RESEARCH ARTICLE OPEN ACCESS

Experimental Study of Minutiae Based Matching Algorithm for Fingerprint Recognition System

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ABSTRACT

Minutia based fingerprint matching algorithm is considered to be the most widely used method for fingerprint recognition applications .Therefore, in this paper the utilization of minutiae based technique is discussed in details to develop a dependable recognition system. We introduce a comparison of results on standard benchmarks such as FVC2002 for assessing the system performance based on the False Acceptance Rate (FAR) and False Rejection Rate (FRR) and accuracy performance metrics. The results show that the approach described in our paper can achieve up to 95.4%, 99.3%, 81.3%and 93.8% accuracy for different datasets DB1_B, DB2_B, DB3_B and DB4_B in FVC2002 database.

Keywords :- Biometric Recognition, Ridges, Valleys, Termination, Bifurcation, FAR, FRR.

I. INTRODUCTION

Biometric Recognition is the automated process that recognizes the individuals based on specific behavioral and biological features. Biological features are the features that related to the human body and rarely change like (fingerprint, iris recognition, veins, face recognition, palm print, hand geometry and DNA).Behavioral features are the features that based on individuals actions like (signature, gait, typing rhythm and voice). Fingerprint: In this paper we focus on using Fingerprint features for human recognition .These features are stable, unique and remain overtime then we can consider fingerprints to be a dependable method for human recognition compared to other methods such as (Password and ID-cards) which can be token and stolen .There are two basic features included in fingerprint can lead us to a reliable human recognition system. These features are the result of a shape includes ridges and valleys on the surface of the finger. The ridges are the dark and raised regions while the valleys are the white and lowered regions. Our paper based on the significant points which appear on each ridge these points called minutiae that divided into two types (Termination points are the points at the termination of the ridge and Bifurcations are points at which a ridge divides into two ridges) as shown in figure1.

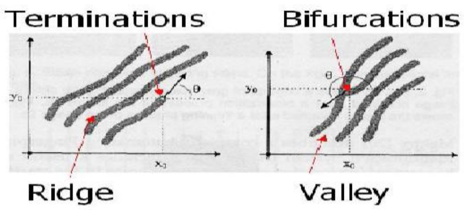

Fig1: Fingerprint Features[7]

II. RELATED WORKS

Avinash Pokhriyal et al. [1] precented a method called MERIT (Minutiae Extraction using Rotation Invariant Thinning in which the minutiae points are extracted from a fingerprint image. First of all, the fingerprint image is binarized , the image are skeletonized by using a 3x3 mask is convoluted . Finally postprocessing is done to remove the false minutiae from the fingerprint. Sangram Bana et al. [11] presented a good study of a Minutiae based matching fingerprint recognition system implementation based on the minutiae points that extracted from the sample fingerprint images and then performing minutiae pairings matching . L.Ravi Kumar et al. [5] implemented a good fingerprint analysis technique based mainly on using minutiae extraction with different image pre-processing techniques to enhance the input image and two major categories of minutiae and bifurcation are used .R K. Nagthane and H. S. Fadewar [9] discussed the types of altered fingerprint images , The altered fingerprint images are using minutiae matching technique and the proposed system and the percentage of altered fingerprints with its original fingerprint are evaluated. Hemlata Patel and

Mr. Vishal Sharma [3] presented a method that describes the various patterns of fingerprint and discussed the drawbacks that affect the accuracy of fingerprint matching like, insensitivity to change the direction of fingerprint, size, difference between the two fingerprints, features of fingerprints and poor quality. M.Sivapriya and S.Pushpa[6] presented a new effective methodology using minutiae matching technique based on the occurrences of singular points with reference to the core point. Ravi.J. et al. [10] produced a Fingerprint Recognition using Minutia Score Matching method (FRMSM) and Fingerprint thinning based on the block filter which scans the image at the boundary to preserves the quality of the image and extract the accurate minutiae extraction. .Iwasokun Gabriel Babatunde et al. [4]presented a report on the experimental study of the impact of false minutiae on the performance of fingerprint matching system by implemented A standard fingerprint matching and assessed the impact of false minutiae points on FAR, FRR and the matching speed.

III. FINGERPRINTRECOGNITION SYSTEM IMPLEMENTATION

Fingerprint recognition refers to the process of comparing a fingerprint against another fingerprint to find the matches between them [12].. We concentrated our implementation on minutiae based algorithm according to particular steps as show in figure2

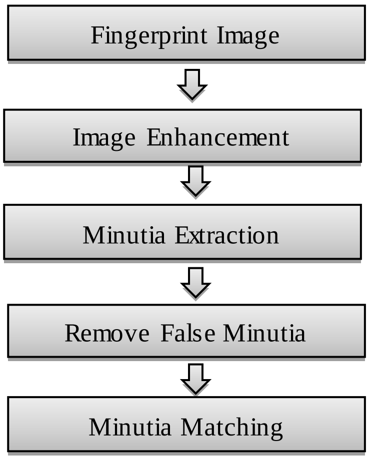

Fig.2: Block diagram of the Fingerprint Recognition

A. *FINGERPRINT PRE-PROCESSING:*

1) **Histogram Equalization:** Important details in images may represented in poorly contrast. histogram equalization technique is used to distribute the intensity values of pixels in the image along the total range of values. This allows the lower local contrast areas to be represented in a better contrast and we can gain a good brightness level balance of the fingerprint image .

Fig.3:Enhanced Image after Histogram Equalization

2) **FAST FOURIER TRANSFORM:**Fast Fourier Transform method is used to transform the image from spatial domain to the frequency domain by decomposing it into its sine and cosine components then the original image is enhanced by perform fast Fourier transformation as follow . The image is divided the into(**32 by 32 pixels**) blocks using the following equation:

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \times exp\left\{-j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \quad (1)$$

for u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31.

We enhance each block in image by using :

$$\mathbf{g(x,y)} = \mathbf{F}^{-1}\{F(u,v)\times|F(u,v)|^{k}\} \quad (2)$$

Where quality factor k=0.45 and $F^{-1}(F(u,v))$ is given by:

$$f(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} F(u,v) \times exp\left\{j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \quad (3)$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.

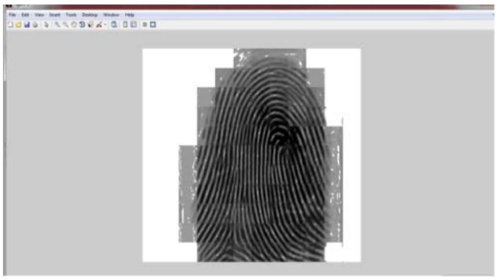

Fig.4 : Enhanced Image after FFT

3) **Binarization:** Adaptive binarization is used to convert the 8-bit Gray fingerprint Image to a 1-bit image in the ones and zeros form. 0-value for each fingerprint ridges and 1-value for grooves. This allows the output image to be represented in black and white colors only depending on a predefined threshold compatible to the entire image .then the pixel with value less than the threshold value is classified as black (zeros values) otherwise, it is classified as white (ones values).

$$B(x, y) = 1 \text{ if } g(x, y) > T$$
$$0 \text{ if } g(x, y) \leq T \qquad (4)$$

Where, g(x, y) is the value of a pixel in gray-scale fingerprint , B(x, y)) is the value of a pixel in binarized fingerprint image and *T* is the threshold.

Fig.5 : Enhanced Image after Binarization

4) **Image Segmentation :** Is the process of partitioning the image into regions according to specific and common features. Then the areas with no significant details are discarded and the remaining areas with effective ridges and furrows are highlighted depending on the ridge orientation flow estimation and region of interest (ROI) techniques.

- **Ridge Orientation Flow Estimation:** The common orientation for each block of the entire fingerprint image with size (32x32) pixels is estimated to define the orientation map :

For each block(with size 32x32 pixels) we calculated the gradient values along x-direction and y-direction .
For all the pixels in each block , the Least Square approximation of the block direction is calculated using :

$$\tan 2\beta = 2 \sum \sum (g_x * g_y) / \sum \sum (g_x^2 - g_y^2) \qquad (5)$$

Finally the blocks with no important information on ridges and valleys are rejected based on the following formula :

$$E = 2 \sum \sum (g_x g_y) + \sum \sum (g_x^2 - g_y^2) / WW \sum \sum (g_x^2 + g_y^2) \quad (6)$$

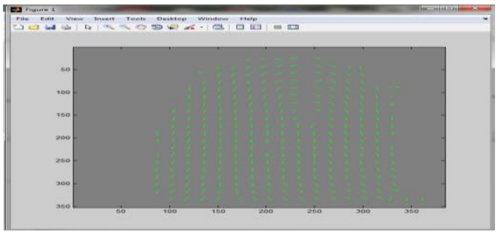

Fig.6:Orientation Flow

- **Region of interest (ROI)**: The region of interest is extracted based on the OPEN and CLOSE morphological operations .Where OPEN operation is used to remove peaks and (CLOSE) operation is used to remove small cavities and shrink fingerprint image.

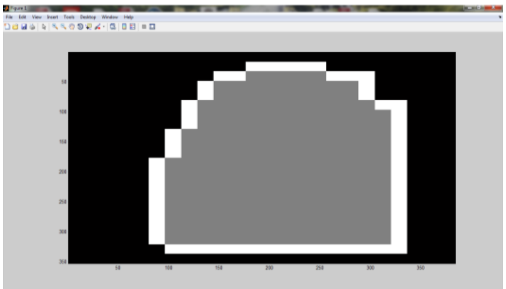

Fig.7:Image Segmentation (ROI)

B. Minutiae Extraction:

1) **Thinning**: Is the process to reduce the ridge thickness to one pixel wide by eliminating the redundant ridge's pixels by using the built- in morphological function in matlab (bwmorph(binaryImage,'thin',Inf)).

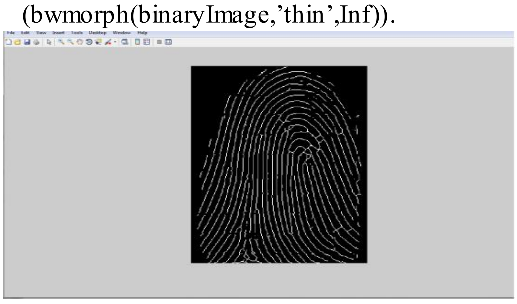

Fig.8: Image after Thinning

2) **Minutiae Marking:** Minutiae marking is the most important step in fingerprint recognition system. The crossing number (CN) method is using to extract minutia from the image by examining the local neighborhood of each ridge pixel using a3x3window.The crossing number value is defined as half the sum of the differences between pairs of neighboring pixels in the 3x3 block.

P_4	**P_3**	**P_2**
P_5	**P**	**P_1**
P_6	**P_7**	**P_8**

Fig.9: 3x3 neighborhood block

The CN value is calculated according to the following formula:

$$CN=0.5\sum_{i=1}^{8}|P_i - P_{i+1}| \qquad (7)$$

Where $P_9=P_1$. If CN= =1 then the minutiae is classified as a ridge ending point and if CN= =3 the minutiae is classified as ridge bifurcation.

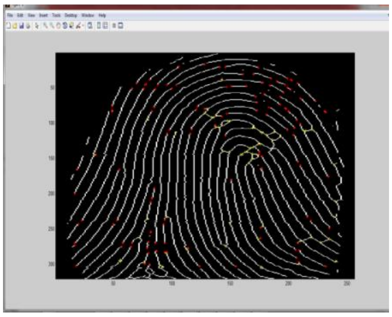

Fig.10: Minutiae Marking
(terminations in red color and bifurcation in yellow)

C. Image Post-Processing:

1) **False Minutiae Removal**: the aim of this stage is to eliminate any false minutia which may be produced due to the noises, insufficient amount of ink and over inking in the fingerprint image. then the average distance 'D' between two parallel ridges is calculated (called the average inter-ridge width) and the false minutia is rejected according to the following cases:

- If one bifurcation point and one termination point are in the same ridge and the distance between them is less than D .Reject both of them.
- If two bifurcation points are in the same ridge and the distance between them less than D. Reject both of them
- If two termination points are in the same ridge and the length of ridge is less the value of D . Reject both of them
- If two termination points are within a distance D and their directions are coincident with a small angle variation and there is no termination point located between them . Then the two terminations are considered as false minutia in a broken ridge and are rejected.

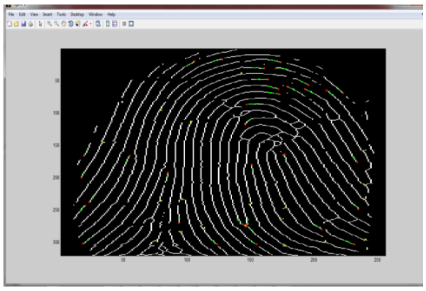

Fig.11: false minutiae removal

D. Fingerprint Matching:

- **Alignment Stage**: let we have two sets of minutia extracted from two fingerprint images**:**

T1= {m_1, m_2, m_M} ,where m_i= (x_i, y_i, θ_i)
T2= {m_1', m_2', m_N'}**,** where m_i'= (x_i', y_i', θ_i') where x_i and y_i are the coordinates of minutia and θ_i is direction discrepancy**.**

We choose one reference minutiae from each set to get the ridge correlation
factor between them. The similarity of correlating the two ridges is done by:

$$S = \sum_{i=0}^{h} x_i X_i / [\sum_{i=0}^{h} x_i^2 X_i^2]\ ^\wedge 0.5 \qquad (8)$$

where (x_i~x_n) and (X_i~X_N) are the set of minutia for the two fingerprint images respectively .n and N are the total number of minutiae in each fingerprint image and h= min(n,N) . We define a threshold value(t = 0.8) . If the value of S is less than t or equal to t , the next new pair of ridges are checked to match .Otherwise, all minutia in each fingerprint are translated and rotated with respect to the reference minutia according to the following formula:

$$\begin{pmatrix} x_{i\_new} \\ y_{i\_new} \\ \theta_{i\_new} \end{pmatrix} = TM * \begin{bmatrix} (x_i - x) \\ (y_i - y) \\ (\theta_i - \theta) \end{bmatrix}$$

$$TM = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (9)$$

where (x,y,θ) are the parameters of the reference minutia.

- **Matching Stage**: An elastic match algorithm is performed to the driven aligned minutiae of the two fingerprint images by counting the matched minutia pairs which have a nearly position and direction and finally the score matching is calculated using:

$$\text{MATCHING SCORE} = \frac{\text{Matched Minutiae}}{\text{Min}(T1,T2)} \quad (10)$$

where T1 ,T2 are the number of extracted minutia in the input image and template image.

IV. EXPREMENTAL RESULTS

Our purposed project was implemented using MATLAB program and FVC2002 database was selected for testing stage. The database contains four datasets DB1, DB2, DB3 and DB4 with each containing 10 different fingerprint images with 8 impressions per finger.Table1 shows the properties of FVC2002 database[2].

TABLE1: Details of FVC2002 fingerprint database

Database	Sensor Type	Image Size	No of images	Resolution
DB1-B	Optical Sensor	388 × 374	10 × 8	500 dpi
DB2-B	Optical Sensor	296 × 560	10 × 8	569 dpi
DB3-B	Capacitive Sensor	300 × 300	10 × 8	500 dpi
DB4-B	SFinGe v2.51	288 × 384	10 × 8	About 500 dpi

The project performance is calculated based on the following performance measurement:.

- **False Acceptance Rate(FAR)).**
- **False Rejection Rate (FRR)).**
- **ACCURACY.**

False Acceptance Rate (FAR): is the probability that the systemincorrectly matches two non-matching samples.

$$\text{FAR} = \frac{\text{No of Incorrectly accepted individuals}}{\text{Total No of wrong matching}} \quad (11)$$

False Rejection Rate (FRR) : Is the probability that the systemincorrectly rejects two matching samples .

$$\text{FRR} = \frac{\text{No of Incorrectly rejected individuals}}{\text{Total No of correct matching}} \quad (12)$$

$$\text{ACCURACY} = 1 - \frac{\text{FAR+FRR}}{2} \quad (13)$$

TABLE 2. FAR and FRR For DB1_B , DB2_B, DB3_B and DB4_B

DATABASE	FAR	FRR	Accuracy%
DB1_B	0.093	0	95.4%
DB2_B	0.015	0	99.3%
DB3_B	0.125	0.25	81.3%
DB4_B	0.125	0	93.8%

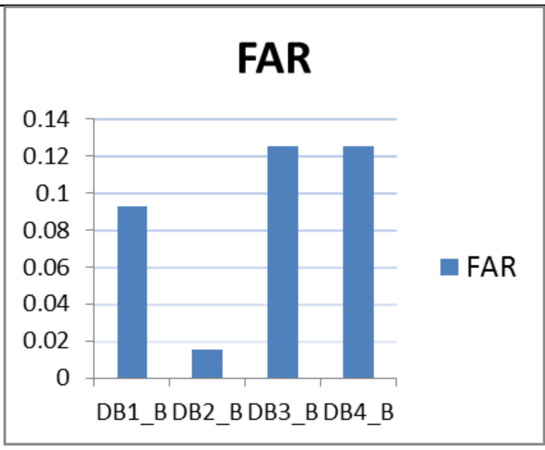

Fig12. Comparison Graph between DB1_B , DB2_B, DB3_B and DB4_B.

V. CONCLUSION

This paper is an effort to explain how to use fingerprint features in human recognition field .It includes the major stages for implementing minutiae matching algorithm to match two fingerprints and calculate the similarity score between them. The minutia matching algorithm performance is affected with the value of reference threshold value and the quality of the images .We used reference threshold 44% value and obtained good system accuracy using different datasets as shown above in table 2.Our future work is adding more improvements to our project and testing it with diverse and noisy databases.

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