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An approach for Fingerprint Recognition based on Minutia Points

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Abstract— Fingerprint Recognition is one of the most powerful and most publicized techniques of biometrics. Because of their uniqueness and consistency over time, fingerprints have been used for identification and recently being automated (i.e. biometrics) due to vast advancements in computing capabilities.

Keywords- fingerprints, identification, verification, minutiae points, bifurcation, termination, segmentation, ROI.

I. INTRODUCTION

Traditionally, passwords have been used to restrict unauthorized access to secure systems. But the security of the system can be easily breached if the password is revealed to an unauthorized user and impostor. This lead to the emergence of biometric systems that addressed the problems associated with the traditional verification techniques. Biometrics refers to automatic identification and verification of an individual based on certain behavioral and physiological characteristics associated with the person (like fingerprints, retina, iris, voiceprint, face, signature, DNA etc.)

Among all the biometric traits, fingerprints [6] provide high degree of reliability and convenience and have been extensively used by forensic experts in criminal investigation to verify the person's identity. It is believed that no two people have identical fingerprint in this world, so the fingerprint verification and identification is most popular way to verify the authenticity or identity of a person wherever the security is a problematic question. The reason for popularity of fingerprint technique is uniqueness of person arises from his behaviour; personal characteristics are like, for instance uniqueness, which indicates that each and every fingerprint is unique, different from one other. Universality, that means every person hold the individual characteristics of fingerprint. Permanence, means that fingerprint are permanent, are impossible to change or forgot, and can never be stolen.

Traditionally fingerprint pattern have been captured by creating an inked impression of fingertip on the paper. Today, highly compact solid-state sensors get the digital images of the fingerprint pattern which can be incorporated into a mouse, keyboard or cellular phone making it very easy to analyze the fingerprint for identification. Fingerprint systems are being increasingly adopted in commercial and forensic applications for user authentification purpose. This paper covers the topics on fingerprint verification, the details of pre-processing of fingerprint image including enhancement, binarization, segmentation, extracting minutiae from image, post processing and matching.

II. WHAT IS A FINGERPRINT?

A fingerprint is a feature pattern of one finger [6]. It is an impression of the friction ridges and furrows on all parts of the finger. However, fingerprints are not recognized using ridges and furrows but using minutiae, which are characterized by some abnormal points on the ridges. Among the variety of minutiae types reported in the literatures, only two types of minutiae are mainly used and are most significant. One is called “termination” which can be characterized as the immediate ending of a ridge and the other one is called “bifurcation” which can be characterized as the point on the ridges where two branches are bifurcated.

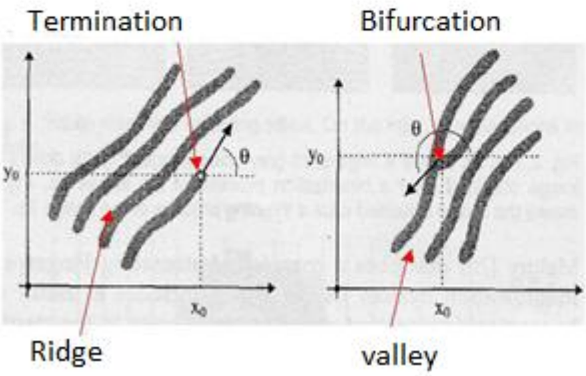

Figure 1. Types of Minutiae [1]

III. WHAT IS FINGERPRINT RECOGNITION?

Fingerprint recognition is the process of comparing the known fingerprint against other fingerprints to determine whether the impressions are from the same finger or palm [6]. It includes two sub-domains: one is fingerprint verification (one-to-one matching) and the other is fingerprint identification (one-to-many matching).

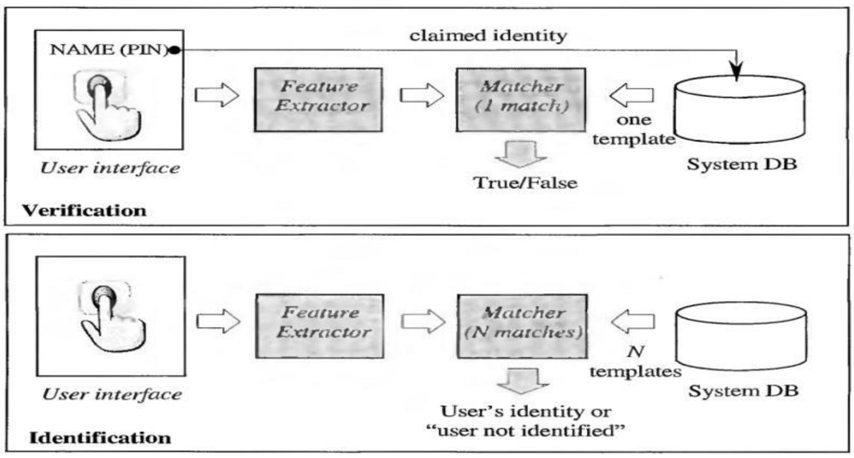

Figure 2. Verification vs. Identification [6]

IV. SYSTEM DESIGN

4.1 System Level Design

A fingerprint recognition system [1] constitutes of fingerprint acquiring device, minutia extractor and minutia matcher. For fingerprint acquisition, optical or semi-conduct sensors are widely used.

4.2 Algorithm Level Design

Minutiae Extractor is implemented by widely used three-stage approaches, viz. Preprocessing, minutia extraction and post processing stage.

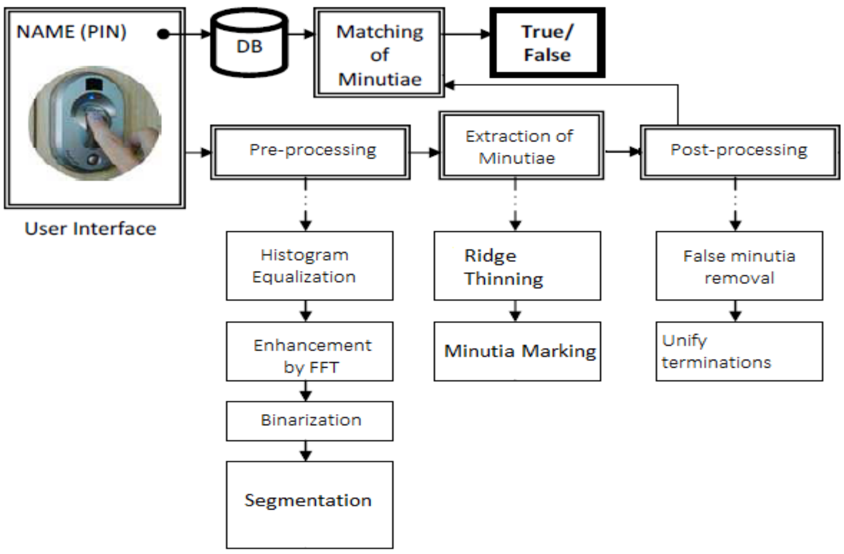

Figure 3. System Design [1]

V. PRE-PROCESSING STAGE

5.1 Fingerprint Image Enhancement

Fingerprint Image enhancement [1] is to make the image clearer for easy further operations. Two Methods are adopted in my fingerprint recognition system: the first one is Histogram Equalization and the next one is Fourier Transform.

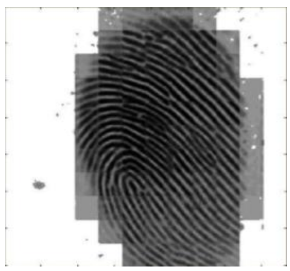

Figure 4.Histogram Equalized image [7] ***Figure5.Enhanced image [7]***

5.1.1. Histogram Equalization

Histogram equalization fig (4) [7] is to expand the pixel value distribution of an image so as to increase the perceptional information.

5.1.2. Fingerprint Enhancement by Fourier Transform

We divide the image into small processing blocks (32 by 32 pixels) and perform the Fourier transform fig (5) [7] according to:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp\left\{-j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\}$$; Where u = 0, 1, 2, …, 31 and v = 0, 1, 2, ... 31.

And enhanced block is obtained according to:

$$g(x,y) = F^{-1}\left\{F(u,v) \times |F(u,v)|^{K}\right\}$$

Where F-1(F (u, v)) is done by:

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

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

Here the value of k is experimentally determined (k=0.45) to calculate. Higher "k" improves the appearance of the ridges, having too high a "k" can result in false joining of ridges.

5.2 Fingerprint Image Binarization

Fingerprint Image Binarization [1] fig (6) [7] is to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After the operation, ridges in the fingerprint are highlighted with black color while furrows are white. A locally adaptive binarization method is performed to binarize the fingerprint image. Such a named method comes from the mechanism of transforming a pixel value to 1 if the value is larger than the mean intensity value of the current block.

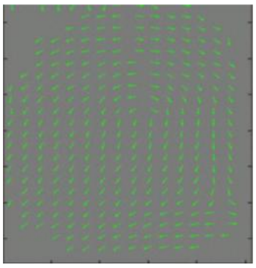

Figure 6. Binarized image [7]

Figure 7. Direction map [7]

5.3 Fingerprint Image Segmentation

In general, only a Region of Interest (ROI) [5] is useful to be recognized for each fingerprint image. The image area without effective ridges and furrows is first discarded. To extract the ROI, a two-step method is used. The first step is block direction estimation and direction variety check, while the second is intrigued from some Morphological methods.

5.3.1. Block Direction Estimation:

Estimate the block direction for each block of the fingerprint image with WxW in size (W is 16 pixels by default). Figure 7 shows direction map. The algorithm is:

Step: 1 Calculate the gradient values along x-direction (gx) and y-direction (gy) for each pixel of the block. Two Sobel filters are used to fulfill the task.

Step: 2 for each block, use following formula to get the Least Square approximation of the block direction for all the pixels in each block.

$$tg2ß = 2 \Sigma \Sigma (gx*gy)/ \Sigma \Sigma (gx2-gy2)$$

The formula is easy to understand by regarding gradient values along x-direction and y-direction as cosine value and sine value. So the tangent value of the block direction is estimated nearly the same as the way illustrated by the following formula.

$$tg2\theta = 2\sin\theta \cos\theta / (\cos2\theta - \sin2\theta)$$

After finished with the estimation of each block direction, those blocks without significant information on ridges and furrows are discarded based on the following formulas:

$$E = \{2\Sigma \Sigma (gx*gy) + \Sigma \Sigma (gx2-gy2)\}/ W*W* \Sigma \Sigma (gx2+gy2)$$

For each block, if its certainty level E is below a threshold, then the block is regarded as a background block.

5.3.2. ROI extraction by Morphological operations:

Two Morphological operations called ‘OPEN’ and ‘CLOSE’ are adopted. The ‘OPEN’ operation can expand images and remove peaks introduced by background noise. The ‘CLOSE’ operation can shrink images and eliminate small cavities. Figure 8. [7].

Figure 8. ROI extraction *Figure 9. Thinning*

VI. MINUTIAE EXTRACTION

6.1 Ridge Thinning

Ridge Thinning [3, 4] or thinning Figure 9. [7] is a process of reducing the width of the ridges in fingerprint image to one pixel wide, eliminate the redundant pixel of ridges and thin to its central pixel.

6.2 Minutia Marking

After the fingerprint ridge thinning, marking minutia points [3] is relatively easy. In general, for each 3x3 window, if the central pixel is 1 and has exactly 3 one-value neighbors, then the central pixel is a ridge branch. If the central pixel is 1 and has only 1 one-value neighbor, then the central pixel is a ridge ending as shown in Figure 10.1 and Figure 10.2

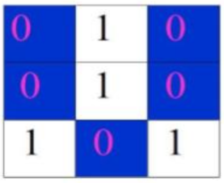

Figure 10.1. Ridge branch [3]

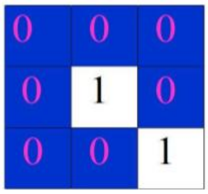

Figure 10.2. Ridge ending [3]

After minutia marking the fingerprint is as shown in Figure 11. [7]

Figure 11. Image with all marked Minutia [7]

VII. POST-PROCESSING STAGE

7.1 False Minutia Recognition

At this stage false ridge breaks due to insufficient amount of ink & ridge cross connections due to over inking are not totally eliminated. Here the average inter-ridge width D is estimated at this stage.

Inter ridge distance = <u>sum all pixels with value 1</u>

Row length

Finally an averaged value over all rows gives D.

7.2 Unify Terminations and Bifurcations

Unification representation is used to convert one type of minutia into another for both, termination and bifurcation. For this, each minutia is represented by three traits, viz. x-co-ordinate, y-co-ordinate and orientation. Three ridges deriving from the bifurcation point have their own direction as shown in fig and simply choose the minimum angle among the three anticlockwise orientations starting from the x-axis. Track a ridge segment whose starting point is the termination and length is D.

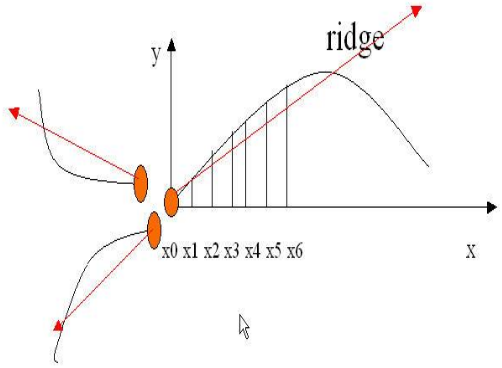

Figure 12. Each termination with its own orientation

$$sx = \frac{\Sigma \text{ x-coordinates of points in the ridge segment}}{D}$$

$$sy = \frac{\Sigma \text{ y-coordinates of points in the ridge segment}}{D}$$

So, direction= tan^-1((sy-ty)/ (sx-tx))

VIII. MINUTIA MATCH

8.1 Alignment Stage

The algorithm [6] is as follows:

Step 1:

Let I1 & I2 be the two minutiae sets given by,

I1= {m1, m2...mn},

I2= {m1', m2'...mn'}; mi= (xi, yi, θi)

Now we choose one minutia from each set to find the ridge correlation factor between them.

The ridge associated with each minutia is represented as a series of x-coordinates (x1, x2…xn) of the points on the ridge.

$$s = \sqrt{\frac{\sum_{i=0}^{m} xiXi}{\sum_{i=0}^{m} xi^{\wedge}2\,Xi^{\wedge}2}}$$

If the similarity score is larger than 0.8, then go to step 2, otherwise continue to match the next pair of ridges.

Step 2:
The approach is to transform each set according to its own reference minutia and then do match in a unified x-y coordinate. Let M (x, y, θ) be reference minutia found from step 1(say from I1). For each fingerprint, translate and rotate all other minutiae (xi, yi, θi) with respect to the M according to the following formula:

$$\begin{pmatrix} xi\_new \\ yi\_new \\ \theta i\_new \end{pmatrix} = TM * \begin{bmatrix} (xi - x) \\ (yi - y) \\ (\theta i - \theta) \end{bmatrix}$$

Where (x, y,θ) is the parameters of the reference minutia, and TM is

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

The new coordinate system is originated at reference minutia M and the new x-axis is coincident with the direction of minutia M. No scaling effect is taken into account by assuming two fingerprints from the same finger have nearly the same size. So, we get transformed set of minutiae I1' & I2'.

8.2 Match Stage

An elastic string (x, y,θ) match algorithm [7] is used to find number of matched minutia pairs among I1' & I2'

According to the elastic string match algorithm minutia mi in I1' and a minutia mj in I2' are considered "matching," if the spatial distance (sd) between them is smaller than a given tolerance r0 and the direction difference (dd) between them is smaller than an angular tolerance Θ0.

$$sd = \sqrt{(xi - xj)^2 + (yi - yj)^2} \leq r0$$

$$dd = (|\theta i - \theta j|, 360 - |\theta i - \theta j|) \leq \theta 0$$

Let mm ( ) be an indicator function that returns 1 in the case where the minutiae mi and mj match according to above equations.

$$mm(mi, mj) = 1; sd(mi, mj) \leq r0 \text{ and } dd(mi, mj) \leq \theta 0$$
$$= 0; \text{otherwise}$$

Now the total number of matched minutiae pair given by, num (matched minutiae) = $\sum$ mm (mi, mj)
And final match score is given by,

$$\text{Match Score} = \frac{\text{num (matched minutiae)}}{\text{max (num of minutia in I1, I2)}}$$

IX. CONCLUSION

Fingerprint Recognition is used as a form of biometric to recognize identities of human beings. It includes all the stages from minutiae extraction from fingerprints to minutiae matching which generates a match score and depending on match score finger print is verified.

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