Fingerprint Recognition for Person Identification and Verification Based on Minutiae Matching

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***Abstract*—There are various types of applications for fingerprint recognition which is used for different purposes .fingerprint is one of the challenging pattern Recognition problem. The Fingerprint Recognition system is divided into four stages. First is Acquisition stage to capture the fingerprint image ,The second is Pre-processing stage to enhancement , binarization ,thinning fingerprint image. The Third stage is Feature Extraction Stage to extract the feature from the thinning image by use minutiae extractor methods to extract ridge ending and ridge bifurcation from thinning.The fourth stage is matching(Identification, Verification) to match two minutiae points by using minutiae matcher method in which similarity and distance measure are used . The algorithm is tested accurately and reliably by using fingerprint images from different databases. In this paper the fingerprint databases used are FVC2000 and FVC2002 Databases, we see that ,the FVC2002 database perform better results compare with FVC2000 database. The recognition system evaluate with two factor FAR and FRR ,In this system the result of FAR is 0.0154 and FRR is 0.0137 with Accuracy equal to 98.55%.**

Keywords:-Fingerprint Recognition , Identification ,Verification, Analysis, Minutiae .

I. Introduction

Fingerprint Recognition is used widely for identification of the persons as compare to the various biometrics techniques because of many reasons such as ease of capture, highly distinctiveness, persistence over time, also the fingerprint sensors are smaller and cheaper compare with other biometric sensors .Biometric system is used for person identification by using his/her characteristics(biological and behavioral). Biological characteristics are based on the physical part of human body such as (face ,fingerprint ,iris ,retina and speech) [2]. The applications such as access control, low enforcement system ,border management system airport and IT Security and so on [11]. The behavioral characteristics are based on an action taken by a human such as (voice, keystroke-scan, and signature-scan).The defined of fingerprint is a combination of many of ridges and many of valleys on the fingertip's surface[17].in case of the ridge which declare as black lines and the valleys declare as white lines are shown in Fig 1.

Fig 1. graphical types of ridges and valleys [14]

A fingerprint modality was used many years ago due to their uniqueness and constancy [16] through a person`s life. The first step to do fingerprint recognition is enrollment which is the process to register the biometric data to database as a template then fingerprint recognition undergo either Verification process or Identification process which is depending on the purpose of study. In the verification process the person's fingerprint is verified from the database by using matching algorithms. Also it is called (1:1) Matching. It is the comparison of a claimant fingerprint against enroll fingerprint, initially the person enrolls his/her fingerprint into verification system, and the result show whether the fingerprint which take from the user is matching with the fingerprint store as a template in database or not match.

In the case of identification process the fingerprint acquired from one person is compared with all the fingerprints which store in database. Also it is called (1:N) matching. it is used in the process of seeking the criminals. Figure 2 show the process of enrollment stage, verification stage and identification stage. The paper consist of seven sections as follow:

The introduction In section I, fingerprint recognition process, in section II, the proposed system of fingerprint recognition in section III ,The identification process in section IV, the verification process in section V, the experimental results are shown in section VI, finally ,conclusion and future work are given in section VII.

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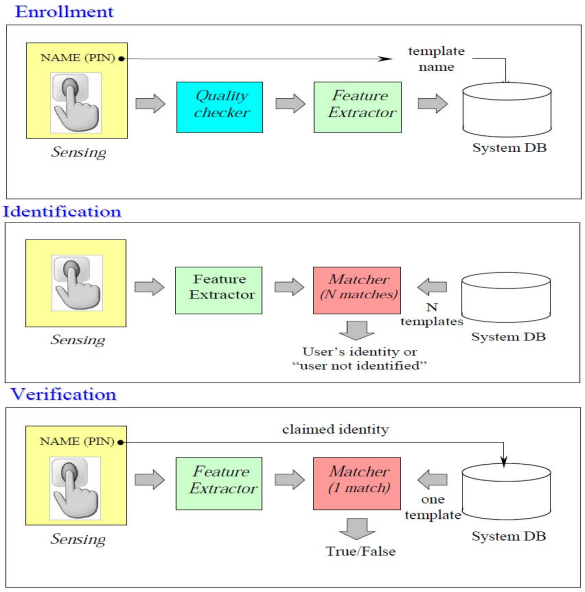


Fig 2. The main process in enrollment, identification and verification[1].

II. Fingerprint Recognition process

The process is performing of two phases:

a. Training (Enrollment).

b. Testing(Recognition).

During the training phase each fingerprint is captured by biometrics sensor or reader to generate digital image. This image is used as training data ,then pre-processing apply to training data for removing unwanted data, noise, reflection,etc.The pre-processing is used to increase the clarity of ridge structure.

The output of pre-processing is passed to the Feature extraction stage for each training data, the feature data can be extracted and stored in database .During the testing stage the similar steps as training stage with deference that the features are compare with the stored features in database to compute the degree of similarity or score .The most popular method is minutiae extraction algorithm which we focus in this paper, the minutiae extraction is a process to find the minutiae in fingerprint image ,the input fingerprint image in grayscale image(2-dimensional matrix with range from 0-255). The minutiae contains (x ,y) coordinate and local ridge orientation in radian.

There are various types of feature from fingerprint the minutiae are divided into two types which known as termination and bifurcation as shows in Fig.1.

In case of termination there is one ridge with two ends whereas in case of bifurcation the one ridge is divided into two separate ridges.

III. Proposed System

The fingerprint recognition system is divided into three stages that are fingerprint image pre-processing, feature extraction and matching . The matching stage is divide into two process identification and verification .At the time of capture fingerprint image the pre-processing stage is applied to it. The output of this stage will be passed to feature extraction stage which is extract the minutiae point(ridge ending, Bifurcation) from thinning fingerprint image, then the false minutiae removal is applied to extract real minutiae. Finally the real minutiae is stored in mat lab file (.mat). Then if the fingerprint is already enroll? then send to matching stage otherwise do enrolment stage and store it in the database as template. In identification case(one-to-many matching) , the input feature set which is matching with N template from database,N matching will be done. The result will be consider as matching Score. If matching Score closer to 1 then both fingers from same user. If matching score near to Zero then both fingers from deferent user . In verification case(one-to-one matching) ,the input feature set which is matching with one template from database ,one matching will be done and decided either the input fingerprint verified or unverified.Figure.3.show the propose of study .

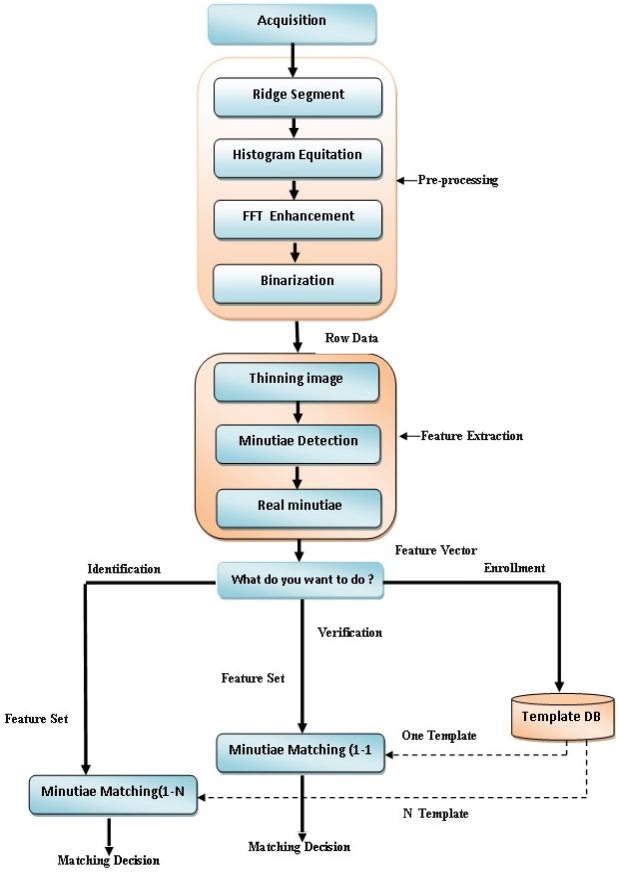


Fig 3. proposed of study of fingerprint Recognition ,Identification and Verification

The propose system stages are discussed as follow:

A. Acquisition stage

The Acquisition stage is the process to obtain image by different ways such as Online and Offline .There are number of methods are used which are discussed in [1].In online method the optical fingerprint reader is used to capture the image of fingerprint . In offline method the fingerprint image is obtained by ink in the area of finger and then put a sheet of white Paper on fingerprint and scan it to get a digital image. The resolution of the fingerprint must be 500dpi while the size is(640x480) pixels. In this paper we have used two standard databases which are available online(FVC2000 and FVC2002),they contain 80 fingerprints of 10 different fingers [2,8,9].

B. Pre-processing stage

The Pre-processing stage is the process of removing unwanted data in fingerprint image such as noise , reflection ,etc. It is used to increase the clarity of ridge structure. The main steps to do Pre-processing stage are enhancement fingerprint image , binarization and thinning. The result of enhancement is shown in the Fig4.For fingerprint enhancement we applied the following steps :

- Identify ridge segment
- Determine ridge orientations
- Determine ridge frequency
- Apply filters
- Histogram Equalization
- FFT Enhancement [13]

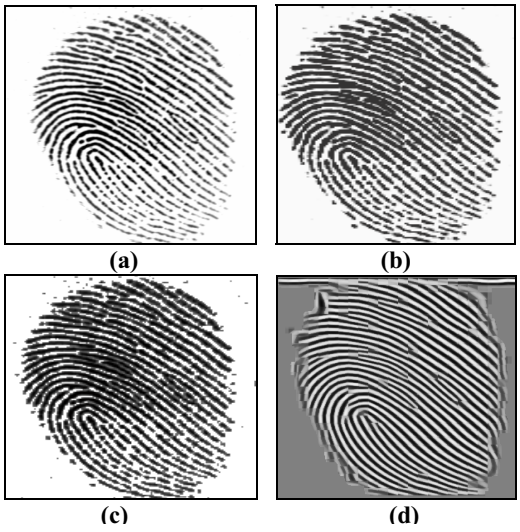


Fig 4. pre-processing stage (a)original image (b)ridge segment (c)Histogram Equalization (d) FFT Enhancement

The second step of pre-processing is binarization of fingerprint image which is a process to transform the image from 256 levels to two levels(0,1)refers to (black and white) respectively . The result of binarization is shown in Fig.5. In this paper we used locally adaptive binarization method which is summarized in this steps below :

1. The image is divided into blocks with size 16x16.
2. mean intensity value for each block is Calculated.
3. For each pixel the following rule is applied.

$$pixel = \begin{cases} 1 & if\ intensity\ value > mean\ intensity\ value\ \ for\ the\ current\ block \\ 0 & if\ \ intensity\ value < \ \ mean\ intensity\ value\ \ for\ the\ current\ block \end{cases}$$

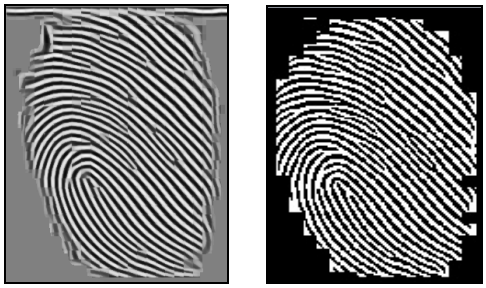


Fig 5.The second step of pre-processing,(a) Enhancement image (b) Binarization.

The third step of pre-processing is thinning which is shows in Fig.6 . It is also called (skeletonization). To enhance the binary image the thinning algorithm is used to reduce the ridges of fingerprint images. There are number of thinning methods. The most popular thinning algorithms are medial axis method, contour generation method, local thickness based thinning approach,sequential and parallel thinning [3 ,4]. We used morphological operation on binary image ,the main steps to do thinning is :

1.Clean up the thin image by remove single isolated , removes H-Breaks and removes spikes.

2. Remove the connected region at the boundary.

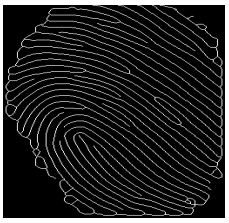


Fig 6. Thinning image

C. Feature Extraction stage

The result of pre-processing stage is passed to the feature extraction. In this stage feature of image are extracted like ridges,valleys,minutiae, singular points and etc. These features are used for verification and identification. The fingerprint recognition technique is divided to two categories :minutiae

based approach [5,6], and pattern-based[7]. In this paper we used minutiae based approach which consists of two approaches ,minutiae detection and minutiae matching . There are various type of minutiae[2].In this paper we use ridge endings and bifurcation to perform matching approach. The summaries of algorithm of finding minutiae of fingerprint are given in the steps as follow :

1) Finding minutiae algorithm

Input: the thinning of fingerprint image, the orientation image in radians and mask.

Output : Ridge ending, Ridge Bifurcation .

Step1: find the size of thinning image .

Step2:find the label connected components in 2-D binary image which get the total number of ridge and ridge map.

Step3:scan the thinning fingerprint image to detect the minutiae ,the 8-neighborhoods pixel are used to determine the ridge endings and ridge Bifurcation for each block have (0 ,1) Zero for thinning and one for determine the minutiae.

Step4:if there is one neighbor for the pixel minutiae considered as ridge ending whereas it is considered as ridge bifurcation if there are at least 3 neighbors for the pixel.

Step 5: store the ridge endings and ridge Bifurcation in mat lab file .

Step 6: End .

2) False Minutiae Removal

The false minutiae removal steps are shown in figure below:

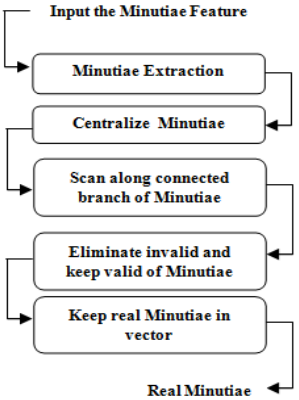


Fig .7. The false minutiae removal steps.

After extract the minutiae from fingerprint image by using minutiae extractor algorithm we passing it to false minutiae removal algorithm which is given above start with the centralize the minutiae on window and scan for all the connected branch of the minutiae and find the false minutiae structure which are taken from [12]. And the Table I, Show the false minutiae points in all cases .

Table I .show the false minutiae points

Case	shap	Description	State
M1		spike pierces into a valley	Distance between bifurcation and termination smaller than D (D is concidered as the average distance between parallel neighbour ridges).
M2		a spike falsely connects two ridges	Two bifurcation present in same ridge and Distance between them smaller than D then the both bifurcation are remove.
M3		Two near bifurcations present in the same ridge	
M4		Two ridge broken points separated by a very short distance and same orientation	Distance between two termination smaller than D and their directions coincident with samll angel variation and no other termination found in between them then they regarded as fales minutiae and part of brocken ridge hence removed.
M5		similar to m4 but one part of the broken ridge is so short .	
M6		extension of the m4 and 3rd ridge is found in between the two parts	
M7		a very short ridge found in the threshold window	Distance between two termination of a very sort ridge smaller than D it is concedered as a false minutiae and is removed.

D. Matching stage

The matching stage is a process to compare two fingerprints images(input and template)and compute the similarity degree between them.

In this paper we use two minutiae set from two fingerprint image.The matching algorithm is used to know either the two minutiae set from the same finger or from different finger .

The minutiae matcher based on ridge alignment is used in this paper in which two images of fingerprint are matched and a minutiae point from each image is selected to calculate the similarity of two ridges with them[18]. The system will do the comparison between the similarity and threshold and when the similarity more than threshold the new coordination system is created to which the sets of minutiae point transform. After apply this step to all minutiae points we get two sets of transformed minutiae point which are passing finally to matching algorithm to calculate the matching score by the following formula:

$$\text{Matching score} = \frac{\text{number of matched minutiae}}{\text{max. number of minutiae}} \times 100\%$$

The matching score is compared with threshold.When the matching score is greater than threshold the fingerprints are considered from same person (matching pair)otherwise the fingerprints are considered from different persons(non matching pair).In another words if the similarity is near or equal to one it is matching pair but if the similarity is near to zero it is non matching pair.

Genuine and Imposter score example:

In this case ,we have 10 users with 8 impression ,the total of 80 enrollee attempts .To compute the Genuine and Imposter score let me to give this simple example with Fig.8 below .

In the case of Genuine score, for one impression user in this example (8 impression – 1 match= 7 Genuine) and for all impression for first user is =7 x 8= 56 . now we compute for 10 users the Genuine = 7 x 8 x 10 = 560 Genuine score for all user in database .

In case of Imposter score , for one impression user in this example (80 – 8 = 72 Imposter) . for all impression for first user is =72 x 8= 576 . now we compute for 10 users the Genuine = 72 x 8 x 10 = 5760 Imposter score for all user in database . FAR and FRR are calculate using formulas below:

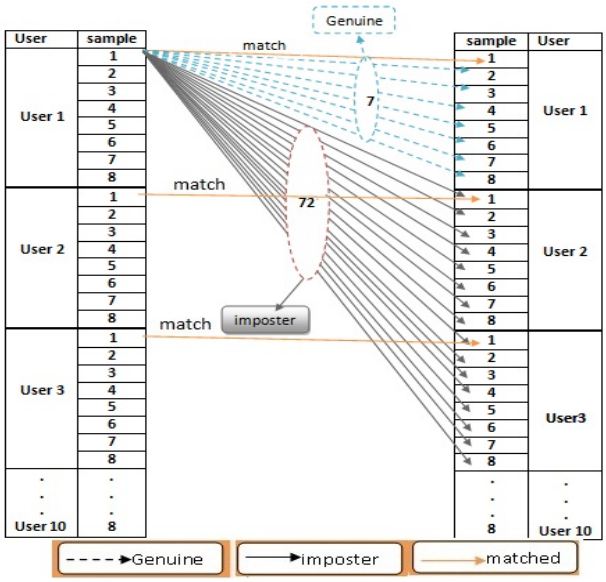


Fig.8. Example of Genuine and Imposter

$$FRR = \frac{Genuine\ score\ failing\ below\ thershold}{All\ Genuine\ score}$$

$$FAR = \frac{Imposter\ Score}{All\ Imposter\ Score}$$

IV. Identification process

It is the process for comparing between the user of biometric data and multiple users of template data which take at enrollment phase. In this process the similarity between input and all user's in template database is found. The Identification process is also known as(1:N)matching. It is performed when the user provides his/her biometric data and performed the multiple comparisons from number of user's to find the matching. The result will be user's fingerprint is identified or not identified.

V. Verification process

It is the process of comparison between the user of biometric data and one template. The Verification contain various of biometric data recorded but one of biometric data is matched. This process also is known as (1:1)matching. The result will be found or not found.

VI. Experimental Results:

The experiment is performed by using mat lab (R2013a) and tested on databases FVC 2000 and FVC 2002 [8,9]. The Table II. show the databases used in our work. figure.10 and figure.14 show the results of pre-processing stage and feature extraction stage respectively .The comparison of minutiae extraction from gray scale image without using enhancement and with used enhancement is shown in Table III. Fig.11. shows the matching stage between two fingerprints from same user and from different users and how much the similarity score between them. Fig.12. shows GUI of identification (one-to-many)matching from input and template. The similarity and distance measure are used to perform the fingerprint identification, the result is user identified or not.

Fig.13.shows GUI of verification system(one-to-one)matching. The result will be match or non match. Finally ,the recognition system shows the result user is recognized or not . To evaluate the fingerprint recognition system FAR and FRR are calculated, we used different databases, The first experiment on FVC2000(DB1_B) which contains 80 images (10 users X 8 impression) ,The second Experiment on FVC2002(DB1_B) which contains 80 images (10 users X 8 impression. We see that the FVC 2002 give good result better than FVC2000.The Table IV. shows the result of FAR,FRR and Accuracy and Fig.9.show the FAR,FRR and rate of the system. The Table V. shows the execution time for every stage of the proposes of study . The formula to calculate Accuracy is shown below:

$$Accuracy = 100 - \frac{FAR + FRR}{2}$$

Table II. Fingerprint Images Databases

Database	**Competitions**	**Image Size**	**Resolution**	**Sensor type**
DB1_B	FVC 2000	300x300	500 dpi	Low-cost optical sensor
DB2_B	FVC 2000	256x364	500 dpi	Low-cost capacitive sensor
DB1_B	FVC 2002	388x374	500 dpi	Optical sensor
DB2_B	FVC 2002	296x560	569 dpi	Optical sensor
DB3_B	FVC 2002	300x300	500 dpi	Capacitive sensor

Table III. comparison Minutiae Extraction without /with Enhancement

Images	**Minutiae**					
	without Enhancement			***with Enhancement***		
	Ridge End	Bifurcation	Total	Ridge End	Bifurcation	Total
101_1	18	375	393	31	11	42
102_1	10	620	630	70	23	93
103_1	147	343	490	41	30	71
104_1	44	770	814	59	29	88

Table IV.The percentage of FAR,FRR and Accuracy

Experiments on Database	Recognition Accuracy		
	FAR	*FRR*	*Accuracy*
FVC2000 DB1_B	0.2049	0.1944	80.03%
FVC2002 DB1_B	0.0154	0.0137	98.55%

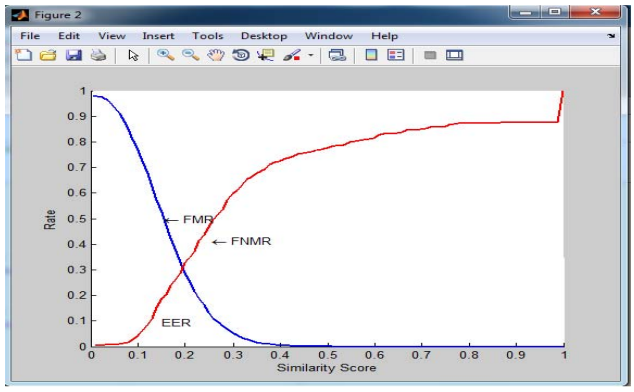


Fig 9. shows the Performance of FAR and FRR

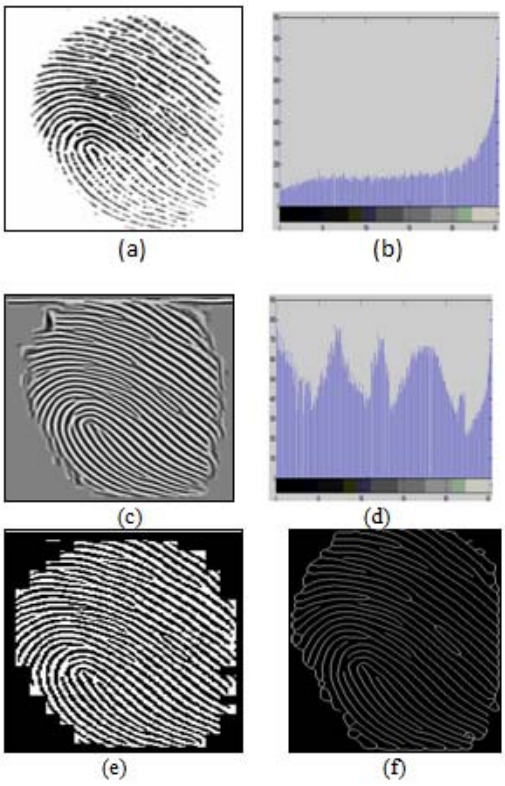
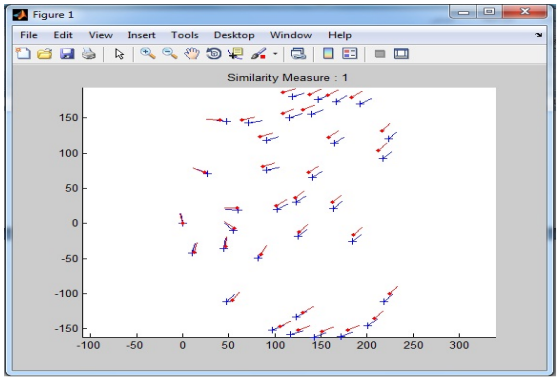
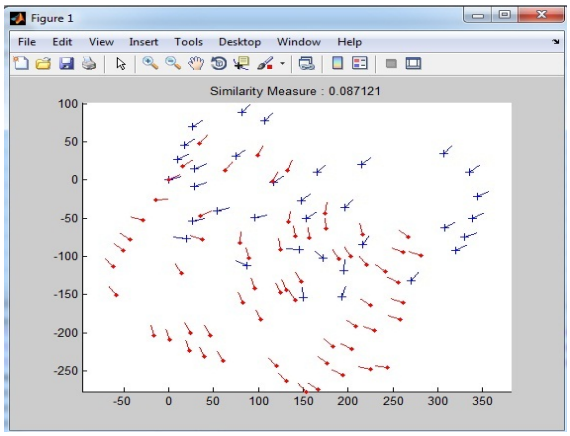


Fig 10.Summary of Pre-processing steps (a)input Image (b)Histogram of input (c)FFT Enhancement (d) Histogram Enhancement (e) Binarization (f) Thinning



(a)



(b)

Fig 11. (a) matching between (101_1) and (101_1) similarity =1.(from same person).(b)Matching between (101_1) and (102_1) similarity =0.087121.(from different person).

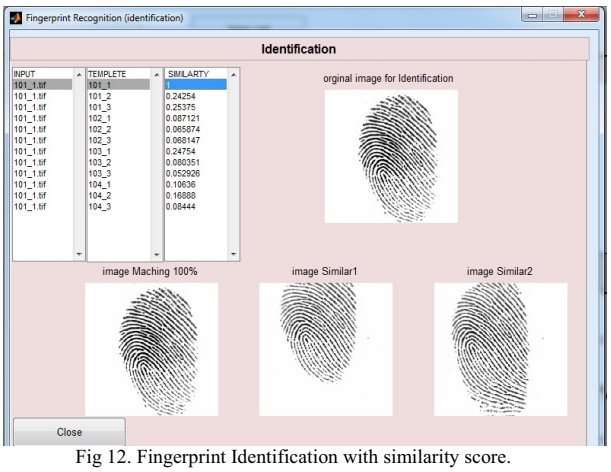
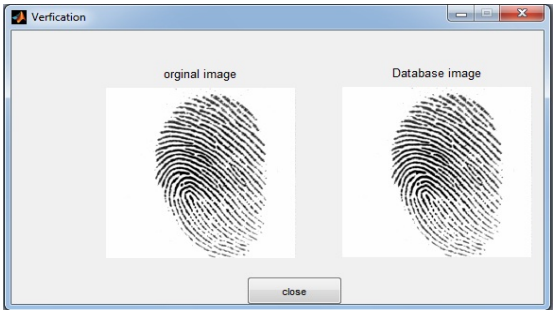


Fig 12. Fingerprint Identification with similarity score.



(a)

Fig 13. Verification System (1:1) matching

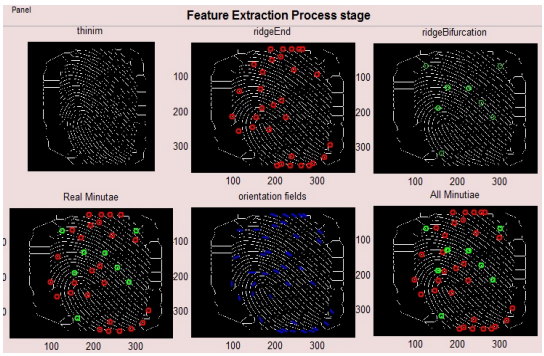


Fig 14. Feature Extraction stage

Table V. Time executing for each stage

Stage	Elapsed time in seconds.
Pre-processing	3.696824
Feature Extraction	0.660177
Matching	0.386971
Identification	4.194027
Verification	0.314468
Recognition	14.885206
Total	24.13767

VII. Conclusion and future work

Our work presented fingerprint identification and verification based on minutiae features. The work is done in sequence start from the first stage which is pre-processing which is used to remove unwanted data and increased the clarity of ridges of fingerprint image. The second step is the feature extraction which is used to extract the fingerprint features. In this work we focus on ridge ending and bifurcation which is done by using minutiae extractor algorithm .The third step of this work is the matching which is divided into two parts identification process also known as(1:N)matching or verification process also known as(1:1 matching).Here we used minutiae matching algorithm with Euclidean distance measure to find similarity score of two fingerprints images.

The experiments are tested on two fingerprint databases which are FVC2000 and FVC2002.The result from the experiment 1 on FVC2000 database of FAR and FRR are 0.2049,0.1944 ,respectively and result from experiment 2 on FVC2002 of FAR and FRR are 0.0154,0.0137,respectively.The accuracy from FVC2000 and FVC2002 are 80.03%,98.55% respectively. The result of FVC2002 is good comparing with FVC2000 in this work.

The future work is to do fingerprint identification and verification by using neural network and fuzzy logic in order to enhance and evaluate the best performance of fingerprint recognition system and to create our own database for testing our work on it .

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