

The first is called the within-class scatter matrix while the second is called the between-class matrix. j denotes the class while i denotes the image number. μ_j is the mean of class j while μ is the mean of all classes. M_j is the number of images in class j and R is the number of classes. The algorithm aims at maximizing the between-class matrix while minimizing the within-class matrix. This can be done by maximizing the ratio $\det|S_b|/\det|S_w$. As with PCA we have a projection matrix G. this matrix is used to maximize the mentioned ratio when its columns are eigenvectors of $S_w^{-1}S_b$. A problem arises when S_w becomes singular [8].

2.3 Independent Component Analysis

ICA is considered as a generalization of PCA. PCA considers image elements as random variables with minimized 2nd order statistics. ICA proposed by minimizes both second-order and higher order dependencies in the input data and tries to get the basis of which the project data is statistically independent. Two different approaches are taken by the ICA for face recognition. In first approach images are considered as random variables and pixels as trials. In other words ICA architecture first tries to find a set of statistically independent basis images. In second approach pixels are considered as random variables and images as trials [10].

The algorithm works as follows [2].

Let X be an n dimensional (n-D) random vector representing a distribution of inputs in environment.

Let W be an n*n invertible matrix, U=WX and Y=f(U) an n-D random variable representing the outputs of n-neurons. Each component of $f = f_{1,\ldots\ldots,} f_2$ is an invertible squashing function, mapping real numbers into the [0,1] interval. Typically the logistics function is used.

$$f_i \quad u \quad = \frac{1}{1+e^{-u}}$$

The $U_1, U_2, \ldots\ldots\ldots U_n$ variables are linear combinations of inputs and can be interpreted as interpreted as presynaptic activations of n-neurons.

$$\Delta W \propto \nabla_W H \quad Y \quad = \quad W^T \quad {}^{-1} + E \quad Y' U^T$$

3. FINDINGS FROM LITERATURE REVIEW

Following are the major findings from survey: We found that the most commonly used parameters for face recognition are as follows: 1) Accuracy 2)Variability in data size 3)Blurriness in test data 4)Image size. In most of the face recognition algorithms, the major mathematical technique used is the autocorrelation matrix of the face image. The eigenvectors (also known as eigenfaces) are drawn from the autocorrelation matrix to analyze the different characteristics of face image. From literature, We found that the major problems which researchers face are 1) curse of dimensionality 2) semantic gap 3) small sample size. ICA method is generalization of PCA method and also these two methods are very commonly used for most of the face recognition algorithms.

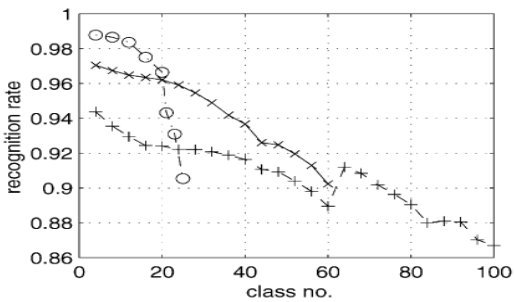

Figure 1 shows the small sample size problem in LDA algorithm

The horizontal axis in Fig. 1 represents the number of classes used for recognition, and the vertical axis represents the corresponding recognition rate. The +, ○, ×, signs in fig. 1 indicate there were 2, 3, and 6 samples in each class, respectively. The results shown in fig.1 reflect that the proposed approach performed fairly well when the size of database was small. However, when K (the number of class) multiplied the M-1 (the number of samples minus 1)

was close to n (the number of features of class, n=128), the performance dropped significantly. The phenomenon was especially true for the case where M=6.

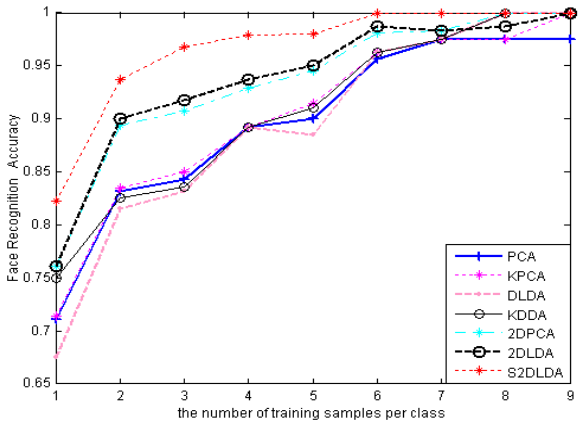

Figure 2 Comparison of the face recognition accuracy by different feature extraction methods

Figure 2 explains the accuracy of different feature extraction methods with varying number of training samples per class.

4. PROBLEM DEFINITION

The aim of current work is to evaluate the comparative analysis of PCA, ICA and LDA for face recognition. First we implement these algorithms and then evaluate the performances of these algorithms under various parameters and then compare it with other methods. The analysis will be done on the following parameters:-

- Accuracy= $\frac{\text{number of correctly match images}}{\text{total number of images}} \times 100$
- Mean Squared Error = $\frac{\sum_{M,N}[I_1(m,n)-I_2(m,n)]^2}{M \times N}$
- PSNR = 10 $log_{10}(\frac{R^2}{MSE})$
- Total execution time = total time taken for execution of algorithm
- After adding noise = Input images corrupted by Gaussian noise.
  - Accuracy
  - Total execution time
- Effect of blurriness level= Input images blurred by a Gaussian filter
- Effect of different image size = Size means pixel values are different

4.1 Methodology

A face recognition system consists of four blocks. First is face detection that scans and captures a digital or an analog image of living personal characteristics. Second is face preprocessing which is used to preprocess the image using histogram technique. Third is the

feature extraction which extracts the image into vector form through PCA, LDA and ICA algorithm. Final step is the feature matching.

4.2 Data Collection

There are a lot of databases available at commercial level for research work. The ATT Face Database [7], Indian Face Database (IFD) [8] and FERET database [12]. We choose the FERET database because the FERET database contains images of 1,196 individuals, with up to 5 different images captured for each individual. The images are separated into two sets: gallery images and probes images. Gallery images are image with known labels, while probe images are matched to gallery images for identification.

5. Experiment Results and Discussion

At first we observed the accuracy of face recognition algorithms (PCA, LDA, ICA) using the FERET Database and plot the output using the graph.

Accuracy Percentage

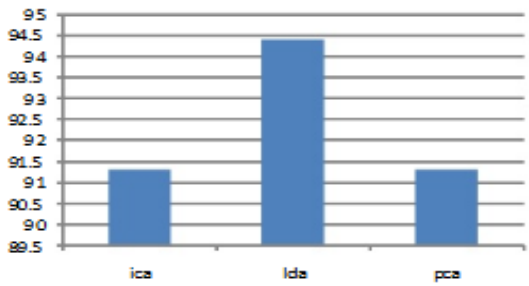

Figure 3 Accuracy of PCA, LDA, ICA Face recognition algorithm

As shown in Fig. 3 LDA outperforms well from other two algorithms. But in PCA and ICA both performance similar.

Total execution time

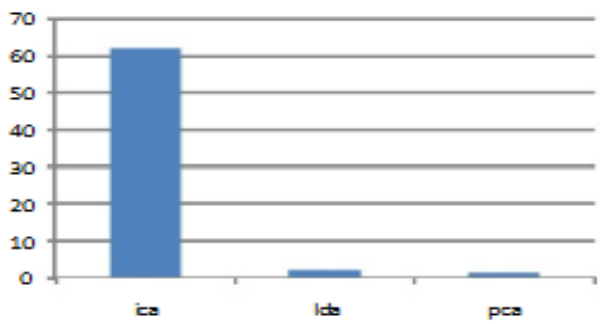

Figure 4 Total Execution Time for ICA, PCA and LDA

As shown in Fig. 4 ICA execution time is more than the LDA and PCA.

6. CONCLUSION AND FUTURE WORK

Face recognition algorithms consists of four stages, first is face detection, which capture the face image. Second is face preprocessing, used to normalize the image i.e. reducing the variation of images obtained during the face detection. For feature extraction there are mainly two types of algorithms. First is geometric based and second is holistic based. In first approach identification relying on specific components such as eyes, nose, mouth and distance among them and the second one is holistic based which is usually based on projecting the original images into lower dimensional subspaces spanned by specific basis vectors. PCA, LDA, ICA come under this. Fourth step of face recognition is feature matching which takes the templates generated from the feature extraction stage and needs a corresponding matching metric. The implementation of algorithm on using parameter accuracy and total execution time is done .The other above mentioned parameters implementation will be implemented in future work. After implementation, analysis and comparison of the methods will be done and finally conclusion will be drawn depending on the results.

REFERENCES

1. Bruce Poon, M. Ashraful Amin, Hong Yan, "PCA based Face Recognition and Testing Criteria", in 8th International Conference on Machine Learning and Cybernetics, pp.2945-2949, 2009.
2. Marian Stewart Bartlett,Javier R. Movellan,Terrence J. Senjnowski, "Face Recognition by Independent Component Analysis", in IEEE Transaction on Neural Networks, vol.13, No.6, pp.1450-1464, 2002.
3. Negar Baseri Salehi, Shohreh Kasaei, Somayeh Alizadeh, "Face Recognition Using Boosted Regularized Linear Discriminant Analysis", in IEEE International Conference on Computer Modeling and Simulation, pp.89-93, 2010.
4. Tahia Fahrin Karim, Molla Shahadat Hossain Lipu, Md. Lushanur Rahman, Faria Sultana, "Face Recognition Using PCA-Based Method", in IEEE International Conference on Advanced Management Science, pp.158-162, 2010.
5. Fei Ye, Zhiping Shi, Zhongzhi Shi, "A Comaparitive Study of PCA,LDA and Kernal LDA for Image Classification", in IEEE Symposium on Ubiquitous Virtual Reality, pp.51-54, 2009.
6. W.Zhao, R. Chellapa, A. Rosenfeld, P.J Phillips, "Face Recognition : A Literature Survey ", in ACM Computing Surveys, Vol.35, No.4, pp.399-458, 2003.

7. Jian Yang David Zhang ,Jing-yu Yang,"Is ICA Significantly Better than PCA for Face Recognition", in 10th IEEE International Conference on Computer Vision (ICCV'05), pp.1348-1354, 2005.
8. Haitao Zhao, Pong Chi Yuen, "Incremental Linear Discriminant Analysis for Face Recognition", in IEEE Transactions on Systems, Man, And, Cybernetics , vol.38, No.1, pp.210-221, 2008.
9. Neerja, Ekta Walia, "Face recognition Using Improved Fast PCA Algorithm", in IEEE Conference on Image and Signal Processing, pp.554-558, 2008.
10. Juwei Lu, Kostantinos N. Plataniotis, Anastasios N. Venetsanopopulos, "Face Recognition Using LDA-Based Algorithms", in IEEE Transactions on Neural Networks, vol.14, No.1, pp.195-200, 2003.
11. M. Turk and A. Pentland, "Eigenfaces for Recognition", in Journal of Cognitive Neuroscience, vol. 13, no. 1,pp.71-86, 1991.
12. P. J. Phillips, H. Moon, S. A. Rizvi, and P. J. Rauss, "The FERET evaluation methodology for face-recognition algorithms", in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 22, no. 10, pp.1090-1104, 2000.