A Survey on Face Recognition Techniques

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Abstract- Events, such as major attacks, exposed weakness in most sophisticated security systems. Various supervision agencies are now more motivated to improve security data based on body or behavioral uniqueness, often called biometrics. Pin or password-based authentication procedures are too easy to crack. Face recognition is non-intrusive since it is based on images recorded by a distant camera, and can be very effective even if the user is not aware of the existence of the face recognition system. The face is the most common characteristic used by humans to recognize other people. Face recognition presents a challenging problem in the field of Pattern Recognition. It has wide range of applications such as law enforcement, banking, logical access control, national identity. In this paper, an overview of some of the well- known methods in various categories are discussed.

Keywords: *Biometric, Face recognition, PCA, LDA, ICA, Neural Networks, Pose, Illumination.*

I. INTRODUCTION

Face recognition is one of the most important biometric which seems to be a good compromise between actuality and social reception and balances security and privacy well. Also it has a variety of potential applications in information security, law enforcement, and access controls [1]. Face recognition system fall into two categories: verification and identification. Face verification basically used in to access some private devices or information. It is a 1:1 match that compares a face images against a template face images, whose identity being claimed .On the other hand, face identification is a 1: N problem that compares a query face image against all image templates in a face database. It is basically used to access device/information which is made for a group of peoples. In last decade, major advances occurred in face recognition, with many systems capable of achieving recognition rates greater than 90%. However real-world scenarios remain a challenge, because face acquisition process is done under some strict orientation, lightning condition, background etc. when these restrictions are not considers the recognition rate falls down drastically. Basically there are five key factors that can significantly affect performances of face recognition systems: [6]

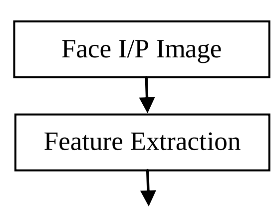
- Illumination variations due to skin reflection properties and due to the internal camera control. Several 2D methods do well in recognition tasks only under moderate illumination variation, while performances drops drastically when both illumination and pose changes occur.
- Pose changes affect the authentication process, because they introduce projective deformations and self occlusion.
- Facial expression that depends on various situations, workplace and scenario can affect the recognition process because the algorithms are written for invariant faces only.
- Another important factor is the time delay, because the face changes over time, in a nonlinear way over long periods. In general this problem is harder to solve with respect to the others and not much has been done especially for age variations.
- Occlusions can dramatically affect face recognition performances, in particular if they located on the upper-side of the face.

Face recognition algorithms developed till date are basically categorized as follows [11]

1. **Holistic methods: -** these methods identify a face using the whole face images as an input the main challenge faced by these methods is how to identify a small size image.
2. **Feature – based methods: -** this method uses the local facial features for recognition. The problem is to deciding how to incorporate global configurationally information into local face methods.
3. **Hybrid methods: -** these methods use both feature-based and holistic features to recognize a face. These methods have the potential to offer better performance than individual holistic or feature based method[1]

II. AUTOMATIC FACE RECOGNITION (AFR)

Automatic face recognition "Fig (1)" can be seen as pattern recognition problem which is hard to solve due to its nonlinearity. We can think of it as a template matching problem, where recognition has to be performing in a high dimensionality space. Since higher the dimension of space is, more the computations are needed to find the match.



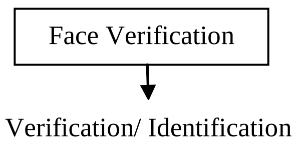


Figure: 1 Major step in Face Recognition Algorithms

Eigen Face Method: Eigen faces [3, 4, 5, 8] can be considered as one of the first approaches in this sense. Later on PCA came into existence. One important date for face recognition was beginning of the 90's when first Eigenfaces approach was implemented, which is surely the most popular face recognition method. This was the beginning of the appearance based methods for face recognition. After Eigenfaces, different statistical approaches have appeared that improve the results of Eigenfaces under certain constraints. Many holistic methods are based on Eigen face decomposition. Here face images are represented as vectors by concatenating the pixels of the image line-by-line. Then the average vector is computed that represents a mean face. Also, a difference vector is computed for each user to qualify the differences to the mean face. Then the covariance matrix of the difference vectors is computed. Finally, principal axes can be obtained by eigen decomposition of covariance matrix. The first N eigenvectors presenting the highest eigen values will be retained and represents the most significant features of faces. Finally, each user model is represented as a linear combination (weighted sum) of coefficients corresponding to each Eigenfaces. As the PCA "Fig (2)" is performed only for training the system, this method results to be very fast, when testing new face images.

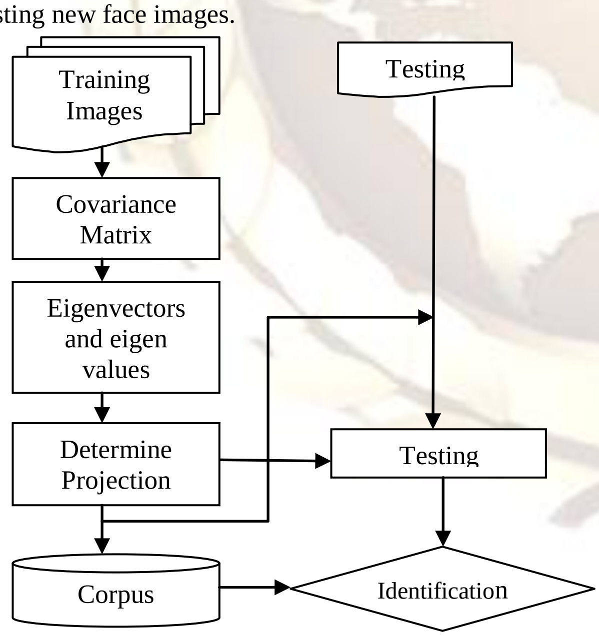


Figure 2: Simple flow chart of LDA algorithm

LDA: The LDA [9, 11, 12] (Linear Discriminate Analysis) has been proposed as a better alternative to the PCA. It specifically provides discrimination among the classes, while the PCA deals with the input data in their entirety, without paying any attention for the underlying structure. Indeed the main aim of the LDA consists in finding a base of vectors providing the best discrimination among the classes, trying to maximize the between-class differences, minimizing the within-class ones. Even if the LDA is often considered to outperform the PCA, an important qualification has to be done. Indeed the LDA provides better classification performances only when a wide training set is available. Besides recent studies also strengthen this argument expressly tackling this problem referred to as the SSS (Small Sample Size) problem. In some approaches, such as the Fisher faces, the PCA is considered as a preliminary step in order to reduce the dimensionality of the input space, and then the LDA "Fig (3)" is applied to the resulting space, in order to perform the real classification. However it has been demonstrated in recent works that, combining in this way PCA and LDA; discriminant information together with redundant one is discarded. Thus, in some cases the LDA is applied directly on the input space. The main disadvantage of the PCA, LDA, and Fisherfaces is their linearity. Particularly the PCA extracts a low-dimensional representation of the input data only exploiting the covariance matrix, so that no more than first- and second order statistics are used.

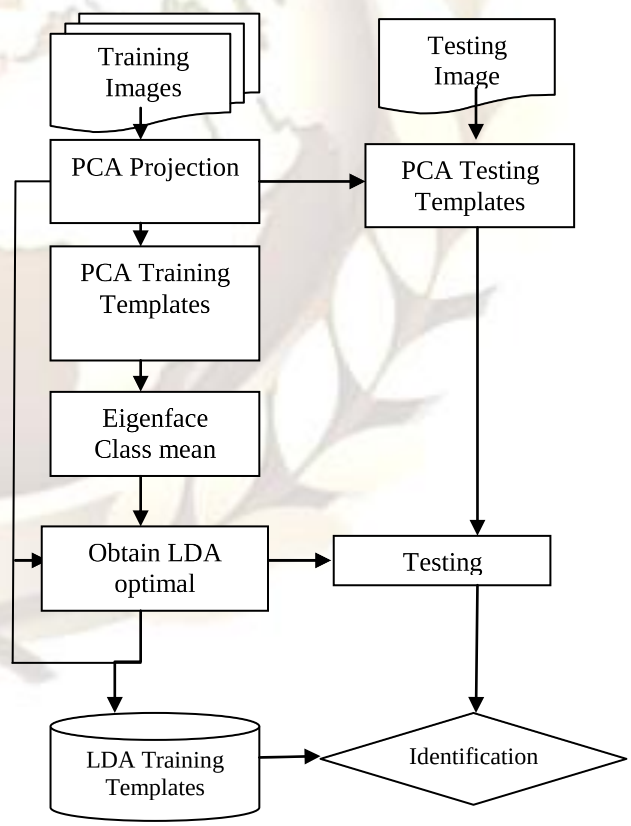


Figure 3: Simple flow chart of LDA algorithm

ICA: Independent component analysis (ICA)[13,14] is currently popular in the field of signal processing; it has been developed recently as an effective feature extraction technique and has been applied to image discrimination. The ICA is introduced as a more powerful classification tool for the face recognition problem. The ICA can be considered as a generalization of the PCA, but providing three main advantages: (1) It allows a better characterization of data in an n-dimensional space; (2) the vectors found by the ICA are not necessarily orthogonal, so that they also reduce the reconstruction error; (3) they capture discriminant features not only exploiting the covariance matrix, but also considering the high-order statistics. Besides linear projection analysis technologies, non-linear projection analysis represented by both KPCA and KFD also has aroused considerable interest in the fields of pattern recognition and machine learning, and over the last few years have shown great potential in biometrics applications. Because of its ability to extract the most discriminatory non-linear features, KFD has been found very effective in many real-world biometrics applications.

Neural Networks: A further nonlinear solution to the face recognition problem is given by the neural networks, largely used in many other pattern recognition problems, and readapted to cope with the people authentication task. The advantage of neural classifiers over linear ones is that they can reduce misclassifications among the neighborhood classes. The basic idea is to consider a net with a neuron for every pixel in the image. Nevertheless, because of the pattern dimensions neural networks are not directly trained with the input images, but they are preceded by the application of such a dimensionality reduction technique [11]. At first, the face image, represented by a vector x, is approximated by a new vector h with smaller dimensions by the first network (auto association), and then h is finally used as input for the classification net. This kind of neural network does not behave better than the Eigenfaces even in optimal circumstances. Other kind of neural networks also have been tested in face recognition, in order to exploit their particular properties. For examples Self Organizing Map (SOM) are invariant with respect to minor changes in the image sample, while convolution networks provide a partial invariance with respect to rotations, translations and scaling. In general, the structure of the network is strongly dependent on its application field, so that different contexts result in quite different networks. In a recent work, the Probabilistic Decision Based Neural Network is modeled for three different applications (a face detector, an eyes localizer and a face recognizer). The flexibility of these networks is due to their hierarchical structure with nonlinear basis functions and a competitive credit assignment scheme. At last hybrid approaches, in which, through the PCA, the most discriminating features are extracted and used as the input of a RBF neural network. The RBFs perform well for face recognition problems, as they have a compact topology and learning speed is fast. In general, neural networks based approaches encounter problems when the number of classes increases. Moreover, they are not suitable for a single model image recognition task, because multiple model images per person are necessary in order for training the system to ‘‘optimal’’ parameter setting.

Gabor filters and wavelets: The Gabor filters [11] represent a powerful tool both in image processing and image coding, thanks to their capability to capture important visual features, such as spatial localization, spatial frequency and orientation selectivity. In the most cases the Gabor filters are then used to extract the main features from the face images. Indeed, it can be applied to specific areas of the face region, corresponding to nodes of a rigid grid. In each node of the grid the Gabor coefficients are extracted and combined in jets. The nodes are linked to form such a Dynamic Link Architecture, so that the comparisons among different subjects can be made by means of a graph matching strategy. The work is further expanded on DLA and developed a Gabor wavelet based elastic bunch graph matching method (EBGM) to label and recognize human faces. Furthermore, comparisons are made in two consecutive steps: a rigid alignment of the grid only accounts for global transformations, such as translations and scale, then the local misplacement of the grid nodes is evaluated by means of a Graph Similarity Function. Generally, dynamic link architecture is superior to other face recognition techniques, in terms of rotation invariant; however, the matching process is computationally expensive. Later on a novel probabilistic deformable model of face mapping, based on a bi-dimensional extension of the 1D-HMM (Hidden Markov Model) was introduced. Given a template face FT, a query faces FQ and a deformable model M, the proposed method try to maximize the likelihood. [1]In another approach A mother wavelet is defined and forty Gabor filters are derived, considering five scales and eight orientations. Each of these filters is convolute with the input image, resulting in forty filtered copies of the face image. To encompass all the features produced by the different Gabor kernels, the resulting Gabor wavelet features are concatenated to derive an augmented Gabor feature vector. Then, in order to reduce the dimensionality of the feature vector, both the PCA and the Enhanced Fisher Linear Discriminant Model (EFM) are investigated. The use of Gabor filters renders this method very robust to changes in expression and illumination; however they dramatically increase the computational cost of the method, requiring that each kernel is convolved with the input image. [2]A faster wavelet based approach was also proposed, which presented a novel method for recognition of frontal views of faces under roughly constant illumination. It is based on the analysis of a wavelet packet decomposition of the face images, because very fast implementations of this procedure are available in hardware. Each face image is first located and then described by a subset of band filtered images containing wavelet coefficients. From these wavelet coefficients, which characterize the face texture, they build compact and meaningful feature vectors, using simple statistical measures.

III. OPEN QUESTIONS IN FACE RECOGNITION

The Automatic Face Recognition (AFR) can be thought as a very complex object recognition problem, where the object to be recognized is the face. This problem is even more difficult to solve, since the search is done among objects belonging to the same class. [1, 2]The sensibility of the classifiers to illumination and pose variations are the main problems researchers have been facing until now, while a smaller effort has been made to cope with occlusions and age variation problems. Therefore, recent works can be classified depending on their main contribution in order to address some of these problems.

1. THE CHANGES IN ILLUMINATION [5, 7, 8]

Ambient lighting changes greatly within and between days and among indoor and outdoor environments. Due to the 3D structure of the face, a direct lighting source can cast strong shadows that accentuate or diminish certain facial features. It has been shown experimentally and theoretically for systems based on Principal Component Analysis that differences in appearance induced by illumination are larger than differences between individuals. Since dealing with illumination variation is a central topic in computer vision numerous approaches for illumination invariant face recognition have been proposed. Three different classes in order to grade the methods are defined: the shape from shading approaches, which extract the shape information of the face, from one or more of its views, the representation based methods, which try to get a characterization of the face invariant to illumination changes and the generative methods, which produce a wide set of synthetic images containing as variations as possible. Several efforts have been made in order to achieve better performances in uncontrolled conditions. In some paper it is suggested that combining several linear methods, performances can be further improved. Nevertheless this hybrid is less adaptable to general face recognition problems, owning to its computational cost.

2. THE CHANGES IN POSE [2, 6]

In many face recognition scenarios the pose of the probe and gallery images is different. For example, the gallery image might be a frontal ‘‘mug-shot’’ and the probe image might be a 3/4 view captured from a camera in the corner of a room. Approaches addressing pose variation can be classified into two main categories depending on the type of gallery images they use. Multi-view face recognition is a direct extension of frontal face recognition in which the algorithms require gallery images of every subject at every pose. In face recognition across pose we are concerned with the problem of building algorithms to recognize a face from a novel viewpoint, i.e. a viewpoint from which it has not previously been seen. Linear subspaces have been extended in order to deal also with the problem of pose changes. Framework was presented for recognizing faces with large 3D pose variations, by means of parametric linear subspace model for representing each known person in the gallery. Two different linear models: (1) the LPCMAP model, that is a parametric linear subspace model, combining the linear subspaces spanned by principal components (PCs) of training samples and the linear transfer matrices, which associate projection coefficients of training samples onto the subspaces and their corresponding 3D head angles; (2) the PPLS model, that extends the LPCMAP by using the piecewise linear approach, that is a set of local linear models, each one providing continuous analysis and synthesis mappings, enabling to generalize to unknown poses by interpolation. While compressing the data size, the PPLS system performed better than the LPCMAP system. However, the number of known people is relatively small and the samples included some artificiality which might accidentally increase the performance. Another drawback is that the recognition systems uses pixel-wise landmark locations for representing facial shape and deriving head pose information, but finding landmark locations in static facial images with arbitrary head pose is an ill-posed problem.

3. THE OCCLUSION [2, 8]

One of the main drawbacks of the appearance based paradigm (e.g., PCA), is its failure to robustly recognize partially occluded objects. One way to deal with partially occluded objects (such as faces) is by using local approaches. In general, these techniques divide the face into different parts and then use a voting space to find the best match. However, a voting technique can easily misclassify a test image because it does not take into account how good a local match is. Each face image is divided into k different local parts. Each of these k local parts is modeled by using a Gaussian distribution (or, equivalently, with a mixture of Gaussians), which accounts for the localization error problem. Given that the mean feature vector and the covariance matrix for every local subspace are drawn out and the probability of a given match can be directly associated with the sum of all k Mahalanobis distances. This approach differs from previous local PCA methods in that it uses a probabilistic approach rather than a voting space. Suppression of 1/6 of the face does not decrease accuracy, while even for those cases where 1/3 of the face is occluded, the identification results are very close to those obtained without occlusions. Worse results are obtained when the eye area is occluded rather than the mouth area. This method suffers from two of the main problems of the NN based approaches: the system retraining in case of new enrolments and the little availability of training samples and is able to deal with both occlusions and illumination changes.

4. THE AGE [8, 10]

Many of the considered techniques drop in performances, when the time lapse between the training and testing images is not negligible. This makes clear that all the introduced methods do not take into account for problems due to the age variations. Some strategies overcome this problem periodically upgrading the gallery or retraining the system. Nevertheless this not very suitable solution only applies to those systems granting services, which perform the authentication, task frequently, while it is impractical in other situations, such as law enforcement. Alternatively the age of the subject could be simulated trying to make the system more robust with respect to this kind of variation. Several techniques for the age simulation are given in literature: Coordinate Transformations, Facial Composites, Exaggeration of 3D Distinctive Characteristics, but none of these methods has been investigated in the face recognition framework. A new method based on age functions. Every image in the face database is described by a set of parameters b, and for each subject the best age function is drawn depending on his/her b. The greatest advantage of this approach is that different subject-based age functions allow taking into account for external factors which contribute towards the age variations. Notice that the number of the subject in the database is very small, emphasizing the absence of a standard FERET-like database, which systematically models the age variations. However to improve the robustness of the face recognition systems with respect to changes in age is an interesting and still unexplored aspect in low enforcement applications, mainly for the prediction of facial appearance of wanted/missing persons. There a more general way to state a technique better than others! Methods presented in previous sections have both advantages and drawbacks. State which one is the best is very difficult and strongly depends on what is required the system to do. Moreover, most of these approaches have been tested on different datasets. One way to make a more general evaluation is to pick a set of significant parameters, rather than considering the recognition rate only the parameter set must includes several aspects that need to be taken into account when testing. Examples are number and database characteristics, probe dimension and gallery sets, input size and so on. It is quite interesting to analyze the way in which these parameters can drive a more accurate comparative study of face recognition algorithms. Obviously, the greater the number of used databases is, the thorough the assessment of the performances can be. On the contrary, the connection between the dimension of the input and the effectiveness of the method is less self-evident. In general, to speed up training/testing tasks, the higher the computational complexity is, the smaller the dimension of the input images can be. The probe and gallery set size also has to be taken into account mainly with respect to the SSS problem. It is well known that only one image is available for training in most real situations, while the identification is performed many times. This suggests that the smaller the gallery set is, the higher the capability of extracting discriminant features is. This can be further improved by a large probe set. It makes sense then to minimize the ratio (gallery size)/(probe size). Many research results show that several approaches are more sensitive to changes in high frequencies than to low ones. Finally, all the methods exposed so far require some kind of input preprocessing; and this could significantly reduce the usefulness of a face recognition algorithm suggesting that the system flexibility increases when normalization on input data is reduced. Based on these considerations is then possible to investigate which techniques provide a better approximation of pinpointed parameters.

V. CONCLUSION

PCA gave average results in case of the illumination and pose variation databases. In case of the dataset, where the training set was small and subject number large, PCA outranked all the other algorithms. In terms of computational efficiency, LDA is certainly more preferable. It gels extremely well with all the distance measures, and the average performance is consistent, in contrast with ICA where the consistency level is lower. Gabor representation gives average recognition results. For face recognition and feature extraction KPCA and KFD performs well than classical PCA and LDA. However, the number of 2D face recognition algorithms is immense and they enclose huge variety approaches, so it would be impossible to make an exhaustive enumeration of all publication related with 2D face recognition.

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