Heterogeneous Techniques used in Face Recognition: A Survey

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Abstract: ***Face Recognition has become one of the important areas of research in computer vision. Human Communication is a combination of both verbal and non-verbal. For interaction in the society, face serve as the primary canvas used to express distinct emotions non-verbally. The face of one person provides the most important natural means of communication. In this paper, we will discuss the various works done in the area of face recognition where focus is on intelligent approaches like PCA, LDA, DFLD, SVD, GA etc. In the current trend, combination of these existing techniques are being taken into consideration and are discussed in this paper.***

Keywords: Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Genetic Algorithm (GA), Direct Fractional LDA (DFLD)

1. Introduction

A Human Face gives a rich source of information about different human behaviors. Face Recognition is a kind of a template matching problem in which recognition is to be performed in a high dimensionality space. So, more computation is needed for fulfilling the above purpose. Face recognition is one of the demanding area of research because of its non-intrusiveness as face images which are to be recognized or detected can be captured without the involvement of the user. Since different people have unique faces, we can recognize different faces with less difficulty. But automatic recognition by system is a bit difficult task in terms of parameters to be used for the above purpose, computational complexity as well as time complexity. So, this is a demanding area of research to solve the above faced complexities in one way or the other.

Face Recognition consists of three main steps: *image acquisition, feature extraction and finally face recognition*. Images are captured usually by a camera and stored in a database. Facial feature detection can be done by a number of methods such as segmentation, background elimination, skin filtering etc. Feature extraction transforms the detected face patch into a vector with fixed dimensions or a set of fiducial points and their corresponding locations. It is generally performed for dimensionality reduction, noise cleaning, etc. Recognition is performed by comparing the extracted features to each face class. Feature extraction and classification techniques are described in each of the face recognition methods discussed in the preceding sections.

Here, in this works related to PCA, DA and LDA SVD and GA based face recognition are discussed. In section II, III, IV and V, various feature extraction and recognition techniques are discussed.

2. Principal Component Analysis

PCA is one of the statistical method for reducing the dimensionality of a data set while retaining the majority of the variation in the data set thereby producing optimal linear least squares decomposition of a training set. Mathematically, it can be explained as below [1]:

- Let there be N images with n pixels, then the entire data set is of $N \times n$ order, where each row represents an image of the data set.
- The mean of the data is found out by averaging the columns of the data matrix and then the mean image is subtracted from each image of the dataset to create the mean centered data vector say U.
- The covariance matrix is calculated as :

$$\Sigma = U^T U \big/ (N-1) \tag{1}$$

- Eigen values and Eigen vectors are calculated from the covariance matrix.
- Eigen vectors are arranged in such a manner that the Eigen values are in the decreasing order denoted by A. So for any given image, only a few of the highest Eigen vectors are considered. Thus reducing the dimension.
- PCA is given by

$$PCA = (Int_i - m) \times A \tag{2}$$

Where, $\boldsymbol{Int_i}$ is the intensity values of each pixel of the original image (***I***) and ***m*** is the mean of the corresponding image.

Turk et.al [2] presented a face detection and identification method using Eigen faces in which face images are projected into a feature space (face space), characterizing an individual face by the weighted sum of the Eigen face features. Eigen faces are nothing but the principal components of the initial training set of face images.

Kim [3] discussed PCA for Face Recognition by constructing 1-D vector of pixels from 2-D facial image for face recognition. After the Eigen faces are computed, face identification is done computing the distance between the stored faces and the Eigen face.

Chung et.al [4] proposed a new PCA based face recognition method in which robust facial features are represented using Gabor features, which are again transformed into Eigen space using PCA for classification. Gabor filters handle illumination and pose variations in original face images are handled during classification.

Moon et.al [5] proposed a generic modular PCA based face Recognition which consists of normalization and PCA projection. Recognition is obtained using nearest neighbor classifier. Normalization improves the performance.

Khan et.al [6] applied PCA to transform directional images into Eigen space for increasing recognition accuracy. Directional images are created from original images using directional filter bank (DFB).

Zhao et.al [7] presented an incremental PCA based face Recognition algorithm in which incremental learning is applied to update the principal subspace without simply re-computing the Eigen decomposition. It is also further discussed that there is no information lost as well as computation time is quite reduced.

Nhat et.al [8] presented a kernel- based 2DPCA face Recognition method to extract the non-linear principal components based directly on input image matrices. Kernel based 2DPCA is obtained by applying KPCA to each row of all training images (column-vector sample).

Scholkopf et.al [9] used KPCA in which dot product matrix $K_{ij} = (k(x_i, x_j))_{i,j}$ is computed and diagonalized to calculate the eigenvalues and eigenvectors of the data matrix. Projections onto the eigenvectors provide the principal components corresponding to the kernel ***k***. A linear SVM is trained for the object classification purpose.

Xie et.al [10] used doubly non-linear mapping KPCA in Face Recognition to reduce the effect of feature variations due to illuminations, expression and perspective disturbance. Facial features are extracted using Gabor wavelets.

Kong et.al [11] used Generalized 2DPCA (G2DPCA) for face image representation and recognition. Bilateral projection based 2DPCA and Kernel based 2DPCA has been proposed which helped in reducing the 2DPCA coefficients.

Welling [12] discussed that in KPCA, if the centered kernel can be computed in terms of the non-centered kernel in the high-dimensional space, no other unnecessary features need to be accessed.

Nhat et.al [13] presented a kernel- based 2DPCA Face Recognition to extract the non-linear principal components based directly on input image matrices. Kernel based 2DPCA is obtained by applying KPCA to each row of all training images (column-vector sample).

Ebied [14] presented a Face Recognition System in which PCA as well as KPCA based feature extraction in which the extracted features are used for classification using 1 nearest-neighbor classifier with Euclidean distance as the distance metric. KPCA is also used with the Gaussian kernel function as the kernel trick to determine the impact of different color spaces on face recognition [15].

3. DA and LDA

Balakrishnama et.al [16] discussed mathematical steps of LDA and implemented as a classification technique mentioned below. They also discuss different approaches to LDA viz., *class dependent and class independent*.

Mathematical steps of **LDA**:

- The data set (set_j) and the test vectors are formulated.
- Mean of each data set (say μ_j ,j=1,2,....n)and the mean(μ_{mean}) of the entire data set is computed as:

$$\mu_{mean} = \sum_j (p_j \times \mu_j) \tag{3}$$

where, $p_{j's}$ are the apriori probabilities of the classes.

- Within class scatter (S_w)is the expected covariance of each of the classes, given as

$$S_w = \sum_j p_j \times \text{cov}_j \tag{4}$$

where $\text{cov}_j = (x_j - \mu_j)(x_j - \mu_j)^T$ (5)

- Between class scatter(R_b) is the covariance of data set whose members are the mean vectors of each class and is given by

$$R_b = \sum (\mu_j - \mu_{mean})(\mu_j - \mu_{mean})^T \tag{6}$$

- The optimizing criterion is the ratio of R_b to S_w and the solution obtained by maximizing this criterion defines the axes of the transformed space. The optimizing criteria for class dependent type is given by

$$criterion_j = inv(\text{cov}_j) \times R_b \tag{7}$$

and, class independent type is

$$criterion = inv(S_w) \times R_b \tag{8}$$

- The transformations are found as the eigenvector matrix (***transformed_j***) defined by equation **9** and **10**.
- The class dependent LDA transform is given by

$$transformed\_set\_j = transformed\_j^T \times set\_j \tag{9}$$

and the class independent LDA is given by

$$transformed\_set = transformed\_spec^T \times data\_set^T \tag{10}$$

Similarly, test vectors are transformed.

- Once the transformations are completed using the LDA transforms. After that, Euclidean distance is calculated as:

$$dist\_n = transform\_n\_spec^T \times \mu_{ntrans} \tag{11}$$

Where, $\mu_{ntrans}$is the mean of the transformed data set and x is the test vector, which is used for classification.

• The smallest Euclidean distance among the n distance classifies the test vector as belonging to class n.

Baudat et.al [17] proposed GDA for Face Recognition which mapped the input space into another feature space, which are non-linearly related to the input space maximizing the inter-classes inertia and minimizing the intra-classes inertia and can be used for supervised .

Yu et.al [18] proposed a direct, exact LDA (D-LDA) based Face Recognition, which optimizes Fisher's criterion directly without reducing the dimension of the data. It discards the null space of between class scatter matrix by first diagonalizing between class scatter matrix and then within class scatter matrix is diagonalized.

Lu et.al [19] introduced a kernel machine-based DA Face Recognition method, which is a combination of GDA and D-LDA. It is an improvement over DLDA by introducing kernel features in which the optimal discriminant features are exactly extracted from both of inside and outside of the within class scatter matrix in the feature space's null space.

Lu et.al [20] proposed DF-LDA Face Recognition, a combination of D-LDA and F-LDA, for feature representation. Face recognition and classification is done using nearest neighbor classifier. A new variant of D-LDA is introduced which utilizes modified Fischer's criterion and a weighing function so that a low dimensional SSS free subspace is obtained and F-LDA is applied subsequently to re-orient the SSS-free subspace resulting in a set of optimal discriminant features for face representation enhancing the discriminatory power of the obtained D-LDA feature space.

Ye et.al [21] proposed 2DLDA based Face Recognition method, in which each datum is represented as a matrix and the collection of data is represented as a collection of matrices and a combination of 2DLDA and LDA is also studied. 2DLDA implicitly avoids the singularity problem and both the above methods have distinctly lower time and space complexity as well as higher classification accuracy than a combination of PCA and LDA.

Yang et.al [22] develops a two phase KFD framework to carry out discriminant analysis in double discriminant subspaces i.e. to extract two kinds of discriminant features and fused for classification purpose.

Zhao et.al [23] developed incremental algorithm for LDA/GSVD known as GSVD-ILDA to handle the computation cost for dynamic database and for large database applying the updating SVD technique to LDA/GSVD.

Chelali et.al [24] presented LDA based face recognition in which a fisher space is established from the training samples in the training phase and the training faces are projected onto the same subspace. Eigen decomposition on the scatter matrices is applied to compute optimal projection and Euclidean distance is used in classification. It is also reported that recognition rate is poor under varying head tilts and illumination.

4. Singular Value Decomposition

The singular value decomposition of a, matrix A is the factorization of A into the product of three matrices A = UDV^T, where the columns of U and V are orthonormal and D is a diagonal matrix. A huge storage space is required to save the face features obtained from training faces in case of the above projection based face recognition systems as in [25].

Cao [26] discussed the application of SVD to Digital Image Processing viz., Image Compression and Face Recognition, in which a matrix A is transformed into product USV^T to refactor a digital image. The steps of SVD is given below:

• A image A of $m \times n$ is taken and a 'training set' S is calculated by:

$$S = [f_1, f_2, ..., f_N] \tag{12}$$

Where, f_i's are the column vectors of A.

• The mean image $\bar{f}$ of set S, is calculated as:

$$\bar{f} = (1/N) \sum f_i \tag{13}$$

• Another $M \times 1$ matrix $B = [a1, a2, ..., an]$ is calculated where, $a_i = f_i - \bar{f}$.

• The range (column) subspace of matrix B, given by $R(B) = \{u1, u2, ..., ur\}$, where u_i's are the orthonormal basis for R (B) and are called base faces. R(B) is called face subspace.

• The coordinate(x) of face image f in the face subspace is the scalar projection of $f - (f - \bar{f})$ onto the base faces:

$$x = [u1, u2, ..., ur]^T (f - \bar{f}) \tag{14}$$

which is used to find the training face which best describes the face *f*.

• The minimum distance between the face space (*f*) and the training face is calculated by $\varepsilon_i = \|x - x_i\|$.The minimum distance as compared with a predefined threshold ϵ_0 for face classification.

Pang et.al [27] proposed fusion of SVD and LDA based face recognition to overcome the drawbacks of each other as well as to increase the recognition performance.

He et.al[28] presented a face recognition method in which Fourier transform is used to combine training image linearly into a new training image, yielding the face's spectrum representation, which is again projected into uniform Eigen space using SVD, producing a coefficient matrix, used as feature for recognition.

Chin et.al[29] proposed an approximate incremental Kernel SVD based Face Recognition algorithm to update in the nonlinear subspace with kernel trick .A reduced set construction method is also applied at each iteration for maintaining constant processing speed as well as memory usage.

Bengherabi et.al [30] proposed a face recognition algorithm in which score of SVD and regularized LDA in the DCT domain are fused. MIN –Max and Z-score normalization techniques are used before fusing the scores of SVD and RCT-LDA as their outputs are heterogeneous.

Cao et.al [31] presented a Face Recognition algorithm in which an improved feature extraction method using SVD in which a sampling window is used to sample overlapping which produce a number of matrices and the k-largest singular values for all these matrices are selected forming a group of vectors as the features of each sampling window in which Euclidean distance is used as classifier.

5. Genetic Algorithm

Melanie [33] discussed the idea of genetic algorithm. It consists of following operators:

- Selection: This operator selects the fittest chromosomes in the population for reproduction.
- Crossover*:* This step chooses a locus randomly and exchanges the subsequences before and after that locus between two chromosomes to create two offspring by recombination.
- Mutation***:*** This operator randomly flips some of the bits in a chromosome.
- Steps of GA:
- A randomly generated population of n number of ***l***−bit chromosomes are found out.
- Fitness $\boldsymbol{f(x)}$ of each chromosome $\boldsymbol{x}$ is calculated among the population.
- The above steps are repeated until *n* offspring have been created.
- The new population replaces the current ones.
- The above process is repeated till the most highly fit chromosome is found out.

Lee et.al [34] proposed a method of face recognition by using SVM as a classifier with the feature set extracted by GA. The feature set which are less dependent on illumination and expression can also be selected by using a tuning data set in the computation of the evaluation function.

Anam [35] proposed a face recognition system using GA and BPN. Feature extraction is done by converting the face image into binary whose centroid is found out, it is then cropped and converted into gray level. The above extracted features are given as the input to the BPN and GA in the third step where classification is done.

Behzad et.al [36] proposed face recognition based on PCA and genetic programming. Feature extraction is done using PCA and recognition is done using genetic programming. It is also mentioned that genetic programming alone is not suitable because of time and computational complexity is also low as proposed in this paper.

Ibrahem [37] proposed a face recognition technique in which genetic programming is used as face feature extractor. They discussed that recognition rate increases as the number of training samples increases and robust in intrinsic conditions such as varying lighting condition, varying facial expression, varying pose, etc.

6. Conclusion

Here, in this paper, we have discussed different techniques used in face recognition like PCA, LDA, GA, and SVD etc. We have discussed different approaches used in feature extraction and recognition phase for face recognition which are used by various researchers. This paper also gives the idea of the use of various new existing techniques which are developed by combining the various techniques in face recognition.

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