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A novel approach for Fingerprint Recognition

Mr. P. P. Chouthmal*
Department of CS & IT,
Dr. B. A. M. University,
Aurangabad, India

Miss. S. A. Bhosale
Department of CS & IT,
Dr. B. A. M. University,
Aurangabad, India

Dr. K. V. Kale
Head, Department of CS & IT,
Dr. B. A. M. University,
Aurangabad, India

Abstract— In this paper minutiae based approach for fingerprint recognition is presented. Accuracy of minutiae based algorithm is highly dependent on the quality of fingerprint used. Since the fingerprint images acquired from sensors or other sources are not assured with perfect quality, an algorithm for enhancing quality of fingerprint by reconnecting broken ridges is presented here. Fingerprint matching is usually consist of two procedures: minutia extraction and minutiae matching. False minutia removal algorithm is implemented to have genuine minutia and alignment based approach is used here for minutiae matching. Experimental results show that proposed algorithm achieves a much better matching performance.

Keywords— Fingerprint enhancement, Gabor filter, Minutia extraction, Minutia matching, Fingerprint recognition.

I. INTRODUCTION

Fingerprint recognition is most commonly used and widely accepted biometric method for person authentication because of its uniqueness, permanence and universality [1]. Fingerprint of an individual is unique and remains unchanged over a lifetime. No two person's not even identical twins have identical fingerprints [2].The probability of finding two fingerprints alike is 1 in $1.9*10^{15}$[3]. That's why fingerprints are effective where high degree of security is required.

In order to implement successful algorithm for fingerprint recognition, it is necessary to understand the topology of fingerprints. A fingerprint is pattern composed of sequence of ridges and valleys [4]. The ridges are dark lines while the valleys are the light areas between the ridges. The uniqueness of an individual fingerprint is can be analysed by using global features and local features. The global features mainly give an overall characteristic of the finger. In this paper local characteristics of finger print are studied. There are various types of local characteristics called minutia in fingerprint, minutiae are the minute details of the fingerprint [5] and they are shown in fig.1. There are more than 100 different types of minutia have been identified, among which ridge terminations and ridge bifurcations are widely used for discriminating one fingerprint form another. Ridge termination is the point where ridge ends abruptly and bifurcation is point where a ridge merges or splits into branch ridges.

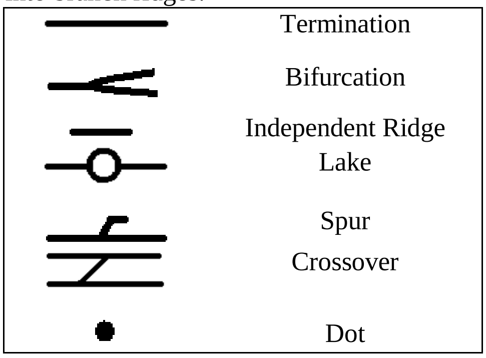


Fig.1: Minutia Types

The remainder of this paper is organized as follows. In section 2 a detailed description of proposed algorithm is given. Experimental results are discussed in section 3. Section 4 concludes this paper.

II. PROPOSED METHODOLOGY

Proposed approach is mainly based on the minutia based representation of a fingerprint. In which the fingerprint is represented by two minutia feature parameters: 1) x and y coordinate of the minutia point 2) θ i.e. the minutia orientation. Our approach gives number of matched minutia on the basis of these features by considering both query and reference fingerprints and uses it to generate similarity scores. According to forensic, when two fingerprints have a minimum of 12 matched minutiae between them they are considered to have come from same finger [6], so more matched minutia yield higher similarity scores. That is when the number of minutia on both fingerprints is large; we can confidently distinguish the legitimate and fake fingerprint using the number of matched minutia.

The proposed methodology of fingerprint recognition is shown in Fig. 2.

Acquisition	• Image is acquired from input device.
Pre-Processing	• Image Enhancement • Conversion to black and white • Thinning
Structural Extraction	• Detection of minutia points
Post Processing	• Removal of false minutia
Matching	• Determines whether two fingerprints are of same person or not

Fig. 2: Flow of the fingerprint recognition system

A. *Fingerprint Image Pre-Processing*

As the performance of system is heavily depends on quality of acquired fingerprint images [7], it is very necessary to have good quality images for processing but due to some environmental factors and user's body conditions, acquired images may be of poor quality. The poor quality image cause two problems: (1) many spurious minutiae may be created and (2) many genuine minutiae may be ignored. Therefore, an image pre-processing is necessary to increase the performance of system. The steps to do pre-processing of fingerprint are explained below.

1) Image Enhancement:

Method adopted for enhancing the fingerprint in our system is built on the techniques developed by Hong et al [8].This method includes four main stages: 1) Normalization 2) Orientation estimation 3)Ridge frequency estimation 4) Gabor filtering.

In normalization stage, intensity values of an input fingerprint image is standardised by adjusting the range of gray level values so that it lies within a desired range of values. After that orientation image is estimated from the normalized fingerprint image by using gradient information.Gabor filtering stage relies on local orientation in order to effectively enhance the fingerprint image. In the next stage, the frequency image is computed from the normalized image and estimated orientation image.The resulting image represents the local frequency of the ridges in the fingerprint. Finally a bank of pre-tuned filter is applied to the ridge and valley pixels in the normalized fingerprint image to obtain the enhanced fingerprint image. In general, gabor filter is employed for enhancement of the fingerprint image.

2) Image Binarization:

Fingerprint image binarization is very important phase in process of ridge extraction. Obtained image from fingerprint scanner is in grayscale format. Binarization phase transforms 256-level image into a 2-level or bi-level image which represents same information as original image. Typically, value of "1" is assigned to ridge pixel and "0" to background pixel [9].

A locally adaptive binarization method is implemented to convert fingerprint image into black and white image. Corresponding pixel value is changed to 1 if the pixel value is larger than the mean intensity value of the current block (16×16) to which pixel belongs.

3) Image Segmentation:

The limitation of image processing is that it can interact only with the pixel values but not with the location of pixels. The only solution to this problem is to select Region of Interest (ROI).The main motive of this phase is to make the image simpler for performing further operation. The image area without useful information is first discarded since it only holds background information. Then the bound of remaining effective area is sketched out. Morphological operations like 'OPEN' and 'CLOSE' are used to remove peaks and small cavities from image.

B. *Minutia Extraction*

1) Fingerprint Ridge Thinning:

Ridge thinning is the process of eliminating the redundant pixels of ridges till the width of ridges become just one pixel thick.This process is also called as skeletonization [10]. Large number of methods are avilable in literature for skeletonization.In proposed work morphological thinnning operation in MATLAB is applied to get thinned image. Resulting skeleton has some unnecessory spurs, bridges ,line breaks which may leads to spurious minutia points.So in order to remove these points morphological operations like 'spur', 'hbreak' and 'clean' are used.

2) Minutia Marking:

Two minutiae points i.e. ridge ending and ridge bifurcation are extracted from thinned fingerprint image by scanning the local neighbourhood of each pixel using 3*3 window (Fig. 3) around a pixel.

P4	P3	P2
P5	P	P1
P6	P7	P8

Fig. 3: 3*3 window

Then the Crossing Number (CN) is computed, which is given by

$$C_n(P) = \left(\frac{1}{2}\right)\sum_{i=1}^{8}|P_i - P_{i+1}| \qquad (1)$$

Where, P_i is the binary pixel value in the neighborhood of P. The crossing number Cn(P) at a point P is defined as half of cumulative successive differences between pairs of adjacent pixels belonging to the 8-neighborhood of P. According to CN values listed in Fig. 4, corresponding pixel can be classified either as ridge ending or bifurcation [11]. For instance, a ridge pixel with a CN of 1 corresponds to a ridge ending, and a CN of 3 corresponds to a bifurcation.

CN Value	Property
0	Isolated Point
1	Ridge Ending
2	Continuous Ridge
3	Bifurcation
4	Crossing

Fig.4: Properties of crossing number

For extracting genuine minutiae points accurately inter ridge width is computed. Inter ridge width refers to average distance between two neighboring ridges. Inter ridge width, D is computed as follows:

i. Scan a row of thinned ridge image and sum up all the pixels in the row whose value is one.
ii. Divide above summation with row length to get value of D.
iii. For more accuracy perform such kind of row scan on several other rows and columns.
iv. Finally average all inter ridge to get final D.

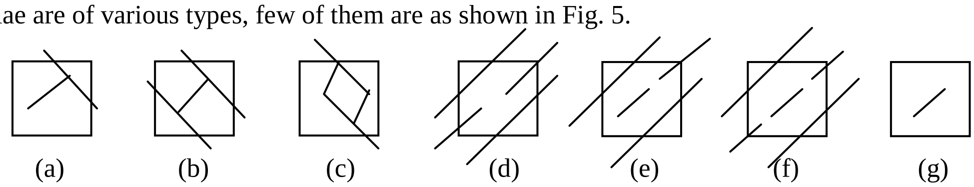
C. Minutia Post-Processing

Steps for minutiae post processing are explained below:

1) False Minutia Removal:

To detect and remove false minutia from fingerprint image this step is performed. It is necessary to remove this false minutia points because they affect the accuracy of matching if we consider them as genuine minutia. Therefore in post processing stage removal of false minutia is important to obtain final minutia which we can use for matching purpose, so that we can get accurate results.

The false minutiae are of various types, few of them are as shown in Fig. 5.



(a) (b) (c) (d) (e) (f) (g)

Fig. 5: False Minutiae

(a)spike piercing into a valley(b)case of spike which falsely connects two ridges(c)two near bifurcations located in the same ridge(d)two ridges are broken and have nearly the same orientation but have short distance(e)same as the case d with exception that one part of the broken ridge is so short that another termination is generated(f)extension of case d but third ridge is found in the middle of the two parts of the broken ridge (g)only one short ridge present in the threshold window.

D. Minutia Matching

Matching phase determines whether two minutia sets are from the same finger or not. This phase takes feature set and enrollment template as input and computes the similarity between them in terms of matching score. If matching score is greater than certain threshold then person is treated as genuine person.

We used an alignment based match algorithm which is partially derived from [12]. This algorithm includes two consecutive stages: first is alignment stage and second is matching stage.

1) Alignment Stage:

Let I1 and I2 be two sets of minutiae given by,

I1= {m1, m2, …mM}
I2= {m1, m2, …mM}

where mi={xi,yi,θi}. Now choose one minutia from each set to find the ridge correlation factor between them. After that similarity of correlating two ridges is given by

$$S = \sqrt{\frac{\sum_{i=0}^{m} x_i X_i}{\sum_{i=0}^{m} x_i^2 X_i^2}} \qquad (2)$$

Where (xi…xn) and (Xi…Xn) are the set of minutia for each fingerprint. If the similarity score is greater than 0.8 then next step is executed otherwise next pair of ridges are continued to check for match.

In next step, Hough transform is used to translate and rotate all minutia points with reference to the reference minutia point. Transformed set of minutia is given by

$$\begin{pmatrix} x_{inew} \\ y_{inew} \\ \theta_{inew} \end{pmatrix} = \begin{pmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_i - x \\ y_i - y \\ \theta_i - \theta \end{pmatrix} \qquad (3)$$

where, (x,y,θ) is the parameter of reference minutia.

2) Matching Stage:

Elastic match algorithm [12] is used to count number of matched minutia points of two fingerprints. Transformed minutia points from alignment stage are used as input to this algorithm. The algorithm needs to be elastic because strict match requires all the parameters (x, y, θ) exactly same for two identical minutia which is not possible due to the slight deformation and inexact quantization of minutia. So, we are assuming here that two minutiae having nearly same position and directions are identical.

To achieve this kind of matching, a bounding box is placed around each template minutia. If the minutia being matched is within the rectangle box and discrepancy between them is very small, then two minutiae are regarded as a matched minutia pair. Total number of matched minutia pairs are computed and finally matched score is computed which is given by

$$score = \frac{num\ (matched\ minutia\ \ pair\ )}{max\ (no.of\ minutiae\ \ in\ I1,I2)} \qquad (4)$$

III. EXPERIMENTAL RESULTS

The experiments are performed on KVK fingerprint database. This database consists of 30 fingerprint images of 10 fingers from each subject. Fingerprint images are acquired with no restriction of place and rotation. After applying proposed algorithm on each fingerprint we got bifurcation and terminations as features. Result of each of the steps is shown in Fig. 6. For matching query image is compared with all images in database. We have to see that by considering these features whether query image matches with the images in database or not. After matching operation matching score is generated, if it is greater than specified threshold then person is authenticated else rejected.

(a) (b) (c) (d) (e) (f)

Fig.6:Fingerprint after different stages of processing.
(a) Original image (b) Enhanced image (c) Binarized image (d) Direction map (e) Thinned image (f) Genuine minutia

FAR and FRR indexes are calculated to determine performance of proposed system. The graph showing FAR and FRR calculations by our approach are shown in Fig. 7.Blue line represents FRR curve and red line represents FAR curve. At threshold value of 51 proposed system falsely accept 1.25% of imposturous minutia pairs and has 98.75 % verification rate.

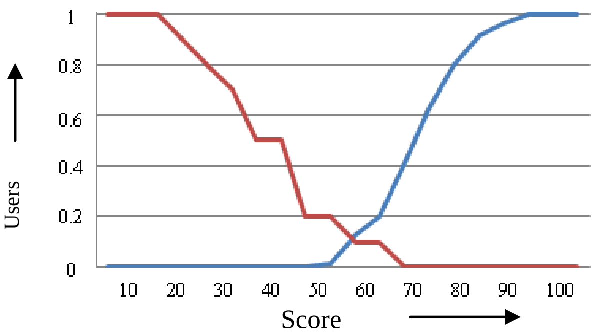


Fig.7: FAR and FRR Curve

IV. CONCLUSIONS

In this paper, a minutia matching systems has been described. Performance of system is strongly relies on quality of fingerprint images and precision obtained in minutia extraction process. Fingerprint enhancement phase found to be sufficient at removing false end points due to breaks. In two simple phases proposed algorithm identify a list of potential minutiae and eliminates many of the erroneous ones from that list. It performs very well at removing false minutiae due to spurs, holes, bridges and spikes. The proposed alignment based elastic matching algorithm is capable of finding correspondence between minutiae. The proposed method results in major improvements in the accuracy and is usable for images of low quality.

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