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An Exploratory Survey on Various Face Recognition Methods Using Component Analysis

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Abstract: Development in Human Computer Interactions (HCI) helps in budding user friendly systems to communicate with computers. One of the fundamental techniques that aid Human Computer Interaction (HCI) is face recognition. Face recognition is one of the most successful applications of image analysis and pattern recognition. Principle Component Analysis (PCA) is considered as the first real time face recognition technology. This paper compares the different PCA methods with standard PCA using eigenfaces. The methods considered in this paper are Kernel PCA, PCA with Image Gradient Orientation, PCA with Singular Value Decomposition and Diagonal PCA with KNN. This paper also suggests a statistical method for face recognition using the component analysis of difference image.

Keywords: Image Processing; Face Recognition PCA; IGO PCA; KPCA; PCA with SVD; DiaPCA

I. INTRODUCTION

Development in Human Computer Interactions (HCI) helps in budding user friendly systems to communicate with computers. One of the fundamental techniques that aid Human Computer Interaction (HCI) is face recognition. Face recognition is one of the most successful applications of image analysis and pattern matching. It has a wide range of industrial and law enforcement applications [1]. One of the first researches on this subject was done by Woodrow W. Bledsoe in 1960[2][3]. But the system is not reliable for recognizing faces in real time. The performance of the system decline circumstances like changes in pose variation, illumination, disguise, expression aging etc.

Study of information in digital images is become increasingly important in many technical and scientific fields, especially in biological sciences. Biometrics uses biological trait to verification of identity of a person. The fundamental principle behind biometrics is that human body contains unique characteristics that can be used to differentiate one person from other persons. Facial recognition techniques one of the major biometric techniques, that has a number of advantages over other biometrics. Human face is irrefutable measure for personal identity. Face recognition system doesn't need to interact with the user. While many biometrics require the subject's assistance and knowledge in order to perform identification, face recognition could be done even without the subject's knowledge. A credible face recognition system can always be confirmed by a human.

The face recognition system has major application areas as Law Enforcement, entertainment, forensic and access control etc. A reliable face recognition system will help to improve the security of the airport, seaport and train stations from treacherous terrorist attacks. Current access control systems are using cards and passwords for personal verification. The ATM card or passwords may be forged or misplaced. For accessing different systems we need to remember different passwords. All these issues of current applications make a real-time face recognition system vital. The face recognition software is able to quickly verify a customer's face, the ATM or check-cashing kiosk captures a digital image of a person and verify the person identity. But the existing face recognition systems are not reliable for accurate real time recognitions. The performance of the present face recognition system deteriorates while severe changes in lighting condition, scaling, occlusion or pose variation occurs.

The paper is organised as follows: Section II discusses the literature review. Section III Summarise the standard PCA method using eigenfaces for face recognition. Different statistical approaches to improve the result of PCA under certain constraints like pose variation, illumination, occlusion, expression evaluation; age grouping using PCA is presented in section IV. A discussion on the comparative study done on the various PCA techniques with Standard PCA and its summary is presented in Section V. The paper is concluded in Section VI.

II. LITERATURE REVIEW

The various methods for face detection can be grouped into four categories: knowledge-based methods, feature invariant

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approaches, template matching methods, and appearance-based methods [1]. Knowledge-based methods are rule-based methods. These methods try to capture human knowledge of faces, and translate them into a set of rules. The feature invariant approach finds some invariant features for face recognition. The idea is to overcome the limits of our instinctive knowledge of faces. The template matching methods compare input images with stored patterns of faces or features.

The Appearance-based methods rely on techniques from statistical or probabilistic analysis and machine learning to find the relevant characteristics of face images. In general, appearance-based methods had been showing superior performance to the others.

Statistical methods provide a way for estimating missing or uncertain information. The statistics works on a big set of data, we want to analyse that set in terms of the relationships between the individual points in that data set. PCA is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. The other main advantage of PCA is data compression, by reducing the number of dimensions, without much loss of information.

The predominant appearance based face recognition methods are Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) and Independent Component Analysis (ICA) [1]. PCA find the Eigen values and corresponding Eigen vectors of the data set using covariance matrix [4][5]. It transforms the face images into a set of basic faces, which essentially are the principal components of the face images. LDA (Fisher-faces) is another dimensionality reduction technique used for face recognition discussed in [6][7][8].

LDA maximize between class scattering matrix measure while minimize the within class scatter matrix measure, which make it more reliable for classification. The ratio of the between class scatter and within class scatter must be high.ICA is a generalization view of the PCA [9].It minimizes both second-order and higher order dependencies in the input data and attempts to find the basis along which the data are statistically independent.

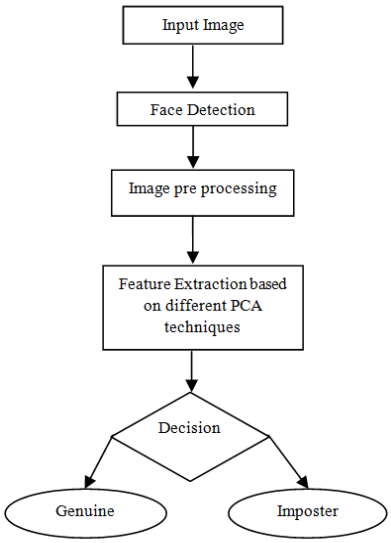

Figure 1. Face recognition system using Different PCA techniques

Eigenface method (appearance based) is one of the first successful approaches for face recognition. When only one image per person is available for training, most face recognition methods fail, while variants of PCA work well [10]. Face detection or recognition systems are facing several challenges [1][11]. These challenges are present in images captured in unpredicted environments. After the success of PCA, different statistical approaches to improve the result of eigenfaces under certain constraints are developed. This paper compares the different methods with standard PCA using eigenfaces. A comparison on the different eigenface methods using PCA is summarised, that in turn aids in developing an efficient face recognition method with promising characteristics. In this paper we also propose a statistical method for face recognition using component analysis of difference images.

III. EIGENFACE APPROACH USING PCA

Eigenface method for face recognition using PCA was proposed by Kirby and Sirovich (1990) and implemented by Turk and Pentland (1991) [4][5]. Eigenfaces uses an information theory approach, in that most significant face information is extracted in a group of faces that will best discriminate the faces. The principle components of the face images (Eigen Vectors) will have input from each image in the training set. It will have a face like look, so it is known as eigenfaces. The prefix Eigen is German word "eigen" for "own" in the sense of a trait description. The basic steps for calculating principal component are given by the following algorithm.

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1. Represent each image I_i as a vector T_i (All images are N X N matrices, which can be represented as N^2 X 1 dimensional vector, i=1.....M)

2. Computation of the global mean

$$\Psi = 1/M \sum_{n=1}^{M} T_n$$

3. Subtraction of the mean from each image ("removing" information that is common)

$$\Phi_i = Ti - \Psi$$

4. Find the Covariance matrix $C=AA^T$
Where $A = [\ \Phi_1, \Phi_2, \ldots\ldots \Phi_M]$, A is a N^2X M matrix

5. Calculate the eigenvectors u_i and eigenvalue λ_i of C such that

$$Cu_i = \lambda_i u_i$$

6. Dimensionality reduction step: Keep only the Eigen vectors corresponding to K largest Eigen values. These Eigen values are called as "principal components"

The dimensionality step is the most important feature of PCA. The most significant principal components are selected based on a trial and error basis. The fig2 explain the face recognition system using PCA.A threshold value is set to reduce the false acceptance rate. The selection of threshold is done heuristically.

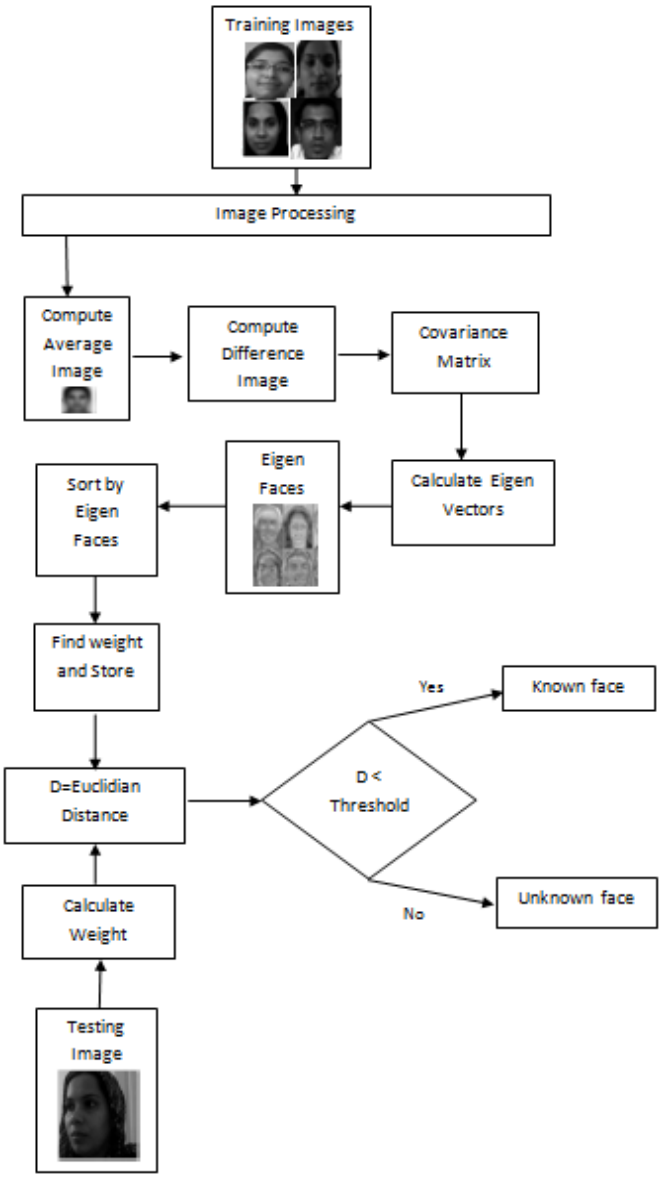

FIG 1. FLOW CHART OF FACE RECOGNITION USING PCA

IV. DIFFERENT PCA TECHNIQUES FOR FACE RECOGNITION

This section summarizes different statistical approaches of PCA. Kernel PCA, PCA with Image Gradient Orientation, PCA with Singular Value Decomposition and Diagonal PCA with KNN are the methods considered in this paper.

A. Kernel Principle component Analysis

The representation in PCA is based on the second order statistics of the image set, and does not address higher order statistical dependencies such as the relationships among

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three or more pixels [12]. PCA aims to find a second order correlation of patterns, kernel PCA provides a replacement which takes into account higher order correlations. Recognition results of kernel PCA outperforms the PCA method in face recognition.

Given a set of m centered sample x_k, KPCA finds each vector x is projected from the input to high dimensional feature space by a nonlinear mapping function Φ, the corresponding eigen values and eigen vector problem is

$$C^{\Phi} u^{\Phi} = \lambda u^{\Phi}$$

C^{Φ} is covariant matrix, u^{Φ} is eigen vector, λ is eigen value.

PCA is compared with KPCA using two image databases [12]. The first experiment with Yale database consists of 165 images of 11 subjects including variation in lighting and expression. The second experiment with AT & T database consists of 400 images of 40 subjects including variation in facial expression and pose but same lighting condition. The result shows that the KPCA method has lesser error rate than PCA method for both the experiments.

B. Principal Component Analysis of Image Gradient Orientations for Face Recognition (IGO PCA)

This method is based on image gradient orientation and a cosine-based distance measure, provides better result compared with PCA for images containing illumination changes, shadow, reflections or occlusion [13].For a given a set of n images {Ii}, corresponding set of orientation images are computed as {Φi}. The equation below represents the measurement of image correlation using the cosine kernel .

$$s(\Phi_i, \Phi_j) \triangleq \sum_{k \in P} \cos[\Delta \Phi_{ij}(k)] = cN(P)$$

Where $c \in [-1, 1]$.

For face reconstruction 50 aligned face images of the Yale B face database were used[13]. The images capture the face of the same subject under different lighting conditions. Two versions of this experiment are performed. The first version used the set of original images. In the second version, 20% of the images were artificially occluded. The result shows that for the 2nd version IGO PCA perform better than PCA. For face recognition the AR database is used, this database consists of more than 4,000 frontal view facial images of 126 subjects. From 126 subjects 100 subjects are randomly selected and 2 experiments were carried out. The first experiment is tested with images of different illumination. The second experiment is tested with images of different occlusion. The recognition rate of experiment 1 and 2 for IGO PCA are 99.67% and 94%, where as intensity based PCA are 74% and 28% respectively.

C. PCA with SVD(Singular Value Decomposition)

Facial expression recognition technique PCA with SVD (Singular Value Decomposition) is superior to Principal Component analysis (PCA) in terms of recognition rate [14]. The universally accepted five principal emotions considered are: angry, happy, sad, disgust and surprise along with neutral. SVD in digital applications provides a robust method of storing large images to smaller and manageable images. The singular value decomposition of a matrix A of m x n matrix is given in the below form,

$$A = U \Sigma V^T$$

Where U is an m x m orthogonal matrix; V an n x n orthogonal matrix, and Σ is an m x n matrix containing the singular values of A along its main diagonal. The singular values α1 α2……, αn are unique, however, the matrices U and V are not unique.

D. Effective Method of Age Dependent Face Recognition(Using DiaPCA)

This approach is based on the Principle Component Analysis using Diagonal PCA (DiaPCA) and K^{th} nearest neighbour classifier (KNN)[15][16]. In contrast to standard PCA, DiaPCA directly seeks the optimal projective vectors from diagonal face images without image-to-vector transformation. The diagonal image B for the original image A is generated. Based on the diagonal faces, the diagonal covariance matrix is define as

$$C = 1/M \sum_{k=1}^{m} (Bk - \bar{B})^T (Bk - \bar{B})$$

Where $\bar{B} = 1/M \sum_{k=1}^{m} Bk$ is the mean diagonal face.

Experiments show that DiaPCA is much more accurate than PCA[14]. KNN is very compatible and very robust to image distortion (rotation, illumination). Therefore, good results can be produced by combining DiaPCA and KNN. It will reduce the time complexity using this approach. The proposed method preserves the identity of the subject while enforcing a realistic recognition effects on adult facial images between 15 to 70 years old and divided into 13 classes with 5 years old range. The accuracy of the system is analyzed by the variation on the range of the age groups.

Face region is extracted from a real image. Noise filtering and image adjusting process are performed for image enhancing. Thirteen age groups are included in a face database. All weight vectors of the person same age group are averaged together. This is known as "face class". When a new image comes in, its weight vector is created by projecting it onto the face space. The face, is then matched

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TABLE 1

COMPARISON OF DIFFERENT PCA METHODS

Methods	Property	Characteristics	Memory Requirement	Computation Complexity	Performance
PCA	Intensity	Pixel wise covariance	Less	Simple	Real-time face recognition system
KPCA	Intensity	Higher order correlations between pixels	More than PCA	More than PCA	KPCA outperform PCA
IGO-PCA	Gradient	Gradient orientation differences	Less than PCA	Less than PCA	Better performance for illumination and occlusion
PCA with SVD	Intensity	PCA calculated from SVD	Less than PCA	More than PCA	Better performance for expression analysis
DiaPCA with KNN	Intensity	Diagonal PCA	Less than PCA	Less than PCA	Better processing time for age grouping

each face class that is minimum Euclidean distance. DiaPCA have better performance that PCA.

V. DISCUSSION.

Section IV spots on Kernel PCA, PCA with Image Gradient Orientation, PCA with Singular Value Decomposition and Diagonal PCA with KNN. All this methods performs better than standard PCA with eigenfaces. Table 1 summarises the comparison of the above methods with standard PCA with eigenfaces. KPCA method shows low error rate than PCA method but the computation is more complex. IGO PCA uses image gradient orientation and a cosine-based distance measure. It provides better results for image reconstruction and recognition compared with PCA for images containing illumination changes or occlusion. PCA of gradient orientations is significantly faster and very robust. PCA with SVD is superior to the PCA technique in terms of recognition rate .Computation time of PCA with SVD is more than PCA and the memory requirement is less than PCA. DiaPCA with KNN performs better than PCA for age grouping and require less memory and computation.

All the above methods are appearance based methods using statistical or probabilistic analysis of images to recognise faces. Humans are identifying one person from another by analysing the difference in features of each person.The Minimum distance measure is one of the major pattern recognition techniques. In this paper we suggest a novel face recognition method using difference component. The difference between two images needs to find initially, this difference image can be termed as difference components. Two exactly matching images have zero difference component. Statistical analysis of this difference component can be done to recognize the person. The difference component of the testing and training images needs to find, and classify the testing image as the least difference component training image.

VI. CONCLUSION

Various approaches to improve the performance of PCA are discussed in this paper. The limitation observed during the comparison is that, each method uses different databases. This paper compares the different methods with standard PCA using Eigenface. Kernel PCA has a less error rate than PCA under constraints like different lighting condition, expression and posing. PCA with Image Gradient Orientation gives better result under constraints like illumination and occlusion. PCA with SVD have good performance for expression analysis. Age grouping and age prediction can be done more efficiently using Diagonal PCA with KNN. A comparison of the different Eigenface methods using PCA is summarised, that in turn aids in developing an efficient face recognition method with promising characteristics. We proposed a new pattern recognition method using difference components analysis .The new method works on the difference components of the two images. This anticipates the improvement in recognition rates because the unnecessary information, that may be noise in the classification, is discarded.

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