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Fuzzy based Hybrid Feature Extraction Approach for Face Recognition

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Abstract

This research exposes a new hybrid approach for feature extraction based on fuzzy logic and it is used to combine the fuzzy approach with existing feature extraction techniques for video dataset based face recognition. Here, fuzzification operation is applied on to pixels and for that pi–shaped membership function is used for obtaining degree of belonging of pixel to all classes. Classification is done on the features extracted from PCA, LDA, Fuzzy+PCA and Fuzzy+LDA using Euclidian distance classifier over ChokePoint Video Dataset. Performance of the methods is measures using evaluation parameters like Recognition rate and Verification rate with Equal Error rate. The results clearly justified the superiority of proposed approach.

Keywords: *Feature Extraction, Principal Component Analysis, Linear Discriminant Analysis, False Acceptance rate, False Rejection Rate, Equal Error rate, Euclidian Distance Classifier*

1. Introduction

Face recognition has been an active research area over the so many years. Face recognition is area which is analyzed by two different fields. One is psychophysical sciences and second is computer sciences. Both the fields are dealing with different parts of topic. Psychologists and neuroscientists deals with the human perception part and engineers studying on machine recognition of human faces deal with the computational aspects of face recognition.

There are many different kinds of applications in face recognition. In the fields of biometrics, access control, law enforcement, security and surveillance systems where face recognition is mostly required. There is an absolute requirement of personal identification in the fields of private and secure systems. These made face recognition one of the main fields among other biometric technologies and defines that it is actual requirement for private and secure systems. The importance of face recognition advances from the fact that a face recognition system does not require the cooperation of the some person while the other systems require such cooperation.

For Face recognition system lots of algorithms are available. These algorithms try to solve the problem of both verification and identification as a part of face recognition system. Although still so much amount work is remaining as per as accuracy is concerned because of whatever human vision system can identified or verified is not possible by available systems. So, work is going on for getting exact or to the best level than the human vision. Ultimately Face recognition is part of biometric research, where biometric is part of pattern recognition and pattern recognition is part of largest field of technology called Computer Vision.

When verification is there, the face recognition system is given a face image and it is given a exacted identity. The system is expected to either reject or accept the claim. On the other hand, in the identification problem, the system is trained by some images of known individuals and given a test image. It decides which individual the test image belongs to. Also there are some problems which can be defined for face recognition system. The problem of face recognition can be stated as follows: Given still images or video of a scene, identifying or recognizing faces from the video sequence by using a stored database of faces. The problem is mainly a classification problem. Some of possible problems for a face recognition system are mainly: Facial expression change, Illumination change, Aging, Rotation, Size of the image, etc, which are the main reasons for the system may have some drawbacks .

In the face recognition system, there are several steps that have to follow to build the system. Face detection where the face is detected from the input of the system. After that feature extraction and dimensionality reduction step, where appropriate algorithms are used for feature extraction. At last classification phase is there where

classifiers are used to get a final results. To perform all these different steps in face recognition system, first trained the system with some images and then test the system by providing images or video sequence as a input to the system.

Face recognition methods can be categorized into two groups: Feature-based Appearance-based. In feature-based approach [5][16], a set of local features is extracted from the image such as eyes, nose, mouth etc. and they are used to classify the face. The major benefit of this approach is its relative robustness to variations in illumination, contrast, and small amounts of out-of-plane rotation. But there is generally no reliable and optimal method to extract an optimal set of features. Another problem of this approach is that it may cause some loss of useful information in the feature extraction step. The appearance-based approaches [5][16] use the entire image as the pattern to be classified, thus using all information available in the image. However, they tend to be more sensitive to image variations. Thus major issue of designing an appearance-based approach is the extraction of useful information which can be used for efficient face recognition system that is robust under different constraints (pose, illumination, expressions etc.). So, appearance based approaches are more important than the feature based approaches. If an image of size m x n pixels is represented as a vector in mn-dimensional space. But for an efficient and fast recognition system, the mn-dimensional space is quite large. This generates the need for dimension reduction algorithms.

These linear algorithms project data linearly from high dimensional image space to a low dimensional subspace. Since the entire image space along with constraints is highly non-linear, they are unable to preserve the non-linear variations necessary to differentiate among different classes. Due to this, the linear methods fail to achieve high face recognition accuracy [5][16]. Soft computing techniques (artificial neural networks, fuzzy logic and genetic algorithms) have emerged as an important methodology for analysis in computer vision research. From soft computing based techniques, the fuzzy logic is used for modeling human thinking and perception. In place of using crisp set (theory of binary propositions), fuzzy systems reason with fuzzy set of multi-values [16].

It is well established that the effectiveness of human brain is not only from precise recognition, but also from analysis based on fuzzy set and fuzzy logic. Uncertainty is always involved in real application constraints and this is a common problem in pattern recognition [16]. Analysis based on fuzzy logic has proved to generate substantial improvement in pattern recognition problems and their results. Face Recognition is the problem from Pattern Recognition domain. The effect of class wise belonging of individual pixels in face recognition is just under the research area. The present investigation explores association of different pixel values of facial images to different classes. So, the new approach defined as Fuzzy based Information Extraction. Fuzzy approach evokes pixel wise information of face images to different classes and thus collects pixel wise belonging to different classes to reduce classification error.

The rest of the paper is organized as follows. The detailed description of proposed approach has been made in Section 2. In section 3, existing algorithms are explained with classification method. In section 4, the experiments and results are given. In section 5 conclusion and future work is given.

2. Proposed Approach

Analysis based on fuzzy logic has proved to generate substantial improvement in pattern recognition problems and their results. Face Recognition is the problem from Pattern Recognition domain. The effect of class wise belonging of individual pixels in face recognition is not yet discovered. The present investigation explores association of different pixel values of facial images to different classes. So, the new approach defined as Fuzzy based pixel wise Information Extraction. Fuzzy approach evokes pixel wise information of face images to different classes and thus collects pixel wise belonging to different classes to reduce classification error. The block diagram of implementation of our face recognition system is illustrated in the below figure.

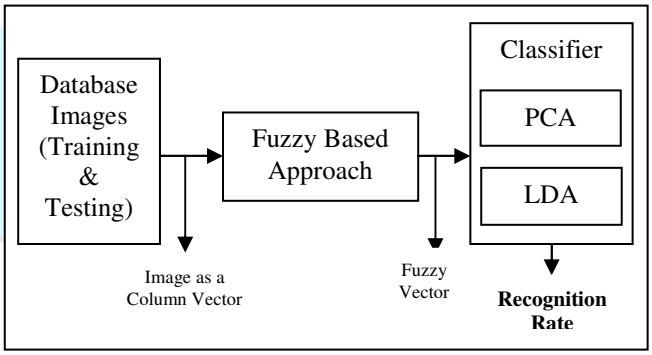

Figure 2.1 Proposed Approach with Existing methods

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. This function can be generalized such that the values assigned to the elements of the universal set fall within a specified range which may be the unit interval [0, 1]. Thus these values, which are real numbers in [0, 1], express the membership grade of the elements of the universal set. Larger values indicate higher degrees of set membership. We can express the MF as mapping function μA for fuzzy set A as follows:

$$\mu_A: z \rightarrow [0, 1] \qquad (1)$$

(where z , is a universal set)

2.1 Proposed Methodology

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×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:

$$z = [z_1, z_2, \ldots, z_d, \ldots, z_D]^T \qquad (2)$$

Here D denotes total number of data points in a pattern, which are total number of pixels (mn) in the face image. FPIE module takes each image of the database in vector form to fuzzify by MF.

The pi - shaped MF for fuzzification. This comprises a parameter, named fuzzifier (m), which can be tuned as per the requirement of the problem and thus provides more flexibility and generalization capability for classification. As shown in Fig. 3.4, the shape of this type of function is similar to that of Gaussian function. By varying the value of fuzzifier m, the steepness of MF can be controlled. The function is given by

$$\begin{aligned}
\Pi(z; \alpha, \gamma, \beta) &= 0 && (z <= \alpha)\\
&= 2^{m-1}\,[\,(z-\alpha)/(\gamma-\alpha)\,]^m && (\alpha < z <= c1)\\
&= 1 - 2^{m-1}\,[\,(\gamma-z)/(\gamma-\alpha)\,]^m && (c1 < z <= \gamma)\\
&= 2^{m-1}\,[\,(z-\gamma)/(\beta-\gamma)\,]^m && (\gamma < z <= c2)\\
&= 1 - 2^{m-1}\,[\,(\beta-z)/(\beta-\gamma)\,]^m && (c2 < z <= \beta)\\
&= 0 && (z >= \beta)
\end{aligned}$$

(Where c1 and c2 are two crossover points) (3)

The pi type membership function is defined in the figure 2.1.

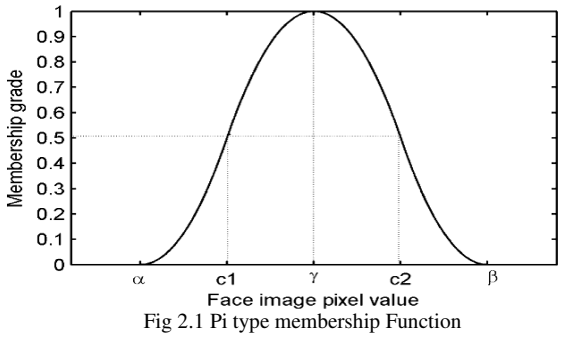

Fig 2.1 Pi type membership Function

From figure; α, β and γ represent the minimum, maximum and mean value of training data set for a particular data point (pixel). πtype MF provides 0.5 membership grade at c1 and c2 and maximum (1.0) at the center γ as shown in Fig.3.4. We have selected the value of m equal to 2 in the present investigation. The MF can be calculated based on minimum, centre and maximum of a particular pixel number (p) in the training data using

$$\begin{aligned}
\alpha &= \min(p)\\
\beta &= \max(p)\\
\gamma &= \text{mean}(p)
\end{aligned} \qquad (4)$$

This function is symmetric about z = γ, and increases monotonically for data values between α and γ, while decreases for data values between γ and ß. This provides the membership grade as 1 to the training data when its pixel value is at the centre of the MF.

The membership grade gradually decreases to reach 0.5 at cross over points c1 and c2 for training data, when it is away from the center. The region beyond c1 and c2 will provide membership grade less than 0.5.This is used to provide more generalization capability by our system to incorporate the variations uncovered by the training data.

For a face image represented in vector form by Eq. 3.4 the membership grade vector after applying Fuzzy approach is expressed as:

$$g = [g_1, g_2, \ldots, g_d, \ldots, g_D]^T \qquad (5)$$

(where g_d denotes the membership grade of the d th pixel of face image z)

3. Methodology

In the face recognition system the flow must be an important thing to be followed. It defines all the required steps in the face recognition system.

The flow of the system is provided into figure 3.1

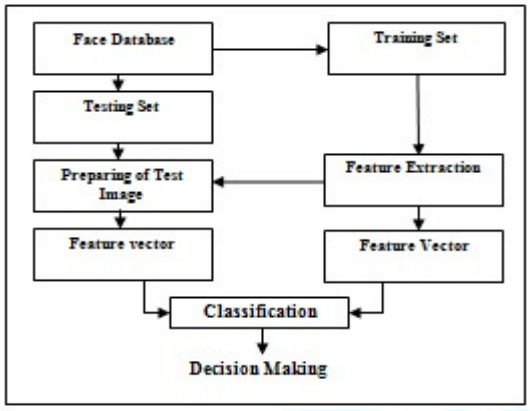

Fig 3.1 Flow of the System

Figure 3.1 defines all the required steps but the most important step is the Feature Extraction which is ultimately used for dimensional reduction as well as for extracting features from input of the system. Extracted features are passed to the last phase that is classification where the identification or verification rate is calculated. Now the existing methods are explained in 31. And 3.2. The proposed approach is applied with existing approaches as a hybrid approach.

3.1 PCA – Principal Component Analysis

PCA is the algorithm for identify the pattern in the dataset and showing the data in proper manner for defining their similarities and dissimilarities. PCA is working differently than the template matching, it reduces the dimension of given data or compress the data. It is included as a one step in the PCA as a dimensional reduction step. This particular step is performed without losing much of the information.

The main idea of using PCA for face recognition is to express the large 1-D vector of pixels constructed from 2-D facial image into the compact principal components of the feature space [8]. This can be called eigenspace projection. Eigenspace is calculated by identifying the eigenvectors of the covariance matrix derived from a set of facial images (vectors).

The steps of PCA are defined as under;
Suppose $x_1, x_2, \ldots, x_N$ are N x 1 vectors[9][10].

(1) Find the Mean:

$$\bar{x} = (1 / M) \sum X_i \quad \text{(where i=1,2, ..., M)} \quad (6)$$

(2)Subtract the mean

$$\Phi_i = \bar{x} - x_i \quad (7)$$

(3) Calculate the covariance matrix

(Form a matrix $A = \{\Phi_1, \Phi_2, \ldots, \Phi_N\}$ (N x M))

$$C = (1/M) \sum \Phi_n \Phi_n^T = AA^T \quad \text{(where i = 1,2, ... ,M)} \quad (8)$$

(4)Calculate the eigenvectors and eigenvalues of the covariance matrix

eigenvalues of C : $\lambda_1, \lambda_2, \ldots, \lambda_N$
eigenvectors of C : $u_1, u_2, \ldots, u_N$ (9)

(5) components and forming a feature vector

Feature Vector = $\{u_1, u_2, \ldots, u_N\}$ (10)

(6) Deriving the new data set

Final Data = FeatureVector x RawDataAdjust (11)

RawFeatureVector is the matrix with the eigenvectors in the columns transposed so that the eigenvectors are now in the rows, with the most significant eigenvector at the top. RawDataAdjust is the mean-adjusted data transposed, ie. the data items are in each column, with each row holding a separate dimension. FinalData is the final data set, withdata items in columns, and dimensions along rows and they are passed to the last step of the system called classification.

3.2 LDA – Linear Discriminant Analysis

The objective perform dimensionality reduction "while preserving as much of the class discriminatory information as possible". It seeks to find directions along which the classes are best separated. It takes into consideration the scatter within-classes but also the scatter between-classes. It is more capable of distinguishing image variation due to identity from variation due to other sources such as illumination and expression.

The steps of LDA are defined as under;
(1)Obtain images each with N x N image size

(2)Represent every image vector Γ (N2 x 1). So" Γ' is an N2 x M vector.

(3)Compute mean of each class mi (N2 x 1) and the mean of all data (N2 x 1).

(4) Compute Within – Class Scatter matrix S_W. (N^2 x N^2)

$$S_W = \sum_i \sum_j (\Gamma_i - m_i)(\Gamma_j - m_i)^T$$
(where (i = 1,2, ... ,K) & (j= 1,2 ,.., M)) (12)

(5) Compute Between – Class Scatter matrix S_b (N^2 x N^2).

$$S_b = \sum_i (m_i - m)(m_i - m)^T$$
(where i = 1,2, ... ,K) (13)

(Maximizing $W = \max | S_b / S_w |$)

(6) Calculate eigen values (λ) and eigen vectors (**w**) to solve fisher's criteria

$$S_b\, w = S_w\, w\, \lambda \qquad (14)$$

Here also the output of the feature extraction phase is applied to the classification phase for final results.

3.2 Euclidian Distance Classifier

The task of the classifier is to use feature vectors (provided by the feature extractor) to assign the object to a category. Perfect classification is often impossible; a more general task is to determine the probability for each of the possible categories. The process of using data to determine the classifier is referred to as training the classifier. Euclidian Distance Classifier is minimum distance classifier. The minimum distance classifier is used to classify unknown image data to classes which minimize the distance between the image data and the class in multi-feature space. The distance is defined as an index of similarity so that the minimum distance is identical to the maximum similarity.

4. Experiments and Results

In this chapter, PCA [10][11], LDA [12][13], Proposed fuzzy Approach, Proposed fuzzy approach with PCA & Proposed fuzzy approach with LDA are tested individually, and their performances are compared relative to changes in training dataset with different no. of training per person in the dataset. Based on this the Recognition Rate, Error Rate, percentage reduction in Error rate and Equal Error rate are calculated. The utilized face database Choke point[7] dataset is used, Chokepoint dataset comprises surveillance video dataset using existing technologies.

For implementation and for applying the different approaches the Chokepoint face dataset is used in this dissertation. Where dataset divided into two parts, first is training and second part is testing. Here in this system total 25 persons are there for testing and 6 different training datasets are created. Training dataset contains different six forms, where first contains only 25 images only one image per person as a trainee. Second contains 50 images only two persons per person as a trainee and so on.

The results are finding out in the form of identification and verification rate in percentage.

For verification rate, there are three different parameters which can be found out from the system. They are listed below;

1) False Rejection Rate (FRR)
2) False Acceptance Rate (FAR)
3) Equal Error Rate (EER)

False Rejection Rate (FRR) is defined as, the recognition system miscarries to identify or to verify the authorized or known person at that instance of the system the error is called Type –I error or False Rejection Rate. It is defined in terms of percentage and it can be calculated as no. of FAR divided by total no. of identifications.

False Acceptance Rate (FAR) is defined as, the recognition system is carried out the identification or verification of the unauthorized or unknown person at that instance of the system the error is called Type –II error or False Acceptance Rate. It is also defined as a serious error of the recognition system. It is defined in terms of percentage and it can be calculated as no. of FRR divided by total no. of identifications.

Equal Error Rate (EER) is defined as, in the recognition system with the use of predetermine threshold values for false acceptance rate and false rejection rate, and threshold value where the false acceptance rate and false rejection rate are same then that is considered as Equal Error rate. These three parameters are defined in the graphs in the next section for all different approaches.

The results for Identification is displayed in the Table 4.1

(Table 4.1 Recognition Rate (in Percentage))

	No. of training per Person					
Methodology	**1**	**2**	**3**	**4**	**5**	**6**
PCA	36	46.66	54.66	60.88	82.22	86.22
LDA	42.67	56.44	67.56	75.56	89.33	91.56
Fuzzy - PCA	39.56	56.89	64.89	69.78	86.22	89.78
Fuzzy - LDA	49.78	63.11	80.89	85.33	91.56	94.22

The figure 4.1 & 4.2 contain graphs which define the recognition accuracy under varying no. of training per samples for all approaches. In Figure 4.1 & 4.2 the thick line is for fuzzy based approach and thin line is for existing approach where Fuzzy based approach has better results than the existing approach.

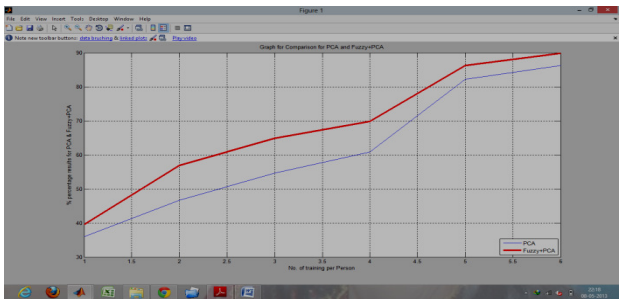

Fig 4.1 PCA vs. Fuzzy + PCA

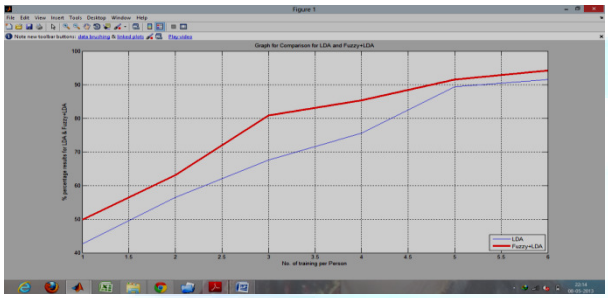

Fig 4.2 LDA vs. Fuzzy + LDA

Now the Table 4.2 contains results for verification for face recognition where the table splits into two parts. Table 4.2(I) gives Equal Error Rate and Verification Rate in percentage for 1 to 3 number of training per person and Table 4.2(II) gives Equal Error Rate and Verification Rate in percentage for 4 to 6 number of training per person.

Table 4.2 (I) verification rate at Equal Error Rate (in %)

	Number of training per Person					
	1		2		3	
Methodology	**RR**	**EER**	**RR**	**EER**	**RR**	**EER**
PCA	21.76	39.12	31.48	34.26	42.96	28.52
LDA	24.28	37.86	40.84	29.58	50.00	25.00
Fuzzy – PCA	31.76	34.12	46.84	26.58	58.96	20.52
Fuzzy – LDA	31.00	34.50	47.16	26.42	63.04	18.48

Table 4.2 (II) verification rate at Equal Error Rate (in %)

	Number of training per Person					
	4		5		6	
Methodology	**RR**	**EER**	**RR**	**EER**	**RR**	**ERR**
PCA	49.80	25.10	76.80	11.60	84.16	7.92
LDA	60.64	19.68	81.00	9.50	89.28	5.36
Fuzzy – PCA	64.92	17.54	84.80	7.60	89.76	5.12
Fuzzy – LDA	81.20	9.40	86.88	6.56	94.12	2.94

In The figure 4.3 and 4.4, the graphs are plotted for FAR & FRR for PCA and Fuzzy based PCA approach for 6 number of training per person respectively. In the figure 4.5 and 4.6, the graphs are plotted for FAR and FRR for LDA and fuzzy based LDA approach respectively. In the figures the Black point at the intersection of both the graphs for FRR and FAR defined as Equal Error Rate.

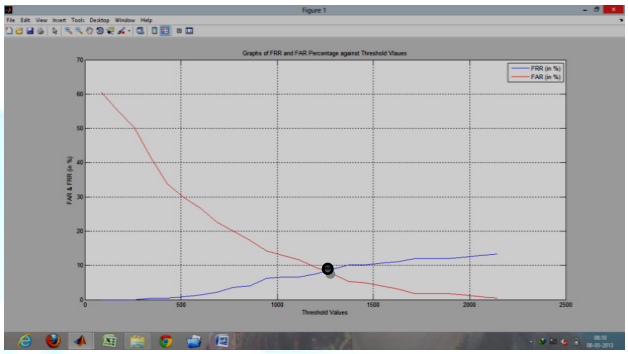

Fig 4.3 ERR for PCA (No. of Training per person = 6)

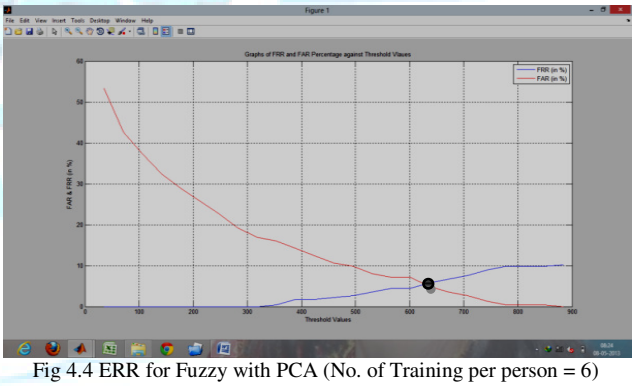

Fig 4.4 ERR for Fuzzy with PCA (No. of Training per person = 6)

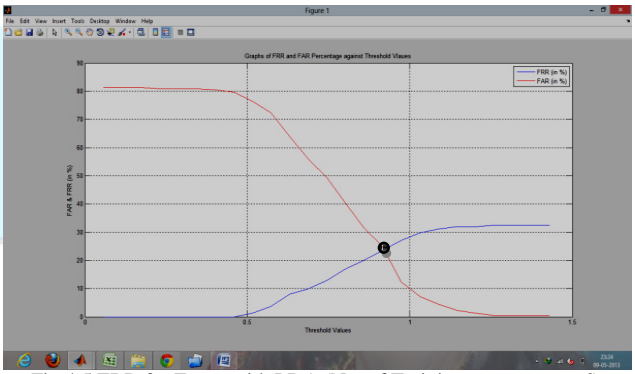

Fig 4.5 ERR for Fuzzy with LDA (No. of Training per person = 6)

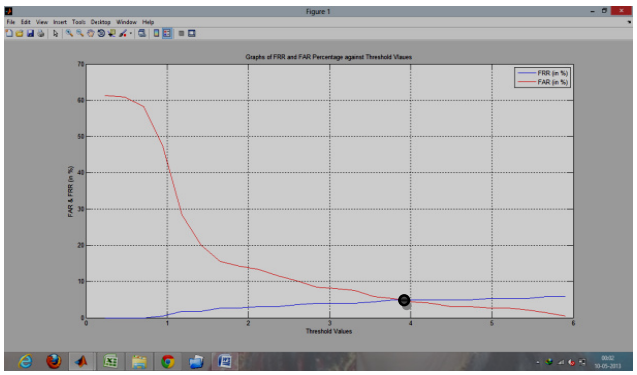

Fig 4.6 ERR for Fuzzy with LDA (No. of Training per person = 6)

5. Conclusions and Future Work

In this paper a new hybrid fuzzy based approach is used for feature extraction phase of face recognition. The new approach is used existing methods PCA and LDA and the results are compared with only PCA and LDA approaches. The results from Fuzzy PCA are better than the only PCA in identification as well as in verification. Also, the results from fuzzy LDA are better than the only LDA for identification as well as for verification. Here as we increased the number of training per person we get the best results in each & every approaches. When we used new hybrid fuzzy based approach with PCA and LDA then we have better results than the existing one due to the fuzzy logic is multi valued logic and it can be come out with the nonlinear information of the input image which is not possible with the existing linear algorithms.

Finally as s future aspect to this particular research, it is clearly definable that the hybrid approach will be used with other existed linear algorithms for feature extraction. Also it has to defined that for choke point dataset which is used in this research and we got better results for proposed approach but still number of dataset are available and this hybrid approach can be used on different datasets and comparison can be med in terms of identification rate and verification rate.

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