Fingerprint Recognition Technique Based on Radial Distance and Radial Angle Matching Score

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Abstract- Fingerprints were one of the first forms of biometric authentication [1] to be used for law enforcement and civilian applications. In this paper, we present reliable extraction of features from poor quality prints is the most challenging problem faced in the area of fingerprint recognition. This paper explores the use of minutiae based fingerprints matching technique. The primary aim of this paper is to study a series of techniques for fingerprint image enhancement and minutiae extraction and to implement minutiae based fingerprint matching technique. The fingerprint images will be used to assess the performance of the fingerprint recognition technique. These techniques are used to extract minutiae from a sample set of fingerprint images and matching fingerprints images. The various methods for fingerprints matching are analyzed..

Keywords – Fingerprint recognition, Minutiae matching, Correlation Matching

I. Introduction

A fingerprint is the feature pattern of one finger. Each fingerprint is unique. Each person has his own fingerprints with the permanent uniqueness. Fingerprints [2] are fully formed at about seven months of fetus development and finger ridge configurations do not change throughout the life of an individual except due to accidents such as bruises and cuts on the fingertips. So fingerprints have being used for identification and forensic investigation for a long time. A fingerprint is composed of many ridges and grooves presenting good. Fingerprints are not distinguished by their ridges and grooves, but by Minutia, which are some abnormal points on the ridges. Fingerprinting does not require a laboratory for analysis, and fingerprints remain relatively constant over time, with the exception of injury.

1.1Fingerprint Feature:

A good fingerprint representation [3] should have the following two properties:

Saliency: Saliency means that a representation should contain distinctive information about the fingerprint.

Suitability: Suitability means that the representation can be easily extracted, stored in a compact fashion, and be useful for matching.

A fingerprint is a unique pattern of ridges and valleys on the surface of a finger of an individual. A ridge is defined as a single curved segment, and a valley is the region between two adjacent ridges. Minutiae points are the local ridge discontinuities, which are of two types: ridge endings and bifurcations .A good quality image has around 40 to 100 minutiae.

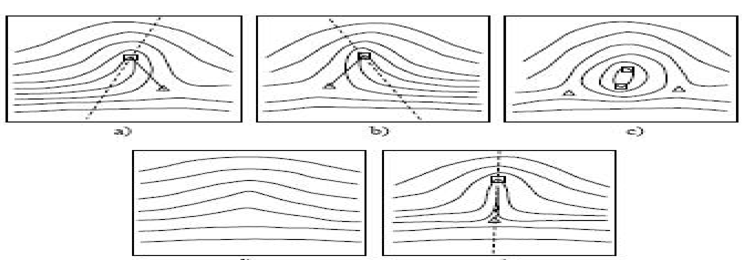

Fig. 1. Fingerprint patterns as they appear at a coarse level: a) left loop; b) right loop; c) whorl; d) arch; and e) tented arch; squares denote loop-type singular points, and triangles delta type singular points.

At the local level, a total of 150 different local ridge characteristics, called minute details, have been identified. These local ridge characteristics depend heavily on the impression conditions and quality of fingerprints and are rarely observed in fingerprints. The two most prominent ridge characteristics [4], called minutiae are:

Ridge Termination: A ridge ending is defined as the ridge point where a ridge ends abruptly.
Ridge bifurcation : A ridge bifurcation is defined as the ridge point where a ridge forks or diverges into branch ridges.

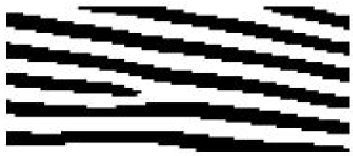

Figure 2 a. Ridge Termination

Figure 2 b. Ridge Bifurcation

2.Fingerprint Matching Techniques:

Reliably matching fingerprint images is an extremely difficult problem, mainly due to the large variability in different impressions of the same finger (i.e., large intra-class variations).The main factors responsible for the intra-class variations are: displacement, rotation, partial overlap, nonlinear distortion, variable pressure, changing skin condition, noise, and feature extraction errors. Therefore, fingerprints from the same finger may sometimes look quite different whereas fingerprints from different fingers may appear quite similar. A (three class) categorization of fingerprint matching approaches is:

A. Ridge Feature Based Technique or Pattern Matching:

Feature extraction and template generation are based on series of ridges as opposed to discrete points which forms the basis of Ridge Feature Based Technique [4]. A matching using the ridge feature in form of finger code consists of computing the difference of two finger code vectors (query and reference). However, before applying the finger code, it is important to align the fingerprint images, which is really a big problem, as in the case of other methods. In some cases the singularity may be used for that purpose. A finger code also may be used as a complementary to minutia based method in order to improve the overall matching accuracy. The original approach of this method used circular finger codes, considering as center the core point. The final result of the finger code difference is normalized and averaged using the eight directions and obtained a value that varies from 0 to 1. The lower the score, the more similar are the fingerprints. Some threshold values are used to decide whether there is matching or not.

B. Correlation Based Technique:

In order to match two fingerprints using the correlation based technique [5] [6], the fingerprints are aligned and the correlation is computed for each corresponding pixels, however, as the displacement and rotation are unknown it is necessary to apply the correlation for all possible alignments. The singularity information may be useful in order to find an approximated alignment. The main drawback of this method is its computational complexity and less tolerance to non-linear distortion and contrast variation. There have been some alternative proposals that compute the correlation locally instead of globally, in which only interesting regions (e.g., minutia and singularity regions) are selected and matched. These algorithms use simple techniques to align two fingerprint images and subtract the input image from the template image to see if the ridges correspond.

C. Minutiae Based Technique:

Majority of the Fingerprint Identification techniques are based on Minutiae. The points where the ridge lines terminate or fork are called Minutiae [7] whereas according to Galton, each ridge is characterized by numerous minute peculiarities called Minutiae. Many types of minutiae exist, including dots (very small ridges), islands (ridges slightly longer than dots, occupying a middle space between two temporarily divergent ridges), ponds or lakes (empty spaces between two temporarily divergent ridges), spurs (a notch protruding from a ridge), bridges (small ridges joining two longer adjacent ridges), and crossovers (two ridges which cross each other). Two fingerprints match if their minutiae are matched.

D. Image-based Techniques:

Image based techniques tries to do matching based on the global features of a whole fingerprint image. It is an advanced and newly emerging method for fingerprint recognition. It is useful to solve some intractable problems of the first approach.

II. IMPLEMENTATION

We have concentrated our implementation on Minutiae based method.

General fingerprints Verification System: The various stages of a typical fingerprint recognition [8] [9] system are shown in figure. The fingerprint image is acquired using off-line methods such as creating an inked impression on paper or through a live capture device consisting of an optical, capacitive, ultrasound or thermal sensor. The first stage consists of standard image processing algorithms such as noise removal and smoothening

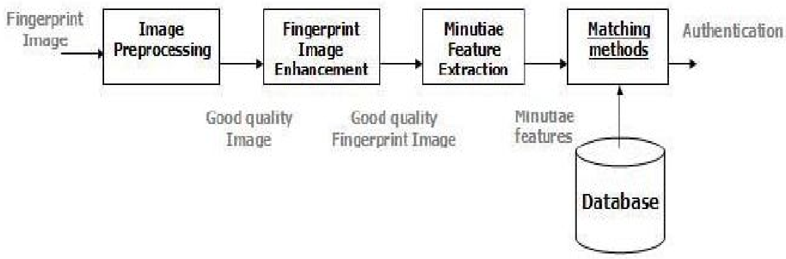

Figure 3. General architecture of a fingerprint verification system

3.1 Algorithm's Methodological Aspect:

Here the minutiae extraction procedure includes these three stages approach: Image preprocessing, minutiae extraction and image post processing. Preprocessing includes binarization, image enhancing and thinning processes. Thereafter minutiae points are extracted with removal of false minutiae removal process. Using the above Minutia Extraction process we get the Minutiae sets for the two fingerprints. Minutiae Matching process iteratively chooses any two minutiae as a reference minutia pair. Matching is conducted for all remaining minutia to generate a Match score.

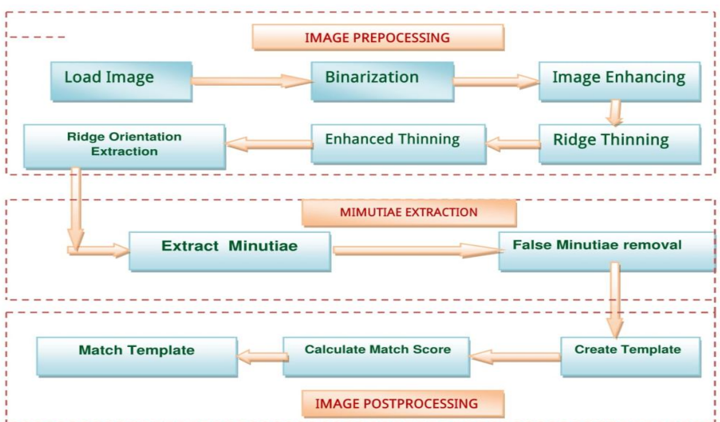

Figure 4. Implementation Procedure

3.1.1 Image Preprocessing

Before minutiae extraction the fingerprints have to be processed. First the image will be binarized and that image has to be enhanced. The steps of image preprocessing are as follows:

a) **Binarization:** Binarization[11] refers to the process of reducing the bit depth of the gray scale image to just 1 bpp. The straight forward approach for binarization relies on choosing a global threshold T. The binarization is then done according to $I(x, y) = 1$ if $I(x, y) > T$

$= 0$ if $I(x, y) \leq T$

In this step, the gray scale image is converted to a binary image through the process of simple thresholding or some form of adaptive binarization. The quality of the binarization output is improved if the gray scale image is enhanced prior to this process

b) **Fingerprint Image Enhancement:** Histogram equalization is used for enhancement of image i. e. fingerprint. In the Histogram equalization, we replace each pixel value of fingerprint image by new value to get a new fingerprint image with equalized histogram [10] [11]. The input fingerprint image have 256 gray level (L), and each pixel I x, y of fingerprint image has value (xi) , where xi = 0, 1, …….., L-1 with probabilities P(xi).

c) **Thinning:** Ridge Thinning [12] is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide. In each scan of the full fingerprint image, the algorithm marks down redundant pixels in each small image window (3x3) and finally removes all those marked pixels after several scans. The thinning algorithmcomprehends three tests; the first two are run sequentially as long as they find pixels that shall be removed, usually 5-8 times. They operate by looking for ridge pixels (value one) and checking a series of conditions against the 3x3 pixel matrix of neighbors (with the ridge pixel in its center):

P_9	P_2	P_3
P_8	P_1	P_4
P_7	P_6	P_5

1	1	1
0	1	1
1	1	1

N(p)=7

1	1	1
1	1	1
0	1	1

N(p)=7

0	1	1
1	1	1
1	0	1

S(P)=2

1	1	1
0	1	0
1	0	1

S(P)=3

N(p1)=p1+p2+……..+p9
S(P1)= number of 0 to 1 (or 1 to 0) transitions in the sequence

d) **Ridge Orientation:** Each minutiae may be described by a number of attributes such as its position (x,y) its orientation θ, its quality. However, most algorithms consider only its position and orientation [13][14]. Given a pair of fingerprints and their corresponding minutiae features to be matched, features may be represented as an unordered set given by:

$I1=\{m_1.m_2 \ldots\ldots m_M\}$, where $m_i=(x_i, y_i, \Theta_i)$
$I2= \{m_1''.m_2''\ldots\ldots m_N''\}$, where $m_i'' =(x_i'',y_i'',\Theta_i'')$

It is to be noted that both the point sets are unordered and have different number of points (M and N respectively).

3.1.2 Minutiae Extraction

After processing the fingerprints the minutia are extracted and false positions are to be removed.

a) **Minutiae Marking and Extraction:** Minutiae extraction is carried out using the crossing number approach [12][13].
Crossing number of pixel ‘p’ is defined as half the sum of the differences between pairs of adjacent pixels defining the 8- neighborhood of p.

$$cn(p) = \tfrac{1}{2} \sum_{i=1..8} |val(p_{i \bmod 8}) - val(p_{i-1})$$

Where p0 to p7 are the pixels belonging to an ordered sequence of pixels defining the 8-neighborhood of p and Val (p) is the pixel value.

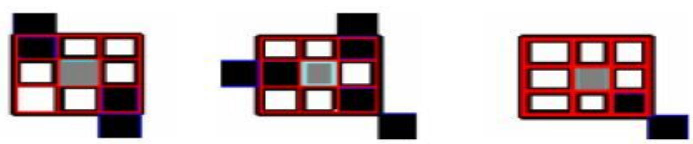

Figure 5. cn(p)=2,cn(p)=3 and cn(p)=1 representing a non minutiae region, a bifurcation and a ridge ending respectively

Crossing numbers 1 and 3 correspond to ridge endings and ridge bifurcations respectively. An intermediate ridge point has a crossing number of 2 as given in figure. A minutiae m is described by the triplet m=,x, y, θ-, where x, y indicate the minutiae location coordinates and θ denotes the minutiae orientation, which is the orientation evaluated for the minutiae location from the orientation image obtained during the enhancement process. The minutiae type is not being used during the matching process since minutiae type can be inverted due to enhancement and binarization steps. We have extracted minutiae using this technique.

b) **False Minutia Removal:** The minutiae obtained from this algorithm must be filtered to preserve only the true minutiae. The different types of false minutiae introduced during minutiae extraction include spike, bridge, hole, break, Spur, Ladder, and Misclassified Border areas.

Figure 6. A. Spike, B. Bridge, C. Hole, D. Break, E. Spur F. Ladder

1. If the distance between one bifurcation and one termination is less than D and the two minutiae are in the same ridge. Remove both of them. Where D is the average inter-ridge width representing the average distance between two parallel neighboring ridges.

2.If the distance between two bifurcations is less than D and they are in the same ridge, remove the two bifurcations.

3.If two terminations are within a distance D and their directions are coincident with a small angle variation. And suffice the condition that no any other termination is located between the two terminations. Then the two terminations are regarded as false minutia derived from a broken ridge and are removed.

4. If two terminations are located in a short ridge with length less than D, remove two terminations.

The average inter-ridge width (D) refers to the average distance between two neighboring ridges. Scan a row of the thinned ridge image and sum up all pixels in the row whose value is one. Then divide the row length with the above summation to get an inter-ridge width. Such kind of row scan is performed upon several other rows and column scans are also conducted, finally all the inter-ridge widths are averaged to get the D.

3.1.3 Minutiae Post processing

Finally after extracting minutia the radial angle and radial distance will be matched with the created template.

a) **Minutiae Matching:** Here is the proposed minutia matching algorithm.

Proposed Minutiae Matching Algorithm

1. Sort the template and input minutiae set by radial angle and radial distance in descending order.
2. Consider, the reference minutiae points and convert into polar coordinate System with reference minutiae [13][14].
3. For all minutiae $(x_i, y_i, \theta_i)t$, apply the following:

$$\begin{pmatrix} r_i \\ a_i \\ \theta_i \end{pmatrix} = \begin{pmatrix} \sqrt{(x_i - x^r)^2 + (y_i - y^r)^2} \\ \tan^{-1}\left(\frac{y_i - y^r}{x_i - x^r}\right) \\ \theta_i - \theta^r \end{pmatrix}$$

where, $(x^r,y^r,\theta^r)t$ is the coordinate of reference minutiae and $(r_i,a_i,\theta_i)t$ is in the polar coordinate system (r_i represents the radial distance, a_i represents radial angle and θ_i represents the orientation of minutiae with respect to reference minutiae).

4. Find the minutiae type, if it is same, then proceeds to step4. Else find next minutiae.
5. For each set of minutiae calculate the following:

L = number of points recorded

- Radial distance = $1/L\ (\Sigma\ |r\ (d_i) - r\ (d_i)\ |)$, for $0 <= i <= L$
- Radial angle = $1/L\ (\Sigma\ |\ a_i - a_j\ |)$, for $0<=i<=L$
- Minutiae direction = $1/L\ (\Sigma\ |\theta_i - \theta_j|)$, for $0<=i<=L$

6. Compute the similarity score of two minutiae sets by summing the radial distance, radial angle and direction.
7. Let, ε is the threshold assumed. If the similarity score is greater than ε then we conclude two minutiae pair is matched [9].
8. Calculate the matching score using:

Match score = $m^2/\ (M_i \times M_r)$

where, m is the total number of matched minutiae pairs, M_i and M_r is the number of minutiae points in the input and template fingerprints.

9. Record the maximum number of matching minutiae pairs.

III. RESULT

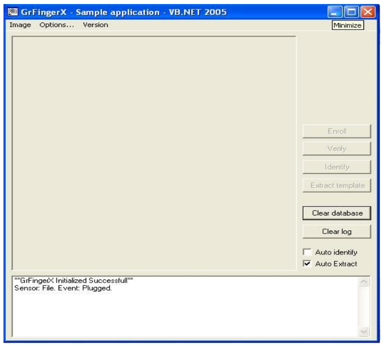

Figure7. (a)Main Form

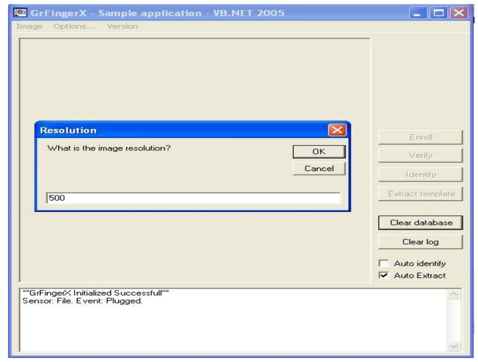

Figure7. (b) Loading Image

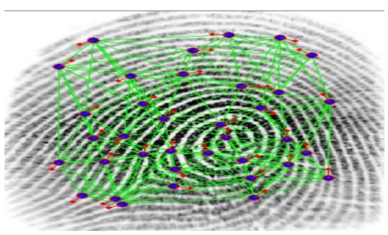

Figure 7. (c) Minutiae points Extraction

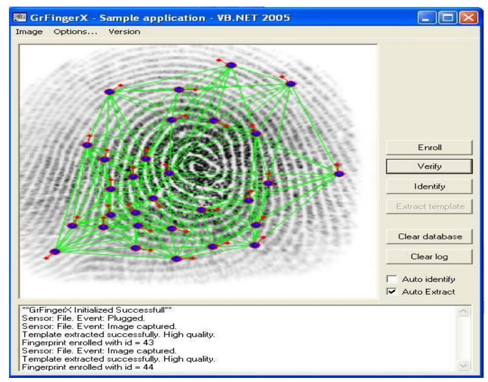

Figure 7. (d) Fingerprint enrolled in database with id

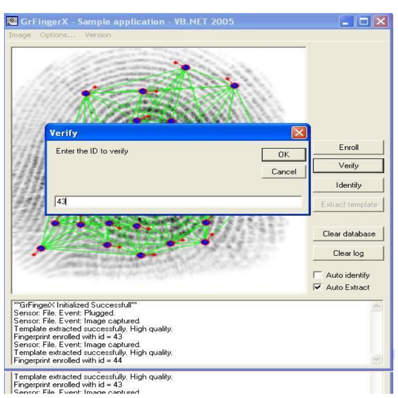

Figure 7. (e) To fingerprint verify taking id

Figure 7. (f) To fingerprint verify taking id

IV. CONCLUSION

This paper represents finger print recognition system. It includes all the stages for minutiae extraction from fingerprints. Various standard minutiae based fingerprint matching technique is studied in detail and implemented both in VB and VC++. Various standard techniques are used in the intermediate stages of processing. For this purpose, several fingerprints are compared. This algorithm can detect all the minutiae, including both true and false minutiae, using the Crossing Number (CN) on the skeleton images after thinning stage. After template extraction a ridge alignment algorithm is used to calculate radial angle and distance. Here two fingerprint images to be matched are taken and any one minutia from each image is chosen. Then the similarity of the two ridges associated with the two referenced minutia points are calculated and generate a match score. Also a major challenge in this paper lies in the pre processing of the good quality of fingerprint images which also add to the low verification rate.

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