Fuzzy Pattern-Based with Laplacianfaces Biometric Pattern Matching Algorithm for Face Recognition

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Abstract
In face recognition system, the efficiency and face detection rate is the key issue for designing the algorithm because the computer can recognize very large number of faces with high computational speed but it is not as efficient as human. There are many modern face recognition algorithms which efficiently detect face but also have false recognition. In this paper, we propose a new hybrid algorithm and method FPBL (Fuzzy Pattern-Based with Laplacianfaces) for face detection to enhance the true recognition rate and minimize the false recognition rate. We analyze and compare the performance and results of modern pattern matching and face recognition algorithms like Eigenfaces, Fisherfaces, Laplacianfaces and Fuzzy method with FPBL. The implementation result shows that performance and accuracy of our proposed method gives the efficient and significant face recognition rate compared to other algorithms.

Keywords
Pattern Matching, Face Recognition, Eigenfaces, Fisherfaces, Laplacianfaces, Fuzzy, FPBL

I. Introduction
Human face structure is a very complex structure and multidimensional, it needs complex and computational techniques for recognition. Many faces can be recognized by learning throughout the lifespan. There may be facial variations due to distractions and aging like beard, moustache, glasses, hair colors and hairstyles. Face recognition [1] technique is an integral area of biometrics pattern matching technique. In biometrics fundamental components of human identification is compared to the existing data and based on result of matching patterns of a human being is recognized. Facial features are extracted and calculated by algorithms which are efficient and some features are modified to improve the existing algorithmic models. Face recognition system [1-2] is very important research area today that covers numerous disciplines and fields. Computing systems detect and recognize faces that can be applied to a broad variety of practical applications including bankcard identification, criminal identification, security systems, friend searching in online social networking, identity verification, access control, surveillance system, and security monitoring. A face recognition methods and techniques are some computer application for automatically identifying or verifying a human face by a digital image or video frame from a video source. It can be done by comparing certain selected facial features from the image with the facial database. For this purpose, face recognition procedure is separated into three steps: Face Detection, Feature Extraction and Face Recognition as shown at fig. 1.

A. Face Detection
The main function of face detection step is to determine the appearance of human faces in a given image, and finding where these are located. The expected outputs of face detection step are patches containing in each face in its input image.

B. Feature Extraction
After the face detection step, human-face patches and features are extracted from the images. Feature extractions are performed with the help of dimension reduction, information packing, noise cleaning, and salience extraction. After this step, a face patches are generally transformed into the fixed dimension vectors or a notable set of facial points with their corresponding locations.

C. Face Recognition
After constructing and formulizing the facial representation, the last prominent step is to recognize the feature based identities of these faces. For each human, usually several images are taken and their extracted features are stored into the database. When an input face image comes into the face recognition system, then system perform face detection and feature extraction, and comparison of its feature to each face stored in the face database. A biometric pattern matching system or biometric face recognition system is composed of many useful components. The component of face recognition system can be illustrated in fig. 2. Three major components of face recognition system are enrollment module, system database and identification module.

Fig. 1: Configuration of a General Face Recognition Structure

Fig. 2: Component of Face Recognition System

1. Enrollment Module
Enrollment Module has an automated mechanism that usually scans and captures a digital image or analog image of a human characteristics. This components involves processing and segmentation mechanism as well as analysis of facial image.
2. System Database

System Database is another entity which generally handles image compression, image processing, storage and comparison of captured data image with stored data image.

3. Identification Module

Identification Module is the third interface of the face recognition system which consists of practical application system for face recognition.

Face recognition usually starts with the detection of face patterns in cluttered data scenes, proceeds by normalization process of the face images for geometrical and illumination changes. By using information about the feature location and appearance of certain facial geometry, it identifies the faces using some appropriate classification algorithms, and then post processes the output results by using model-based schemes.

II. Background

In this paper we analyzed, reviewed and explored some basic and modern pattern matching and face recognition algorithms [19], like Eigenfaces, Fisherfaces, Laplacianfaces and Fuzzy method.

A. Eigenfaces Method

Eigenfaces method is one of the most fundamental and basic face recognition method. Eigenfaces [4-6] is the name given by a set of eigenvectors as they are used in the computer vision problems of human face recognition. The eigenvectors are calculated from covariance matrix of high-dimensional vector space of digital face images. The eigenfaces form a basis set of images used to be covariance matrix. This reduces dimension by allowing the smaller set of basis featured images to represent its original training images.

1. Eigenface Generation

By performing Principal Component Analysis (PCA) on a large set of images, a set of eigenfaces [4-6, 8] can be generated depicting different human faces. PCA is generally a mathematical process. Eigenfaces are usually a set of standardized face ingredients, which are derived from statistical analysis of many face images. The human face can be considered as the combination of these standard faces.

PCA [16, 18] is a well-known mathematical technique commonly applied in multivariate linear data analysis. The main concept of PCA is dimensionality reduction of an image data set with retaining as much variation as possible in the image data set. Let a digital face image be a two-dimensional $n \times n$ array of pixels. The corresponding image $z_i$ can be represented as a vector with $n^2$ coordinates that results from the concatenation of successive rows of the image. Training set of N faces can be denoted by $Z = \{Z_1, Z_2, \ldots, Z_N\}$. The corresponding covariance matrix in the standard manner can be defined as

$$R = \frac{1}{N} \sum_{i=1}^{N} (Z_i - \bar{Z}) (Z_i - \bar{Z})^T$$

where

$$\bar{Z} = \frac{1}{N} \sum_{i=1}^{N} Z_i$$

The eigenfaces method of face recognition was motivated by information theory, now it used for face recognition on a image of small sets. Although eigenfaces is not an elegant solution to the all object recognition problem. It is simple, relatively fast, and performed well in some constrained environment.

Advantages of Eigenfaces Method:

- The implementation of eigenfaces computation is easy.
- The knowledge of geometry or specific feature of the faces are required.
- This method is computationally fast and less complex.
- The processing work is also less in this method.

Limitation of Eigenfaces

- This method is sensitive to head scale.
- This method is high sensitive to lighting.
- Method is applicable only to front view of face.
- Performance is good only under controlled background excluding natural scenes.

B. Fisherfaces Method

The fisherfaces method is extensively used for feature extraction in digital face images. This method tries to find out the projection direction in which, digital images belonging to different classes which are separated maximally. Mathematically, this method finds the projection matrix or the weights of the matrix so that the ratio of between-class scatter matrix and in-class scatter matrix of projected images is maximized. PCA is commonly used to project digital face space from a high-dimension image space to some low dimensional vector space, it is targeted at data representation. It defines a subspace of image that represents the greatest variance of projected sample vectors among all subspaces [10-11]. But, such type of projection is effective for classification because large and unwanted variations remain still retained. Finally, the projected samples for each class may not be well clustered and result in the patterns being smeared together. Fisher’s Linear Discriminant (FLD) [11] is a class specific method, in the sense that it tries to “shape” the scatter in order to make it more reliable for classification. This method selects W in [1] in such a way that the ratio of the between-class scatter and the within class scatter is maximized.

Let the between-class scatter matrix can be defined as

$$S_B = \sum_{i=1}^{c} N_i (\mu_i - \mu)(\mu_i - \mu)^T$$

and the within-class scatter matrix can be defined as

$$S_W = \sum_{i=1}^{c} \sum_{x_k \in X_i} (X_k - \mu_i)(X_k - \mu_i)^T$$

The fisherfaces comprises two phases: first it projects the image set to a lower-dimensional space using PCA that is followed by the FLD phase. The use of the LDA helps us achieve non-singularity of the resulting within-class scatter matrix SW prior to any computations of the optimal projection WFLD. Proceeding with the presentation of the fisherfaces approach, let the between-class scatter matrix be defined in the usual manner [11].

Advantage of Fisherfaces

- Fisherface method have better recognition accuracy for the frontal faces and marginally better by 1% for the database having head tilts when compared with the Eigenface method.
- Fisherfaces have the advantage of being more computationally efficient i.e. it is faster than Eigenfaces selection.
Limitations of Fisherfaces Method

- If the between-class scatter is large in this method, then the within-class scatter also may be still a relatively large value.
- Computational complexity is more in this method.
- This method fails to deal with nonlinear changes in face images caused by large pose variation, lighting and facial expression.
- Variations in the dataset such as changes in the number of samples for each human face, affect the accuracy of recognition rate.

C. Laplacianfaces Method

Laplacianfaces [17] method of face recognition is an appearance-based method of human face recognition and representation. This method uses Locality Preserving Projection (LPP) to learn the locality preserving subspace which captures the intrinsic geometry of the data image and the local structure. When the projection is obtained, then each face image in the image space is mapped to the low-dimensional face subspace, which is usually characterized by a set of feature images, they are called the Laplacianfaces. Basically, the Laplacianfaces are the optimal linear approximations to Eigen functions of Laplace Beltrami operator on face manifold [14].

Many of research efforts have presented that the face images possibly reside on a nonlinear sub manifold and some nonlinear method have created an impressive performance on some image data sets. On the other hand, low-dimensional representations through kernel-based techniques have been developed for face recognition and can discover the nonlinear structure of the face images. However, they are computationally more expensive. Against this background and limitation the Laplacianfaces is proposed.

Laplacianfaces algorithm generally targets to preserve the local structure of the digital image space. It usually considers the manifold structure in which by an adjacency graph models it. In many practical classification problems, especially when nearest-neighbor type classifiers are used for classification, the local manifold structures are more important than the global Euclidean structure.

LPP algorithm which generates the Laplacianfaces, shares similar properties to LLE, like locality preserving character. It is linear and defined everywhere, simply applied to any new image data point to locate it in the minimized representation space. So Laplacianfaces are expected to be a natural alternative to Eigenfaces in face recognition and representation.

Advantages of Laplacianfaces Method

- Accuracy higher than Eigenfaces & Fisherfaces.
- Error rate is less.

Limitations of Laplacianfaces Method

- Still some false recognition.

D. Fuzzy Method

Fuzzy method [7, 20-21] of face recognition evokes pixel wise information of face images to different classes and thus collects pixel wise belonging to different classes to reduce classification error. The database images are read in column vector form and on these, fuzzification process are applied. One fuzzy vector is generated corresponding to one face image. Nearest neighbor classification is applied on these fuzzy vectors. Fuzzy module generates pixel wise degree of association of a face image to different classes using membership function (MF). This takes a face image as an input and using MF, fuzzifies the pixel values of the image. This generates the membership of individual pixel to different classes. The concept of MF is basically the generalization of characteristic function of a crisp set. The characteristic function of a crisp set assigns a value of 1 to the member and 0 to non-member to discriminate between member and non-member elements in the universal set.

In this method [20], first input and database images are segmented into 4 partitions. Then moment feature vectors of a definite order for all images are extracted. After this step, the distance measure is used for searching minimum distance between input vector and other vectors and the related person is recognized. Then order comparator is performed to increase the accuracy. For an input test image, the proposed method is implemented for three types of moments (Geometric, Legendre and Complex) separately and finally a fuzzy combination of these three states is used for final decision.

A fuzzy system is used for combination of results of three types of moments for performance enhancement of the recognizing system [20-21]. Indeed, the input test image is recognized based on the results of Geometric, Legendre and Complex moments. The fuzzy system decides based on at least two identical results of three moments [20]. Really, if the recognized person of two or three moments be same then that person will be accepted as the output of fuzzy system.

Advantages of Fuzzy Method

- Accuracy is better than Laplacianfaces method.
- Error rate is less.

Limitations of Fuzzy Method

- Complexity increases as resolution of the image is increased.

Eigenfaces, Fisherfaces, Laplacianfaces and Fuzzy method have their own advantages and disadvantages. To improve the face recognition rate and accuracy, our proposed protocol FPBL is observed to be better than these methods and algorithms.

III. Proposed Method and Algorithm

In this section we discuss our new proposed method and algorithm FPBL (Fuzzy Pattern-Based with Laplacianfaces) biometric pattern matching algorithm for face recognition which is based on Laplacianfaces method with fuzzy level calculation. The face recognition methods and algorithms discussed in literature review basically utilize two level of face image pixel value either 0 or 1 as minimum and maximum pixel values, but fuzzy method uses some intermediate values between 0 and 1 pixel values.

The proposed method presents a new approach of fuzzy based pixel wise value extraction with Laplacianfaces method for face recognition. System evokes pixel wise value extraction of face images to different classification and thus collects pixel wise values belonging to different classification for classification error reduction. The block diagram in figure 3 illustrates the implementation of proposed face recognition system.

The database images which contains training and testing sets of images are read in column vector form and on which, the fuzzification process will be applied. One fuzzy vector usually is generated corresponding to only one face image. The nearest neighbor classification is applied on that fuzzy vectors.
Fuzzy Pattern Based Image Pixel-Wise Value Extraction:

Fuzzy pattern based module generates image pixel wise degree of association of a face image to different classification using the membership function. A face image is taken as an input and using membership function, fuzzy pixel values of the image is generated. This usually generates the membership of individual pixel to different classification. The characteristic function of a crisp set assigns a value of 1 to the member and 0 to non-member. This function can now be generalized so that the values assigned to the elements of the universal set fall within a specified range which may be the unit interval [0, 1]. Larger values indicate higher degrees of set membership. The membership function can be expressed as mapping function $\mu_A$ for fuzzy set $A$ as follows:

$$\mu_A : z \rightarrow [0, 1]$$

where $z$ is the universal set under consideration.

In the appearance-based face recognition system, the universal set is generated by pixel values of 2-dimensional face image. A face image can be represented as a $m \times n$ dimensional matrix with $m$ number of rows and $n$ number of columns. This can be expressed in the form of $mn$ dimensional vector $z$ as:

$$z = \begin{bmatrix} z_1, z_2, \ldots, z_D, \ldots, z_D \end{bmatrix}^T$$

Here $D$ is the total number of data points in the pattern, which are total number of pixels ($m \times n$) in the face image. It takes each image of the database in vector form to fuzzify by membership function.

The $\pi$-type membership function was used for fuzzification. This comprises a parameter, named fuzzifier ($m$), which is tuned as per the requirement of the problem and thus provides more flexibility and generalization capability for classification. As shown in Fig. 4, the shape of this type of function is similar to that of Gaussian function. By varying the value of fuzzifier $m$, the steepness of membership function can be controlled. The function is given by

$$\pi(z; \alpha, \gamma, \beta) = \begin{cases} 0, & z \leq \alpha \\ 2^{m-1} \left[ \frac{z - \alpha}{\gamma - \alpha} \right]^m, & \alpha < z \leq \alpha \\ 1 - 2^{m-1} \left[ \frac{\gamma - z}{\gamma - \alpha} \right]^m, & c_1 < z \leq \gamma \\ 2^{m-1} \left[ \frac{z - \gamma}{\beta - \gamma} \right]^m, & \gamma < z \leq \gamma \\ 1 - 2^{m-1} \left[ \frac{\beta - z}{\beta - \gamma} \right]^m, & c_2 < z < \beta \\ 0, & z \geq \beta \end{cases}$$

where $c_1$ and $c_2$ are the two crossover points and $\alpha$, $\beta$ and $\gamma$ represent the minimum, maximum and mean value of training data set for a particular data point (pixel). $\pi$-type membership function provides 0.5 membership grade at $c_1$ and $c_2$ and maximum (1.0) at the center $\gamma$ as shown in fig. 4. The membership function can be calculated based on this minimum, center and maximum value of a particular pixel number ($p$) in the training data using the following:

$$\alpha = \min(p)$$

$$\beta = \max(p)$$

$$\gamma = \text{mean}(p)$$

This provides the membership grade as 1 to the training data when its pixel value is at the center of the membership function.

Nearest Neighbor Classification

Classification is a very important step in any biometric pattern matching and face recognition application. The non-parametric techniques is the Nearest Neighbor Classification (NNC), which simply states that the unclassified object is assigned to the class of its Nearest Neighbor (NN) among the set of design objects. The major variants are k-Nearest Neighbor Classifier (k-NNC) and Nearest Mean Classifier (NMC). In k-NNC, instead of 1-NN, generally, $k$-nearest neighboring data objects are considered. The parameter $k$ is the number of neighbors involved. Tuning $k$ as a way to regularize the NNC gives a trade-off between the distributions of the training data with a priori probability of the classes involved. In this implementation, k-NNC with $k$ is used as the number of images per subject in the training set for classification. Two variants of distance metrics are used to find NN of a test image in our classification process.

Correlation Coefficient:

The correlation coefficient between two images sets $A(x, y)$ and $B(x, y)$ can be defined as

$$\text{Correlation Coefficient} = \frac{\sum_{s} \sum_{t} [A(s, t) - \bar{A}] [B(s, t) - \bar{B}]}{\sqrt{\sum_{s} \sum_{t} [A(s, t) - \bar{A}]^2 \sum_{s} \sum_{t} [B(s, t) - \bar{B}]^2}}$$
where \( x = 0, 1, 2, \ldots, M - 1 \), \( y = 0, 1, 2, \ldots, N - 1 \), and the summation is taken over the whole image region, as we are taking the images \( A \) and \( B \) of same size. \( A \) and \( B \) are the average values of images. The value of correlation coefficient can vary from a negative value to highest possible value as one. Value one means accurate matching. So higher values of correlation coefficient imply better biometric pattern matching.

**Principle Component Analysis**

Principal component analysis (PCA) is extensively used technique under appearance based approach for dimension reduction. In a training set of \( M \) face images, let a face image is represented as a two dimensional \( N \) by \( N \) array of intensity values, or a vector of dimension \( N^2 \). All images of known faces (training set) are projected onto the face space to find sets of weights that describe the contribution of each vector. If the image pixel values are considered as random variables, the PCA based vectors are defined as eigenvectors of face matrix \( S \) can be defined as:

\[
S = \sum_{i=1}^{M} (x_i - \mu)(x_i - \mu)^T
\]

Here \( \mu \) is the mean of all images in the training set and \( x_i \) is the \( i \)th face image in the training set represented as a vector as its columns are concatenated in a vector form. As this face space is constructed using eigenvectors of face matrix, so this is also called as Eigen space. The Euclidean distance is taken as the distance metric for the analysis in PCA. All the images, the training as well as the test images are projected to generate the set of weights. The Euclidean distances are calculated between weights corresponding to the unknown face (test data set) and known faces (training data set).

The minimum of these Euclidean distances is examined to find the unknown face (test data set). The Euclidean distance is taken as the distance metric for checking the correctness of NN for all test images.

**Adding Laplacianfaces Features**

Laplacianface is a recently proposed linear method for face recognition and representation. It is generally based on Locality Preserving Projection and explicitly considers the manifold structure of the face space. Given a set of face images \( \{x_1, \ldots, x_n\} \subseteq \mathbb{R}^m \), let \( X = [x_1, x_2, \ldots, x_n] \). Let \( S \) be a similarity matrix defined on the data points. Laplacianfaces method can be obtained by solving the following minimization equation:

\[
a_{opt} = \min_{a} \sum_{i=1}^{m} \sum_{j=1}^{m} (a^T x_i - a^T x_j)^2 S_{ij}
\]

\[
= \min a^T X L X^T a
\]

with the constraint

\[
a^T X D X a = 1
\]

Where \( L = D - S \) is the graph Laplacian and \( D_{ij} = \sum S_{ij} \). It measures the local density around \( x_i \). Laplacianface constructs the similarity matrix \( S \) as:

\[
S_{ij} = \begin{cases} 
\frac{1}{e^{\frac{\| x_i - x_j \|^2}{\sigma}}} & \text{if } i, j \text{ are among } p \text{ nearest neighbors} \\
0 & \text{otherwise}
\end{cases}
\]

Here \( S_{ij} \) is actually heat kernel weight. The objective function in Laplacianface incurs a heavy penalty if neighboring points \( x_i \) and \( x_j \) are mapped far apart. Therefore, using it is an attempt to ensure that if \( x_i \) and \( x_j \) are “close” then \( y_i (= a^T x_i) \) and \( y_j (= a^T x_j) \) are close as well [9]. Finally, the basic functions of Laplacianface are the eigenvectors associated with the smallest eigenvalues of the following generalized eigen problem:

\[
X L X^T a = \lambda X D X^T a
\]

The proposed method and algorithm combines these membership function used for fuzzycation of pixel of face image with Laplacianfaces method.

**IV. Result and Evaluation**

In this section, the utility of the proposed method of image pixel value extraction is implemented. Experiments are conducted on Yale face database [14, 24]. This database comprises 1200 different images of each of forty distinct subjects. The database images were taken with various illumination, different poses, expression and facial details as glasses, no glasses and at different times. All the images were taken against a dark homogeneous background with the subjects in the upright, frontal position with tolerance for little side movement. The images are stored as \( 80 \times 80 \) pixel array with 256 grey levels. Some sample images from this database are shown in fig. 5.

![Fig. 5: Sample Images of Database](image)

Performance attributes used in our Java simulations are as follows:

1. **True Positives (TP):** The number of faces of criminal. It is the number of criminal face detection.
2. **True Negatives (TN):** The number of faces of citizen classified as non-criminal faces.
3. **False Positives (FP):** The number of non-criminal faces classified as criminal faces.
4. **False Negatives (FN):** The number of criminal faces classified as non-criminal faces.

Report presents practical performance for face recognition. For testing our proposed system, we take 600 criminal faces and 600 non-criminal faces of citizen. Among these faces, 30 faces present false negative, 20 faces present false positive and 580 faces present true negative responses.
A. TP (True Positives Rate)
It is the criminal face detection rate. It indicates the detection preciseness of a system. TP is also called the detection rate and defined as

\[
\text{True Positive Rate} = \frac{TP}{TP + FN} \times 100 \%
\]
\[
= \frac{600}{600 + 30} \times 100 \%
\]
\[
= \frac{600}{630} \times 100 \%
\]
\[
= 95.24 \%
\]

B. FP (False Positives Rate)
It is the false face detection rate. A false positive, also called false alarm means a non-criminal face being misclassified to criminal face. The FP rate is defined as.

\[
\text{False Positive Rate} = \frac{FP}{FP + TN} \times 100 \%
\]
\[
= \frac{20}{20 + 580} \times 100 \%
\]
\[
= \frac{20}{600} \times 100 \%
\]
\[
= 3.33 \%
\]

C. OA (Overall Accuracy)
Evaluating performance of a system, both higher TP and lower FP are necessary to be considered. The overall accuracy may be a compromise and it is defined as

\[
\text{Overall Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \times 100 \%
\]
\[
= \frac{600 + 580}{600 + 580 + 20 + 30} \times 100 \%
\]
\[
= \frac{1180}{1230} \times 100 \%
\]
\[
= 95.93 \%
\]

Table 1: Accuracy of Face Recognition Methods

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Face Recognition Method</th>
<th>Overall Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Eigenfaces</td>
<td>82.40</td>
</tr>
<tr>
<td>2.</td>
<td>Fisherfaces</td>
<td>89.95</td>
</tr>
<tr>
<td>3.</td>
<td>Laplacianfaces</td>
<td>92.60</td>
</tr>
<tr>
<td>4.</td>
<td>Fuzzy Method</td>
<td>95.05</td>
</tr>
<tr>
<td>5.</td>
<td>FuzzyPattern-Based with Laplacian</td>
<td>95.93</td>
</tr>
</tbody>
</table>

The overall accuracy can be summarized in Table 1, the FPBL method for face recognition achieves the highest accuracy. After comparison of FPBL with Eigenfaces, Fisherfaces, Laplacianfaces and Fuzzy method, we evaluated that using our proposed algorithm FPBL, we are getting high true face recognition rate, low false face recognition rate and high accuracy.

V. Conclusion and Future Work
In this paper, we proposed FPBL (Fuzzy Pattern-Based with Laplacianfaces) biometric pattern matching algorithm as a hybrid algorithm with combining Laplacianfaces and Fuzzy method. FPBL combines the best features of Laplacianfaces and Fuzzy method. Due to the concept of fuzzy logic and Laplacianfaces method FPBL produces high true detection rate, low false detection rate and enhanced overall accuracy as shown in the implementation result. In comparison with Eigenfaces, Fisherfaces, Laplacianfaces and Fuzzy method it can be concluded that our FPBL algorithm will perform well in realtime face recognition critical security applications.

However our implementation performed on gray level images in pgm format with around 80×80 resolution. Our future direction will be the implementation of FPBL method on color images including all image formats with some higher resolution.

References


