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Critical Review on Face Recognition Algorithms

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ABSTRACT
Face Recognition has always been a fascinating research area. It has drawn the attention of many researchers because of its various potential applications such as security systems, entertainment, criminal identification etc. The goal of this paper was to produce a review of the face detection and face recognition literature as comprehensive as possible.

Keywords
Image Processing, Face Recognition, ICA, IPCA, PCA

1. INTRODUCTION
Face recognition is one of the most relevant applications of image analysis. It's a true challenge to build an automated system which equals human ability to recognize faces. Although humans are quite good identifying known faces, we are not very skilled when we must deal with a large amount of unknown faces. The computers, with an almost limitless memory and computational speed, should overcome human limitations. Today, we have a variety of biometric techniques like fingerprints, iris scans, and speech recognition etc. but among of them face recognition is still most common technique which is in use. It is only due to the fact that it does not require aid or consent from the test subject and easy to install in airports, multiplexers and other places to recognize individuals among the crowd.
The technologies using face recognition techniques have also evolved through the years now days diverse enterprises are using face recognition in their products one good example could be entertainment business. Products like Microsoft's Project Natal or Sony's PlayStation Eye will use face recognition. It will allow a new way to interact with the machine. The idea of detecting people and analyzing their gesture is also being used in automotive industry. Companies such as Toyota are developing sleep detectors to increase safety. These and other applications are raising the interest on face recognition. It's narrow initial application area is being widened.
The challenges of facial recognition in the visible spectrum include reducing the impact of variable lightning and detecting a mask or photograph. Some facial recognition systems may require a stationary or posed user in order to capture image through many systems, though many systems use a real time process to detect a person's head and locate the face automatically.
Most research on face recognition falls into two main categories (Chellappa et al., 1995): feature-based and holistic. Geometric approaches dominated in the 1980's where simple measurements such as the distance between the eyes and shapes of lines connecting facial features were used to recognize faces, while holistic methods became very popular in the 1990's with the well-known approach of Eigen-faces .

2. SYSTEM STRUCTURE
The input of a face recognition system is always an image or video stream. The output is an identification or verification of the subject or subjects that appear in the image or video. Some approaches define a face recognition system as a three step process - see Figure 1.

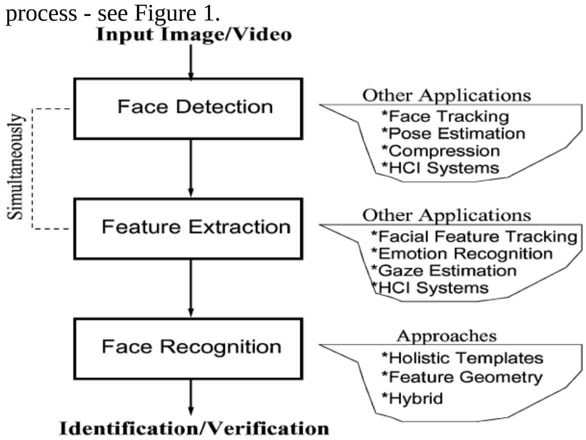

Figure 1: Face recognition structure [11]

Finally, the system does recognize the face. In an identification task, the system would report an identity from a database. This phase involves a comparison method, a classification algorithm and an accuracy measure. This phase uses methods common to many other areas which also do some classification process -sound engineering, data mining et al. These phases can be merged, or new ones could be added. Therefore, we could find many different engineering approaches to a face recognition problem. Face detection and recognition could be performed in tandem, or proceed to an expression analysis before normalizing the face.

3. LITERATURE SURVEY
The method for acquiring face images depends upon the underlying application. For instance, surveillance applications may best be served by capturing face images by means of a video camera while image database investigations may require static intensity images taken by a standard camera. Some other applications, such as access to top security domains, may even necessitate the forgoing of the nonintrusive quality of face recognition by requiring the user to stand in front of a 3D scanner or an infra-red sensor. Therefore, depending on the face data acquisition methodology, face recognition techniques can be broadly divided into three categories: methods that operate on intensity images, those that deal with video sequences, and those that require other sensory data such as 3D information or infrared imagery. The following discussion sheds some light on the methods in each category and attempts to give an

idea of some of the benefits and drawbacks of the schemes mentioned therein in general

3.1 Feature-Based Face Detection

Feature-based approaches first process the input image to identify and extract (and measure) distinctive facial features such as the eyes, mouth, nose, etc., as well as other fiducially marks, and then compute the geometric relationships among those facial points, thus reducing the input facial image to a vector of geometric features. Standard statistical pattern recognition techniques are then employed to match faces using these measurements [5].

Early work carried out on automated face recognition was mostly based on these techniques. One of the earliest such attempts was by Kanade, who employed simple image processing methods to extract a vector of 16 facial parameters - which were ratios of distances, areas and angles (to compensate for the varying size of the pictures) -and used a simple Euclidean distance measure for matching to achieve a peak performance of 75% on a database of 20 different people using 2 images per person (one for reference and one for testing). More sophisticated feature extraction techniques involve deformable templates, Hough transform methods, Reisfeld's symmetry operator and Graf's filtering and morphological operations. Another well-known feature-based approach is the elastic bunch graph matching method proposed by Wiskott et al[11] . This technique is based on Dynamic Link Structures. The main advantage offered by the featured-based techniques is that since the extraction of the feature points precedes the analysis done for matching the image to that of a known individual, such methods are relatively robustto position variations in the input image. In principle, feature-based schemes can be made invariant to size, orientation and/or lighting [5]. Other benefits of these schemes include the compactness of representation of the face images and high speed matching .The major disadvantage of these approaches is the difficulty of automatic feature detection (as discussed above) and the fact that the implementer of any of these techniques has to make arbitrary decisions about which features are important. After all, if the feature set lacks discrimination ability, no amount of subsequent processing can compensate for that intrinsic deficiency [19] .

3.2 Holistic Based Face Detection

Holistic approaches attempt to identify faces using global representations, i.e., descriptions based on the entire image rather than on local features of the face. These schemes can be subdivided into two groups: statistical and AI approaches. An overview of some of the methods in these categories follows.

3.2.1Statistical

In the simplest version of the holistic approaches, the image is represented as a 2D array of intensity values and recognition is performed by direct correlation comparisons between the input face and all the other faces in the database [5]. Sirovich and Kirby were the first to utilize Principal Components Analysis (PCA) to economically represent face images [12]. They demonstrated that any particular face can be efficiently represented along the Eigen pictures coordinate space, and that any face can be approximately reconstructed by using just a small collection of Eigen pictures and the corresponding projections ('coefficients') along each Eigen picture.

3.2.2 AI

AI approaches utilize tools such as neural networks and machine learning techniques to recognize faces. In, 50 principal components were extracted and an auto-associative neural network was used to reduce those components to five dimensions. A standard multi-layer perception was exploited to classify the resulting representation. Though favorable results were received, the database used for training and testing was quite simple: the pictures were manually aligned, there was no lighting variation, tilting, or rotation, and there were only 20 people in the database [5]. The main advantage of the holistic approaches is that they do not destroy any of the information in the images by concentrating on only limited regions or points of interest, several of holistic algorithms have been modified and/or enhanced to compensate for such variations, and dimensionality reduction techniques have been exploited (note that even though such techniques increase generalization capabilities, the downside is that they may potentially cause the loss of discriminative information), as a result of which these approaches appear to produce better recognition results than the feature-based ones in general[5]. In the latest comprehensive FERET evaluation, the probabilistic Eigen face, the Fisher face and the EBGM methods were ranked as the best three techniques for face recognition [4].

3.3Holistic Based Single Classifier Systems

3.3.1 Principal Component Analysis (PCA) Approach

PCA calculates the Eigen vectors of the covariance matrix, and projects the original data onto a lower dimensional feature space, which is defined by Eigen vectors with large Eigen values[13]. PCA has been used in face representation and recognition where the Eigen vectors calculated are referred to as Eigen faces. Eigen faces have been used to track human faces. They use a principal component analysis approach to store a set of known patterns in a compact subspace representation of the image space, where the subspace is spanned by the Eigen vectors of the training image set [10]. PCA is a useful statistical technique that has found application in fields such as face recognition and image compression, and is a common technique for finding patterns in data of high dimension. The basic goal is to implement a simple face recognition system, based on well-studied and well-understood methods. One can choose to go into depth of one and only one of those methods. The method to be implemented is the PCA (Principle Component Analysis). It is one of the more successful techniques of face recognition and easy to understand and describe using mathematics. This method involves using Eigen faces. The first step is to produce a feature detector (dimension reduction). Principal Components Analysis (PCA) was chosen because it is the most efficient technique, of dimension reduction, in terms of data compression [12, 15]. This allows the high dimension data, the images, to be represented by lower dimension data and so hopefully reducing the complexity of grouping the images. The basic Benefit in PCA is to reduce the dimension of the data. No data redundancy as components is Orthogonal. With help of PCA, complexity of grouping the images can be reduced. Application of PCA in the prominent field of criminal investigation is beneficial. CA also benefits entrance control in buildings, access control for computers in general, for automatic teller machines in particular, day-to-day affairs like withdrawing money from bank account, dealing with the post office, passport verification, and identifying the faces in a given databases. PCA computes means, variances, covariance, and correlations of large data sets PCA computes and ranks principal components and their variances [4].

3.3.2Incremental Principal Component Analysis (IPCA)

A shortcoming of the training process for PCA is that the entire training dataset images must be available beforehand in order to start the training process. This defect is elegantly handled by Incremental PCA (IPCA) methods which allow adding new images and updating the PCA representation accordingly; thus offering the great benefit of dispensing with the recently added images after model update. Incremental PCA methods have been studied by several researchers [3, 6]. Ref [3] presented a weighted and robust incremental method for subspace learning based on incremental method, which sequentially updates the principal subspace. In this method, the staring state can be obtained by two approaches:

(1) Batch PCA is applied on an initial set of images to obtain the average images, the eigenvectors, and the weight coefficients;

(2) The first training image is used to set the initial Eigen space, thus the algorithm is fully incremental from the start.

The incremental methods proposed in [6,8] are tailored for temporally weighted learning allowing newer images to have a larger influence on the estimation of the current subspace than the older ones. Ref [8] studied incremental learning for online face recognition and proposed new approach to face recognition in which not only a classifier but also a feature space of input variables is learned incrementally to adapt to incoming training samples; as suggested, a benefit of this type of incremental learning is that the search for useful features and the learning of an optimal decision boundary are carried out in an online fashion. Incremental PCA algorithms that compute the principal components without computing the covariance matrix are presented in [3, 6, 8, and 9].

Ref [8] introduced a fast incremental principal component analysis (IPCA) algorithm, called candid covariance-free IPCA (CCIPCA), to compute the principal components of a sequence of samples incrementally without estimating the covariance matrix (thus covariance-free).The algorithm keeps the scale of observations and computes the mean of observations incrementally. The method is suggested for real-time applications, and thus it does not allow iterations. It converges very fast for high dimensional image vectors. The candid covariance-free IPCA was selected for the current study. The algorithm generates “observations” in a complementary space for the computation of the higher order principal components.

IPCA requires far less memory and is often faster with a slight degradation in accuracy.

As IPCA incrementally updates the Eigen faces, the weights for previously trained images become invalid because the Eigen space in which they reside has been changed. Consequently, the previously trained face images must be kept and projected into the updated Eigen space. Liu et al. in [16] describes a fully incremental method that does not require trained face images for updates. Instead of creating a single Eigen space to represent all faces, a smaller set of 5-10 Eigen faces is created for each individual person. Recognition is not done by nearest neighbor, but by projecting the unknown face into each user’s Eigen space and finding the one that best represents the face (determined by the minimum residual error). Training times are very fast and fully incremental, but accuracy is poorer and recognition is slower.

3.3.3Independent Component Analysis (ICA)

In ICA the general idea is to separate the signals, assuming that the original underlying source signals are mutually independently distributed. Due to the field’s relatively young age, the distinction between BSS and ICA is not fully clear. When regarding ICA, the basic framework for most researchers has been to assume that the mixing is instantaneous and linear, as in infomax[14]. ICA is often described as an extension to PCA that uncorrelated the signals for higher order moments and produces a non orthogonal basis.

PCA considered image elements as random variables with Gaussian distribution and minimized second-order statistics. Clearly, for any non-Gaussian distribution, largest variances would not correspond to PCA basis vectors. ICA [5] minimizes both second order and higher-order dependencies in the input data and attempts to find the basis along which the projected data are statistically independent. A number of algorithm exist; most notable are Jade, InfoMax, and FastICA[7].

ICA is used today in many different applications, e.g. medical signal analysis, sound separation, image processing, dimension reduction, coding and text analysis A key concept that constitutes the foundation of independent component analysis is statistical independence.

3.3.4FastICA

FastICA is a fixed point ICA algorithm that employs higher order statistics for the recovery of independent sources. FastICA can estimate ICs one by one (deflation approach) or simultaneously (symmetric approach). FastICA uses simple estimates of Negentropy based on the maximum entropy principle, which requires the use of appropriate nonlinearities for the learning rule of the neural network.

3.4Holistic Based Multiple Classifier System

Since the performance of any classifier is more sensitive to some factors and relatively invariant to others, a recent trend has been to combine individual classifiers in order to integrate their complementary information and thereby create a system that is more robust than any individual classifier to variables that complicate the recognition task. Such systems have been termed as multiple classifier systems (MCSs) and are a very active research area at present. Examples of such approaches proposed for face recognition include the following: Lu et al. fused the results of PCA, ICA and LDA using the sum rule and RBF network-based integration strategy ; Marcialis and Roli combined the results of the PCA and LDA algorithms ; Achermann and Bunke utilized simple fusion rules (majority voting, rank sum, Baye’s combination rule) to integrate the weighted outcomes of three classifiers based on frontal and profile views of faces; Tolba and Abu-Rezq employed a simple combination rule for fusing the decisions of RBF and LVQ networks; Wan et al. used a SVM and HMM hybrid model; Kwak and Pedrycz divided the face into three regions, applied the Fisher faces method to the regions as well as to the whole face and then integrated the classification results using the Choquet fuzzy integral ; Haddadnia et. al. used PCA, the Pseudo Zernike Moment Invariant (PZMI) and the Zernike Moment Invariant (ZMI) to extract feature vectors in parallel, which were then classified simultaneously by separate RBF neural networks and the outputs of these networks were then combined by a majority rule to determine the final identity of the individual in the input image[5][16].

4. FUTURE WORK

To conclude our paper, we present a critical review on face recognition algorithm. We conjecture that different mechanisms are involved in human recognition of familiar and unfamiliar faces. There are different approaches present for face recognition algorithm. Performance of any classifier is more sensitive to some factors and relatively invariant to others, a recent trend has been to combine individual classifiers in order to integrate their complementary information and thereby create a system that is more robust than any individual classifier to variables that complicate the recognition task. Two major techniques of holistic base approach IPCA and ICA [1, 2] used sequentially in a real-time fashion in order to computes the principal components of a sequence of image vectors incrementally.

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