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Kernel Principle Component Analysis in Face Recognition System: A Survey

Ritu Upadhayay
M.Tech Scholar
CSE, SET, IFTM University, India

Rakesh Kumar Yadav
Computer Science & Engg.
SET, IFTM University, India

Abstract - Face recognition is a dynamic topic in the fields of biometrics. Many achievements have been obtained in face recognition. Principal Components Analysis (PCA) and kernel principal components Analysis (KPCA) is a elementary technique broadly used in face feature extraction and recognition. This research paper presents nitty-gritty of KPCA and an up to date review of techniques KPCA. Papers also notify benefits of KPCA over PCA. Finally, it finds that it is appropriate technique in face recognition system. Therefore, it will be a possibility to seek a good system using this approach.

Keywords: kernel, principal components Analysis, PCA, KPCA, Face recognition

I. Introduction

A face recognition system is automatically identify or verifies a person from a digital figure or a video frame. Many facial recognition algorithms identify faces by extracting landmarks, or features, from an image of the subject's face. A human face reveals a great deal of information to a perceiver. It may tell about mood and intention and attentiveness, but it can also serve to identify a person. A person can be identified by other means than the face. Voice, body shape, gait or even clothing may all establish identity in circumstances where facial detail may not be available. However, a face is the most distinctive and widely used key to a person's identity. The problem of automatic [1] face recognition contains three key steps: 1.Detection and rough normalization of faces 2. Feature extraction and accurate normalization of faces 3. Identification or verification.

A. Face Detection:

This step is to determine, whether human faces appear in a given image, and where these faces are located at. The estimated results of this step are patches containing each face in the input image. With the intention of [2] making further face recognition system more healthy and easy to design, face configuration are performed to justify the scales and orientations of these patches. Besides serving as the preprocessing for face recognition, face detection could be used for region of interest detection, retargeting, video and image classification, etc.

B. Feature Extraction:

After the face detection step, human-face patches are extracted from images. Directly using these patches for face recognition have some disadvantages, first, each patch usually contains over 1000 pixels, which are too large to build [2] a robust recognition system. Second, face patches may be taken from different camera alignments, with different face expressions, illuminations, and may suffer from occlusion and clutter. To conquer these drawbacks, feature extractions are performed to do in-formation packing, dimension reduction, salience extraction, and noise cleaning. In several literatures, feature extraction is either included in face detection or face recognition.

C. Role of Face Recognition

Face recognition is used for two primary tasks: [3][4]. First is verification (one-to-one matching): When presented with a face image of an unknown individual along with a claim of identity, ascertaining whether the individual is who he/she claims to be. Second is identification (one-to-many matching): Given an image of an unknown individual, determining that person's identity by comparing (possibly after encoding) that image with a database of (possibly encoded) images of known individuals. There are numerous application areas in which face recognition can be exploited verification and identification a few of which are outlined below Table 1.

Table 1: Applications of Face recognition System

Area	Examples
Security	access control to buildings, airports/seaports, ATM machines, email authentication on multimedia workstations

Surveillance	a large number of CCTVs can be monitored to look for known criminals, drug offenders, thieves
identity verification	electoral registration, banking, electronic commerce, identifying newborns, national IDs, passports, drivers' licenses, employee IDs
Criminal justice systems	mug-shot/booking systems, post-event analysis, forensics
Image database investigations	searching image databases of licensed drivers benefit recipients, missing children, immigrants and police bookings
Smart Card	SIM Card
Note :Multi-media environments with adaptive human computer interfaces, Video indexing, Witness faces reconstruction are may be defined as are of Face recognition	

On the basis of latest researches, eigenface technique is found as most populating technique of statistics. It is also known as Principle component analysis (PCA) .Today, numerous extension of PCA are exiting like Improved PCA, Fuzzy PCA, Incremental PCA, and Kernel PCA.

II. PCA

The PCA classifier is one of the oldest and simplest methods for classification. PCA involves a mathematical course of action that transform a number of possible correlated variable into a smaller no of uncorrelated variable called principle component. PCA is mathematically defined as an orthogonal linear transform that transform the data to a new coordinate system such that greatest variance by any projection of the statistics comes to lie on the first coordinate. The second greatest variance on the second coordinates and so on. PCA computes means, variances, covariance's, and [5] correlations of large data sets. PCA computes and ranks principal components and their variances. Automatically transforms data sets. PCA can analyze datasets up to 50,000 rows and 200 columns. The basic Benefit in PCA is to reduce the dimension of the data. I this no data redundancy as components is Orthogonal. With help of PCA, complexity of grouping the images can be reduced.

A. Improved PCA

Original face image [6] can be represented as a two-dimensional matrix. In some methods, this face image matrix must be converted into a high-dimensional vector. So it is very difficult to process and recognize the face image matrix directly. Thus the first step need reduce the dimensions of face matrix. It is necessary to obtain the main features to represent the whole face. PCA is designed to transform a high-dimensional image into a low-dimensional one. It is based on statistical features, and eigenvectors of covariance matrix from a set of face image samples are used to represent the whole face features approximately.

B. Fuzzy PCA

PCA does not always show the real similarities structure on the data in the higher dimensional space. In order to resolve this problem we use Fuzzy PCA. To get data into more feasible form we use fuzzy PCA. Fuzzy two-dimensional principal component analysis [7] (F2DPCA), which combines the two-dimensional principal component analysis (2DPCA) and fuzzy set theory. 2DPCA preserve the total variance by maximizing the trace of feature variance, but 2DPCA cannot preserve local information due to pursuing maximal variance. So, the fuzzy two-dimensional principal component analysis (F2DPCA) algorithm is proposed, in which the fuzzy k-nearest neighbor (FKNN) is implemented to achieve the distribution local information of original samples.

C. Incremental PCA

According to [8], many PCA-based face-recognition systems have also been developed in the last decade. However, existing PCA-based face recognition systems are hard to scale up because of the computational cost and memory-requirement burden. To overcome this limitation, an incremental approach is usually adopted. Incremental PCA (IPCA) methods have been studied for many years in the machine-learning community. The major limitation of existing IPCA methods is that there is no guarantee on the approximation error.

D. Kernel PCA

Traditional PCA only allows linear dimensionality [9] reduction. However, if the data has more complicated structures, which cannot be simplified in a linear sub-space, traditional PCA will become invalid. Fortunately, Kernel PCA allows us to generalize traditional PCA to nonlinear dimensionality reduction. A kernel principal component analysis (PCA) was previously proposed as a nonlinear extension of a PCA. The basic idea is [11] to first map the input space into a feature space via nonlinear mapping and then compute the principal components in that feature space. This article adopts the kernel PCA as a mechanism for extracting facial features. Through adopting a polynomial kernel, the principal
Components can be computed within the space spanned by high-order correlations of input pixels making up a facial image, thereby producing a good performance. KPCA is a development of the PCA method.

III. Study of Existing Model of PCA and KPCA in Face Recognition System

A. Model of PCA

PCA is designed to transform a high-dimensional image into a low-dimensional one. It is based on statistical features, and eigenvectors of covariance matrix from a set of face image samples are used to represent the whole face features approximately. Fig 1 is best represented of PCA method

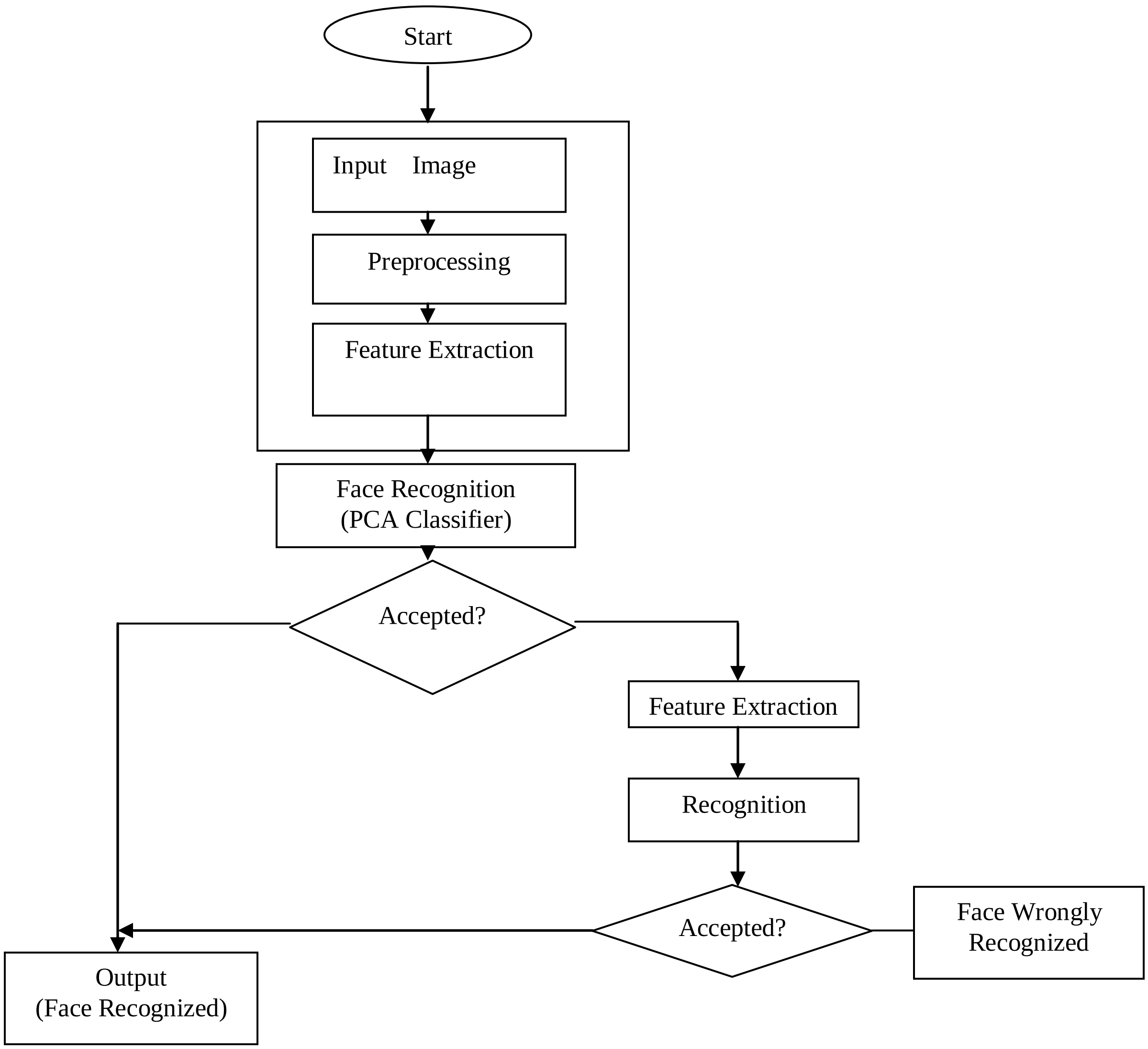

Fig 1: Model of PCA face recognition

PCA algorithm [10]

1. Subtract the mean from all the data points
2. Compute the covariance matrix S=

$$\sum_{n=1}^{c} x_n x_n^{\ T}$$

3. Diagonalize S to get its eigenvalues and eigenvectors
4. Retain c eigenvectors corresponding to the c largest eigenvalues such that

$$\sum_{j=1}^{c} \lambda_j / \sum_{j=1}^{N} \lambda_j$$

equals the desired variance to be captured

5. Project the data points on the eigenvectors

$$a_n = E^T\left(x_k - \frac{1}{N}\sum_{i=1}^{N} x_i\right)$$

Limitations of PCA

I. The directions with largest variance are assumed to be of most interest.
II. We only consider orthogonal transformations (rotations) of the original variables. (Kernel PCA is an extension of PCA that allows non-linear mappings).
III. PCA is based only on the mean vector and the covariance matrix of the data. Some distributions are completely categorized by this, but others are not.
IV. Dimension reduction can only be achieved if the original variables were correlated. If the original variables were uncorrelated, PCA does nothing, except for ordering them according to their variance.
V. PCA is not scale invariant.

Existing face recognition system using Kernel PCA has the limitations of low accuracy and more space complexity. Using Improved Kernel PCA this limitation may be removed which will make face recognition system more accurate and less space occupied. Therefore, it is required to further study to KPCA.

B. Model of KPCA

Fundamentally, the KPCA is used to tackle the nonlinearity of face recognition problem. By using a nonlinear kernel function, a dimensional reduction (i.e., nonlinear projection) is performed. The images are first transformed from image space into a feature space. In the feature space, the manifolds of the data become simple. Fig 2 is best represented of KPCA method in Face recognition of Training and Testing Phase

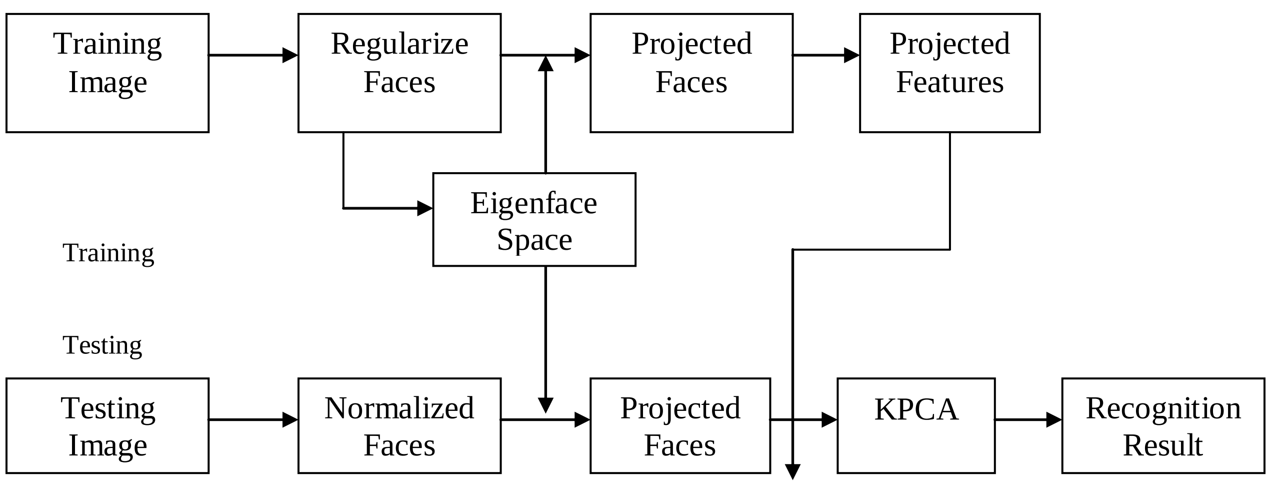

Fig.2. Model of KPCA face Recognition System

Kernel PCA algorithm

1. Given N data points in d dimensions let $X=\{x_1|x_2|..|x_N\}$ where each column represents one data point
2. Subtract the mean from all the data points
3. Choose an appropriate kernel k
4. Form the NxN Gram matrix $K|_{ij}=[k(x_i,x_j)\}$
5. Form the modified Gram matrix

$$\widetilde{K} = \left(I - \frac{1_{NxN}}{N}\right)^T K\left(I - \frac{1_{NxN}}{N}\right)$$

Where 1NxN is an NxN matrix with all entries equal to 1

6. Diagonalize K to get its eigenvalues l_n and its eigenvectors a_n

7. Normalize $a_n \leftarrow a_n / \sqrt{\lambda_n}$
8. Retain c eigenvectors corresponding to c largest eigenvalues such that
$$\sum_{j=1}^{C} \lambda_j / \sum_{j=1}^{N} \lambda_j$$
Equals desired variance to be captured
9. Project the data points on the eigenvectors
$$y = a^T \left(I - \frac{1_{NxN}}{N} \right) \left(\begin{bmatrix} k(x_1, x) \\ \ldots \\ k(x_N, x) \end{bmatrix} - K \frac{1_{NxN}}{N} \right)$$

Subsequent to technical study it requires to survey of existing work.

IV. Survey

In reference [12, 2001], principal component analysis and fisher linear discriminate methods was demonstrated their success in face detection, recognition and tracking. The representation in these subspace methods was based on second statistics of the image set, and does not address higher order statistical dependencies such as the relationships among three or more pixels. This paper investigates the use of kernel principal component analysis and kernel fisher linear discriminates for learning low dimensional representations for face recognition. Experimental result shows that kernel methods provide better representations and achieve lower rates for face recognition. A kernel principal component analysis (PCA) [11, 2002] was previously proposed as a nonlinear extension of a PCA. The basic idea was to first map the input space into a feature space via nonlinear mapping and then compute the principal components in that feature space. This article adopts the kernel PCA as a mechanism for extracting facial features. Through adopting a polynomial kernel, the principal components can be computed within the space spanned by high-order correlations of input pixels making up a facial image, thereby producing a good performance. Reference [13, 2010], was presented a face recognition method based on the combined kernel principal component analysis (KPCA) and support vector machine (SVM) methods. First, the KPCA method is utilized to extract features from the input images. The SVM method is then applied to these extracted features to classify the input images. We compare the performance of this face recognition method to other commonly-used methods. Experiments show that the combination of KPCA and SVM achieves a higher performance compared to the nearest neighbor classifier, support vector machine, and the combination of kernel principal component analysis and nearest neighbor classifier. Therefore, this paper motivates to use of KPCA. This paper [14, 2011] was applied KPCA to construct a reduced-order stochastic input model for the material property variation in heterogeneous media. KPCA can be considered as a nonlinear version of PCA. Through use of kernel functions, KPCA further enables the preservation of higher-order statistics of the random field, instead of just two-point statistics as in the standard Karhunen–Loève (K–L) expansion. Thus, this method can model non-Gaussian, non-stationary random fields. This paper was also proposed a new approach to solve the pre-image problem involved in KPCA. Moreover, polynomial chaos (PC) expansion was used to represent the random coefficients in KPCA which provided a parametric stochastic input model. Thus, realizations, which are statistically consistent with the experimental data, can be generated in an efficient way. Paper [9,2012], firstly talk about the basic ideas of PCA and kernel PCA, and then focus on the reconstruction of pre-images for kernel PCA. This also given an introduction on how PCA is used in active shape models (ASMs), and discussed how KPCA can be applied to improve traditional ASMs. Experiment results were comparing the performance of kernel PCA and traditional PCA for pattern classification. It also finds that KPCA is much better than traditional PCA According to [15, 2012], practical face recognition systems were sometimes confronted with low-resolution face images. To address this problem, a super-resolution method was presented that used nonlinear mappings to infer coherent features that favor higher recognition of the nearest neighbor (NN) classifiers for recognition of single LR face image. Canonical correlation analysis was applied to establish the coherent subspaces between the PCA based features of high-resolution (HR) and LR face images. The obtained features from PCA were not good enough for dimensionality reduction and computational complexity when large set of databases are taken into consideration. To overcome that problem Kernel PCA is introduced. Then, a nonlinear mapping between HR/LR features can be built by radial basis functions (RBFs) with lower regression errors in the coherent feature space than in the KPCA feature space. Thus, it may compute super-resolved coherent features corresponding to an input LR image according to the trained RBF model efficiently and accurately. And, face identity can be obtained by feeding these super-resolved features to a simple NN classifier. Extensive experiments on the Yale database show that the proposed method outperforms the state-of-the-art face recognition algorithms for single LR image in terms of both recognition rate and robustness to facial variations of pose and expression. In this paper [16, 2012], face recognition was done using two feature extraction techniques PCA and MPCA (Modular Principal Component Analysis). PCA is a linear projection method in which dimensionality reduction is applied to the original image space. MPCA is an improved version of PCA in which each image is divided into number of sub-block image and then PCA is applied for each sub-block image. The experimental result was showed that the accuracy of PCA is les than MPCA for different database images. However, this paper was not attempt t KPCA technique. This is author's opinion that it may be used. Paper also motivated that any researcher's may be used any other extension version of PCA or MPCA. Once reviewing of above existing system using Kernel PCA, It is found that this system has the limitations of low accuracy and more space complexity. Therefore, it is necessary to improve Kernel PCA.

V. Conclusions and future work

Principal component analysis (PCA) is a popular tool for feature extraction and linear dimensionality reduction the representation in these subspace methods is based on second order statistics of the image set. It does not address higher order statistical dependencies such as the relationships among three or more pixels. Kernel PCA is the nonlinear form of PCA, which is capable in exposing the more complicated correlation between original high-dimensional features. The basic idea is to first map the input space into a feature space via nonlinear mapping and then compute the principal components in that feature space. Through adopting a kernel concept, the principal components can be computed within the space spanned by high-order correlations of input pixels making up a facial image, thereby producing a good performance. Some difficulties still exist in practical applications of KPCA. So it is essential to improve traditional methods of face recognition. . Once reviewing of above existing face recognition system using KPCA, We obtained highest recognition rate as 98 %. Once reviewing of existing face recognition system using KPCA, It is found that this system has the limitations of low accuracy and more space complexity. Therefore, it is necessary to improve Kernel PCA.

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