Abstract

Biometrics are now replacing today's authentication systems due to its accuracy. This paper introduces a new multimodal biometric system which uses multiple algorithmic approach for the reduced data set.
Multimodal biometric systems can overcome the drawbacks of unimodal systems. Two modalities used in this approach are face and fingerprint. Multi algorithmic approach used for face uses two algorithms PCA (Principal Component Analysis), followed by LDA (Linear Discriminant Analysis). And Fingerprint recognition is done using crossing number method. These two modalities are finally fused at a matching score level using a sum rule to improve the accuracy.
Experimental results shows that the proposed system has better results compared to the unimodal face and fingerprint recognition systems. This work also compares the PCA and LDA approach with the combined multi algorithmic approach.

Introduction

In this present world, with an increase in number of threats, it is must for us to increase the security measures. Traditional authentication systems which use the things that we carry or remember are more vulnerable to the attacks. Biometrics provides a change in the way how we are identified and thereby increases the security. So conventional systems are now replaced by biometric systems due to its universality, uniqueness, presence, accuracy and so on. But Unimodal biometric systems have certain drawbacks like intra-class variation, inter-class similarity, spoofing, noisy data etc. Multimodal biometric systems can overcome the limitations of unmoral systems as it combines more than one biometric to increase the accuracy.

The various biometric modalities used can be combined at different levels like feature level, matching score level, decision level etc. This process of combining various biometric modalities is referred to as biometric fusion. In feature level fusion, features are extracted from each

Biometric trait and a composite feature vector is created. This composite feature vector is then used for further classification. In matching score level fusion, each biometric trait is processed separately and a score is generated from each trait. This score is then used for classification. In decision level fusion each trait is independently processed and classified as accept/reject. The output result from each trait is then finally used for classification.

Multi-algorithmic approach can also be used along with multimodal biometrics to furthur improve the performance.
Proposed method uses face and fingerprint biometrics and multi-algorithmic approach for face. Multi-algorithmic approach used for face uses two algorithms PCA(principal component analysis), followed by LDA(linear discriminate analysis).

II. RELATED WORKS

A multimodal biometric system is developed using fingerprint and iris biometric in The system fuses fingerprint and iris at feature level, even though their features at image level are incompatible and non-homogeneous. The system provides single feature vector obtained by fusing fingerprint and iris image and extracting a unique textural pattern from fused image by efficient wavelet transform. Matching is carried using Hamming distance. Here independent databases are used for face and iris images and each fingerprint is assigned a corresponding iris image.

A multimodal biometric system in [14] combines palm print and fingerprint in feature level. Palm print and finger print images were fused using wavelet based image fusion techniques with min-min approximation. Features were extracted using Discrete Cosine Transform (DCT) and feature reduction achieved using Information Gain (IG). In their work also independent databases are used for palmprint and fingerprint and they are combined by assigning a fingerprint image to each palmprint image. Their shows that multi modal biometrics are more efficient than conventional palm print based methods.

The multimodal biometric system in [15] combines face and fingerprint biometrics in matching score level. They used the gray-level co-occurrence matrix (GLCM) as an effective method for extracting the texture features in the face recognition and crossing number method is used for fingerprint feature extraction. For matching process they used correlatiion coefficient as the similarity measure. A multimodal biometric system is developed by combining face and fingerprint biometric by score level fusion. According to \cite{19} face recognition is done using PCA and fingerprint recognition is done using minutiae matching and gabor filtering.

III. PROPOSED METHOD

Proposed method uses face and fingerprint biometrics and multi-algorithmic approach for face. Overall proposed System is divided into four modules

1. Face feature extraction and score generation
2. Fingerprint feature extraction and score generation
3. Fusion module
4. Decision module

In module 1 face features are extracted and a score is generated. Multi-algorithmic approach used for face uses two algorithms- Principal Component Analysis (PCA) and Linear Discriminate Analysis (LDA).
In module 2 fingerprint features are extracted and a matching score is generated. Crossing number method is used for fingerprint feature extraction. The features extracted are minutiae points namely ridge ending and ridge bifurcation and then generate a score. In fusion module, scores generated from different modules are combined using sum rule and make decision in the decision module.

Future Of Extraction

A. Face feature extraction and score generation

Face feature extraction using PCA: First face images are projected to low dimensional feature space using Principal Component Analysis or PCA. PCA is a dimensionality reduction technique that is widely used in face recognition. It is a procedure for identifying a smaller no: of uncorrelated variables, called principal components, from large set of data. It requires two stages: training stage and classification stage. In training stage, an Eigen space is created from the training samples by using PCA. Then training face images are mapped to the Eigen space for classification. PCA uses orthogonal transformation to convert a set of N face images into a set of K uncorrelated variables called eigenfaces. Eigen faces are computed from the covariance matrix which is constructed by using training data set . Consider to be the matrix obtained by subtracting mean from each face image.

eigenfaces can safely represent the whole original training set, as they depict major features that make up the data set. In the classification phase, an input face image is projected to the same Eigenspace and is then classified by using Euclidian distance classifier. Major steps in PCA algorithm is as follows:

Calculate projected images from k large eigen values by multiplying with eigen values

So images are projected to a low dimensional feature space created by PCA. Now apply the second algorithm linear discriminant analysis (LDA) to the images projected in this low dimensional feature space.

Face Feature Extraction using LDA: Linear Discriminate Analysis (LDA) is a dimensionality reduction technique widely used for face recognition It overcomes the draw-backs of the PCA technique by applying the linear discriminant criterion. This criterion tries to maximize the ratio of the determinant of the between-class scatter matrix of the projected samples to the determinant of the within class scatter matrix of the projected samples Linear discriminate groups the images of same class and separates images of different classes of the face images. Class seperation in LDA is shown in Fig 1. Within class scatter matrix (Sw) and the between class scatter matrix (Sb) is defined as follows:

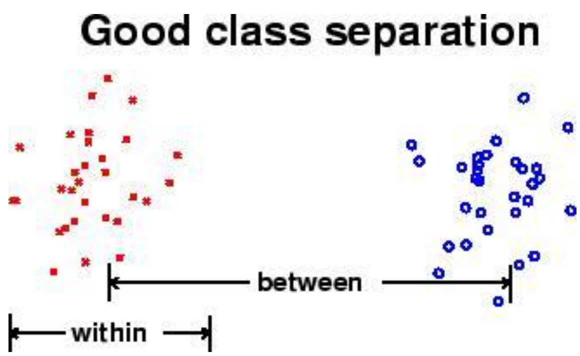


Figure 1: Class separation in LDA

In this proposed work multi-algorithmic approach is used for face. So first PCA is used to project images to low dimensional space and then LDA is applied to images projected on this low dimensional feature space. Euclidean distance classifier is used to classify the image into different classes. Image with minimum Euclidian distance is the best match and the normalized minimum euclidian distance is used to compute the score from face module. Score from face module is calculated.

B. Fingerprint Feature Extraction and Score Generation

Fingerprint is one of the most unique feature of human body. It has been primarily used for authentication[4]. Fingerprint recognition is a method of authenticating an individual by comparing two fingerprints. Identification is based on fingerprint features called minutiae. They are the point of interest in fingerprints. Minutiae include

- Ridge ending : Abrupt end of ridge
- Bifurcation : Bifurcation is a single edge that divides into two.

Figure 2: Ridge ending and bifurcation

The fingerprint image can be taken either using off-line methods such as through inked impression on paper or on-line through a live capture device consisting of an optical, capacitive, ultrasound or thermal sensor. The performance of fingerprint feature extraction and matching mainly depends on the quality of the input fingerprint image. The robustness of the fingerprint recognition system can be improved by incorporating an enhancement stage prior to feature extraction. The first step in image enhancement is to make fingerprint images more clearer for further operations. For that Histogram equalization and Fourier transform is used. The enhanced image is then binaries and thinned to obtain a Skelton image to be used for further operations. Next step is the feature extraction using crossing number method.

This method uses the skeleton image where the ridge flow pattern is eight-connected. This method uses 3x3 neighborhood of the ridge pixel and extracts two types of minutiae features, ridge endings and ridge bifurcations. It is done by examining the local neighborhood of each ridge pixel in the skeleton image using a window of size 3x3. For a pixel P, its eight neighboring pixels are scanned in anti-clockwise direction as shown

P5	P4	P3
P6	P	P2
P7	P8	P1

The Crossing Number (CN) for the given ridge pixel P is given by:

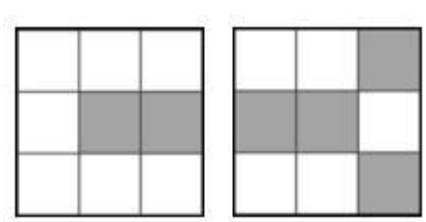


Figure 4: Ridge ending with crossing no:1 and bifurcation with crossing no:3

Crossing number is defined as the half the sum of difference between adjacent pairs of pixels in the eight connected neighborhood So the fingerprint skeleton image is first scanned and then all the pixels are labeled by the properties of corresponding crossing number. Using the CN values, each pixel is identified as ridge ending, bifurcation or non-minutiae point as shown in table I.

TABLE I: Crossing number and its properties

Crossing Number	PROPERTY
0	Isolated Point
1	Ridge Ending
2	Continuing Ridge
3	Ridge Bifurcation

Next step is fingerprint matching. The most important stage of a fingerprint verification system is the matching process. Matching algorithm determines whether two fingerprints are from same fingerprint or not. Matching is

normalized to a resolution of 112 x 92 pixel. For evaluating face recognition algorithm, experiment is conducted by reducing the number of images in the training data set.

II shows the comparison of results of proposed method with that of face recognition in terms of false acceptance rate.

TABLE 2: Comparison with face recognition in terms of FAR(%)

No: of training images per person	PCA	PCA+LDA	Proposed Method
9	0.5	0.25	0
8	1.25	0.25	0.25
7	2.25	0.75	0

6	3.5	1.5	0
5	11	5.75	0.5

For face, first 9 face images per person is used for training and last image is used for testing and obtained 0.5% FAR for PCA, 0.25% FAR for PCA+LDA and 0% FAR for proposed method. Then the no: of face images per person in training set is reduced from 9 to 8 and obtained 1.25% FAR for PCA, 0.25% FAR for PCA+LDA and 0.25%FAR for proposed method. This process is repeated until no: of images in training set becomes 5 and observed that

1. PCA+LDA has low FAR than single PCA method which means multi-algorithm approach for face has improved results than using a single algorithm.

2. Proposed method has very low FAR than unmoral face recognition system.

3.No: of images in the training set reduces, TAR reduces and FAR increases. But even in the reduced no: of training images, proposed method has greater true acceptance rate and low FAR compared to PCA and PCA+LDA methods.

shows that for the given dataset with 9 training face images per person it has 100% TAR , 0% FAR and 2.5% FRR.

Performance of fingerprint recognition is evaluated using fingerprint of 40 persons with one training fingerprint image per person. For that 2 databases FVC2002 and FVC2004 are used. It gives 8 different poses of 10 distinct fingers and images are taken using optical sensor. In addition to this 10 imposter images of 10 different individuals are also used to analyze false acceptance rate. Table IV shows the performace of fingerprint recognition algorithm

TABLE III: Results of proposed method

No: of training images per person	TAR	FAR	FRR
9	100	0	2.5
8	99.75	0.25	2.25

7	100	0	2.5
6	100	0	2.75
5	99.5	0.5	4.5

TABLE IV : Performance of fingerprint recognition algorithm

Threshold	FRR	FAR
0.42	0	0.2
0.43	0.05	0.2
0.45	0.075	0.2
0.46	0.075	0.1
0.5	0.1	0

Results shows that as threshold increases FAR reduces but FRR increases. So an optimim threshold is selected by trial and error method. Table V shows the comparison of results of proposed method with that of fingerprint part. It shows that proposed method has improved results than using only fingerprint as biometric.

Table VII shows the overall performance analysis. From the table we can infer that multi-algorithm used for face reduces FAR by .25% and increases TAR about 0.7% for 9 training face images per person. Also by combining both face and fingerprint biometrics, TAR increases and FAR reduces to a great extend.

TABLE V: Comparison with fingerprint recognition

Method	TAR	FAR	FRR
Fingerprint	85	12.5	2.5
Proposed Method	100	0	2.5

SYSTEM REQUIEMENT SPECIFICATION:

Requirement analysis in system engineering and software engineering will Encompasses those tasks that go into determining the needs or conditions to meet for a new or altered product, taking into account the possibly conflicting requirements of the various stakeholders, analysing, documenting, validating and managing software or system requirements. Requirements analysis is critical to the success of a systems or software or hardware project. The requirements should be documented, actionable, measurable, testable, traceable, related to identify business needs or opportunities, and defined to a level of detail sufficient for system design.

HARDWARE REQUIREMENTS

- 2GB RAM
- 7GB Hard Disk
- 32 or 64 bit processor
- Any integrated graphical processor

Laptop/Desktop PC consist minimum of 7GB, it is a measurement of how much physical memory is installed in your machine. System should have 32 or 64 bit processor and any integrated graphical processor are good.

SOFTWARE REQUIREMENTS

- Operating System: Windows XP or above/Linux
- Language: MATLAB
- IDE : Any compatible MATLAB software.

Advantages and Disadvantages of using Multi-Modal Biometrics

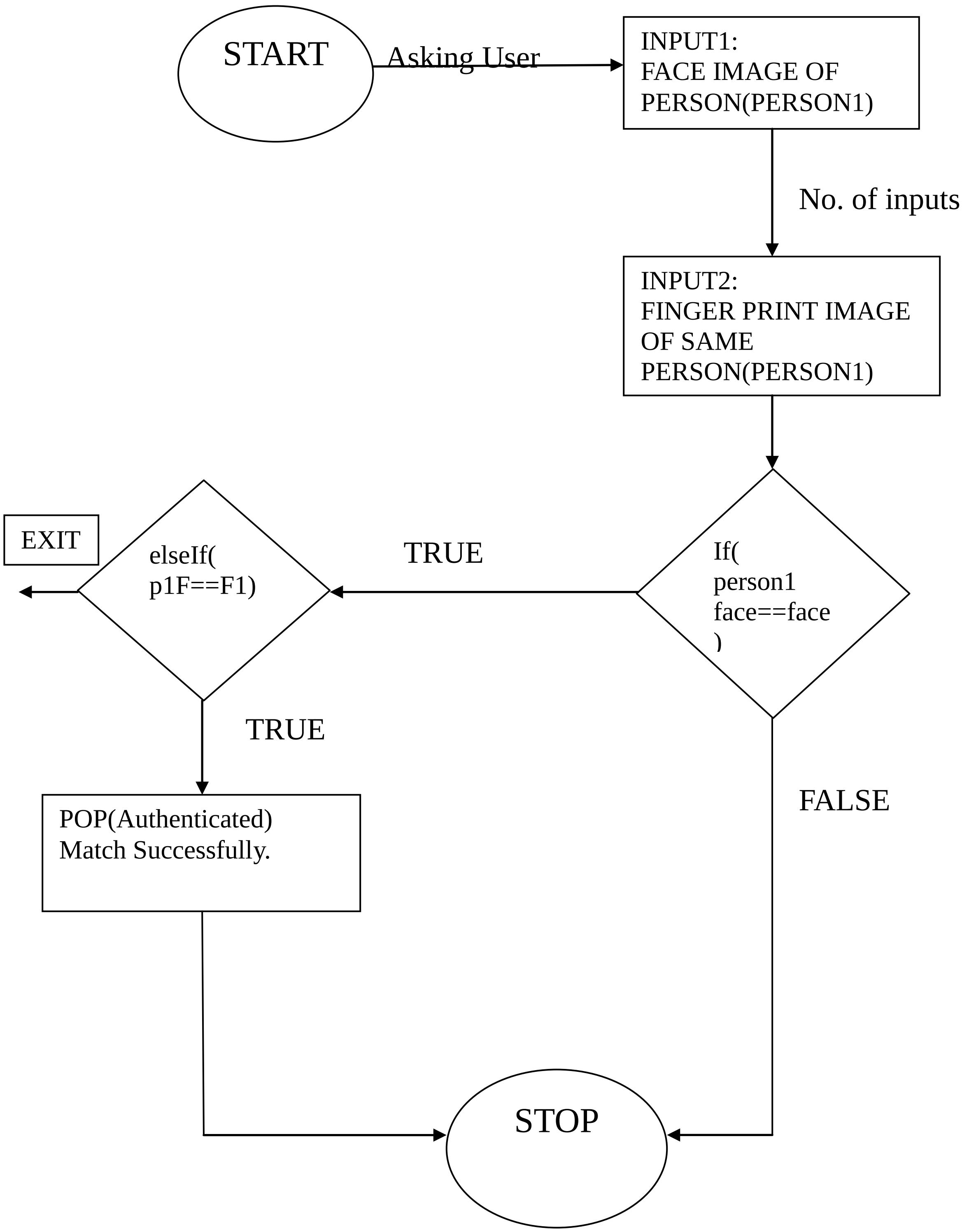
Advantages:

The benefits of multi biometrics system from the complementarily (diversity) of the component experts. It is generally true that some experts perform better than others and the adopted fusion strategy should reflect the reliability of each opinion. However, the term reliability has many aspects which are often not distinguished. In consequence, any counter measures adopted may not be as effective as expected.

Disadvantage:

- Environment and usage can affect measurements
- Systems are not 100% accurate.
- Require integration and/or additional hardware
- Cannot be reset once compromised

DESIGN AND IMPLEMENTATION



CODE:

(MAIN)

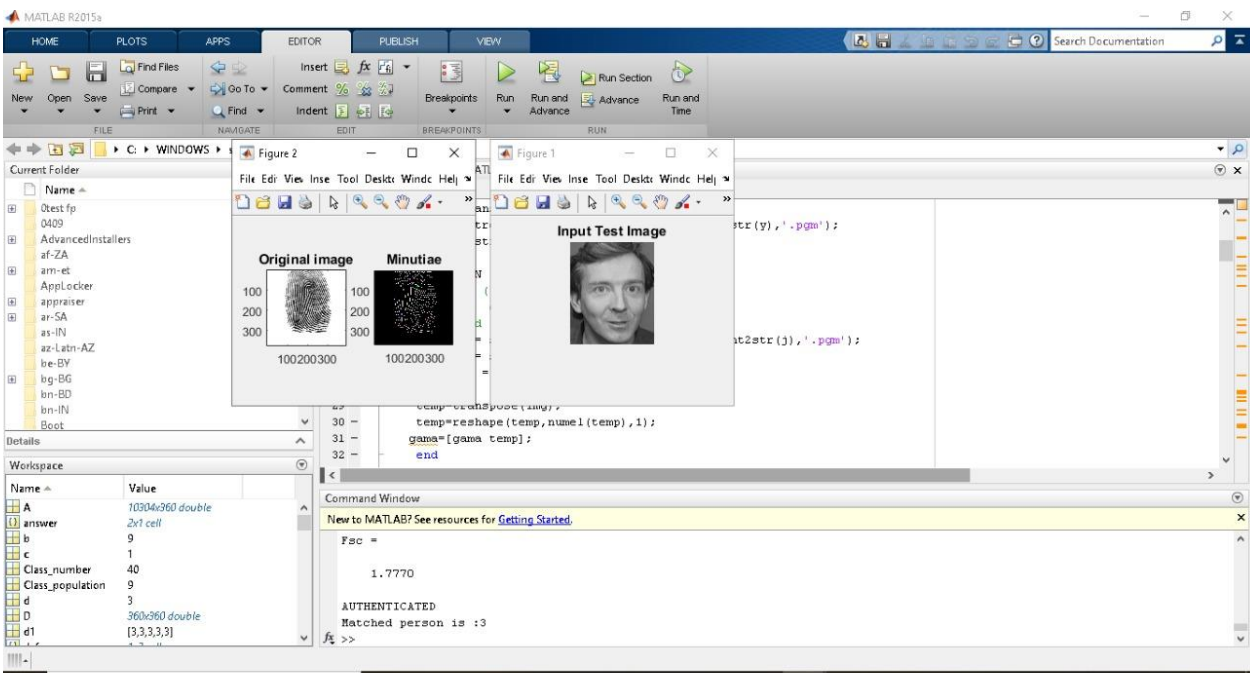
```
clc;%for clear the page
close all;%close all
clear all;%close all the
TrainDatabasePath = uigetdir('C:\Users\Keshav\Multimodal-
MultiAlgorithmic_Biometric-Fusion-master\test fp\Databases\orl', 'Select
training database path');
M=40;%Size of the image in pixel
N=9;
%P=2;
M1=M*N;
gama=[];%initialization
num_lines= 1;
def = {'1','10'};
prompt={'Enter test image name (a number between 1 to 40):','enter the matrix
size 1 to 10'};
dlg_title = 'Input of PCA-Based Face Recognition System';%Principal Component
Analysis (PCA) is a method for compressing high dimensional databases [1]. If
it used for image compression
TestDatabasePath = uigetdir('C:\Users\Keshav\Multimodal-
MultiAlgorithmic_Biometric-Fusion-master\test fp\Databases\orl', 'Select test
database path');
answer = inputdlg(prompt,dlg_title,num_lines,def);
x = str2num(answer{1});%converting string to number(pixels)
y = str2num(answer{2});
TestImage= strcat('\s',sprintf('%d',x),'\',int2str(y),'.pgm');%pgm defiened
as portable grey mapping
TestImage = strcat(TestDatabasePath,TestImage);%Testing the image from data
base.
for i=1:M %looping
    for j=1:N

        str = strcat('\s',sprintf('%d',i),'\',int2str(j),'.pgm');%Here
concation the file of image integer to string
        str = strcat(TrainDatabasePath,str);
         img = imread(str);%reading the image

    temp=transpose(img);
    temp=reshape(temp,numel(temp),1);
   gama=[gama temp];
    end
end
mean_All= mean(gama,2);%taking the mean of every pixels
A = [];  %Initialization of the variable
for i = 1 : M1
    t = double(gama(:,i)) - mean_All;
    A = [A t];
end
L=A'*A;
```

```
[V D] = eig(L);
L_eig_vec = [];

for i=360:-1:320;

        L_eig_vec = [L_eig_vec V(:,i)];

end
Eigenfaces = A * L_eig_vec;

 ProjectedImages_PCA= [];
 for i = 1 :M1
    temp = Eigenfaces'*A(:,i); % Projection of centered images into facespace
    ProjectedImages_PCA = [ProjectedImages_PCA temp];
 end
 P=M*N;
 Class_population=N;
 Class_number=M;
 m_PCA = mean(ProjectedImages_PCA,2); % Total mean in eigenspace
m = zeros(41,Class_number);
Sw = zeros(41,41); % Initialization os Within Scatter Matrix
Sb = zeros(41,41); % Initialization of Between Scatter Matrix

 for i = 1 : Class_number
    m(:,i) = mean( ( ProjectedImages_PCA(:,((i-
1)*Class_population+1):i*Class_population) ), 2 )';

    S  = zeros(41,41);
    for j = ( (i-1)*Class_population+1 ) : ( i*Class_population )
        S = S + (ProjectedImages_PCA(:,j)-m(:,i))*(ProjectedImages_PCA(:,j)-
m(:,i))';
    end

    Sw = Sw + S; % Within Scatter Matrix
Sb = Sb + Class_number*((m(:,i)-m_PCA) * (m(:,i)-m_PCA)'); % Between Scatter
Matrix
end
 [J_eig_vec, J_eig_val] = eig(Sb,Sw); % Cost function J = inv(Sw) * Sb
J_eig_vec = fliplr(J_eig_vec);

%%%%%%%%%%%%%%%%%%%%%%%% Eliminating zero eigens and sorting in descend order
for i = 1 : Class_number-1
    V_Fisher(:,i) = J_eig_vec(:,i); % Largest (C-1) eigen vectors of matrix J
end

for i = 1 : Class_number*Class_population
    ProjectedImages_Fisher(:,i) = V_Fisher' * ProjectedImages_PCA(:,i);
end
 InputImage= imread(TestImage);
 figure;
 imshow(InputImage);title('Input Test Image');%taking the input as image
 temp = InputImage(:,:,1);
[irow icol] = size(temp);
InImage = reshape(temp',irow*icol,1);
Difference = double(InImage)- mean_All; % Centered test image
```

```
ProjectedTestImage = V_Fisher' * Eigenfaces' * Difference; % Test image
feature vectorED = [];
ED=[];
for i=1:M1

q = ProjectedImages_Fisher(:,i);
d= ProjectedTestImage - q;
d1=sum(d.*d);
ED=[ED d1];
end
[Euc_dist_min , Recognized_index] = min(ED);
n = Recognized_index;
for L=1:M
    if n<=9*L
        str =  strcat('Matched person is :  ',int2str(L));%result has been
showed in connsole part
        disp(str);%displayig the image in string either its is authenticated
or not
        break
    end
end

b= mod(n,9);
if b==0
    b=9;
end

outputname= strcat('\S',sprintf('%d',L),'\',int2str(b),'.pgm');
disp(outputname);
outputname = strcat(TestDatabasePath,outputname);
outputname=imread(outputname);
figure,imshow(outputname);
title('Matched Image');
INDEX=[];

 u=[];
 t=[];
 for i=1:5
[Euc_dist_min , Recognized_index] = min(ED);
n = Recognized_index;
u=[u n];
t=[t Euc_dist_min];
ED(n)=100
end
 INDEX=u;
 T=size(INDEX,2)
 if T==0
  display('Not authenticated');
  break
 end

 FT=[];
for i=1:5
fvi=u(i);
  FM=FINGERFIN5(fvi);
  FT=[FT FM];
```

```
end
%disp(FT);
[d R Q]=mainedt6()
d1=[];
FD=[];
c=0;
 for i=1:5
     for j=1:5
         if FT(i)==R(j)
             c=1;
             d1=[d1 FT(i)];
             Fsc=(1-t(i))+Q(j)
             FD=[FD Fsc];
             display('AUTHENTICATED');
         end
     end
 end
 if c==0
     display('NOT AUTHENTICATED');
 end
[q v]=max(FD);
r=d1(v);
if c==1
str =  strcat('Matched person is :  ',int2str(r));
disp(str);
end
```

OUTPUT



MATLAB R2015a
Original image
Minutiae
Input Test Image
Fsc =
1.7770
AUTHENTICATED
Matched person is :3

CONCLUSION

Multimodal biometrics can overcomes the drawbacks of unimodal biometrics like intra-class variation, inter-class similarities, and spoofing. Proposed method combines multi- modal biometrics and multi-algorithmic approach to reduce the issues with unimodal biometrics and to increase security.
Two algorithms, PCA and LDA were used for processing face and crossing number based method is used for processing fingerprint.
We compare the results of face recognition algorithms and fingerprint recognition algorithm with the proposed method in terms of false acceptance rate, false rejection rate and true acceptance rate by reducing the number of face images per person in the training data set. The experimental results shows that proposed method performs better than unimodal face and fingerprint recognition systems. Proposed method reduces false rejection rate and false acceptance rate and improves true acceptance rate as compared to unimodal biometric systems but with increased computational time.