THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Fingerprint Recognition Using Minutiae Matching

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Abstract:
Fingerprints are the most common authentic biometrics for personal identification, especially for forensic security. A minutiae matching is widely used for fingerprint recognition and can be classified as ridge ending and ridge bifurcation. For Fingerprint thinning, the block filter is used, which scans the image at the boundary to preserves the quality of the image and extract the minutiae from the thinned image. FPR provides reliable and better performance than the existing technique. The False Matching Rate (FMR) is better compared to the existing algorithm. Usually a technique called minutiae matching is used to be able to handle automatic fingerprint recognition with a computer system

Keywords: *Fingerprint Recognition, Block Filter Method, Minutiae extraction, Minutiae Matching, False Matching Ratio (FMR), False Non Matching Ratio (FNMR)*

1. Introduction

1.1. What is Biometric ?
Biometric is the science of establishing the identity of an individual based on the physical, chemical or behavioral attributes of the person. Human have used fingerprints for personal identification for many decades. A fingerprint is the pattern of ridges and valleys on the surfaces of a fingertip whose formation is determined during the first seven months of fetal development. Automatic fingerprint recognition technology has now rapidly grown beyond forensic applications and into civilian applications. Now a days, most civil and criminal AFISs accept live-scan digital images acquired by directly sensing the finger surface with and electronic fingerprint scanner. No ink is required in this method, and all that a subject has to do is to press his/her finger against the flat surface of a live-scan scanner.

1.2. What is Fingerprint Recognition ?
A fingerprint is the representation of the epidermis of a finger it consists of a pattern of inter-leaved ridges and valleys. At the local level, other important features, called minutiae can be found in the fingerprint patterns. Minutiae refers to the various ways in which the ridges can be discontinuous. For example, a ridge can abruptly come to an end (termination), or can divide into two ridges (bifurcation). A good quality fingerprint contains 25 to 80 minutiae depending on sensor resolution and finger placement on the sensor. The false minutiae are the false ridge breaks due to insufficient amount of ink and cross-connections due to over inking. It is difficult to extract reliably minutiae from poor quality fingerprint impressions arising from very dry fingers and fingers mutilated by scars, scratches due to accidents, injuries. Minutiae based fingerprint recognition consists of thinning, minutiae extraction, minutiae matching and computing minutiae score.

1.3. Techniques for Fingerprint Recognition
Following are some of the Techniques:

- **Minutiae Extraction based Technique -** Mostly accepted finger scan technology is based on minutiae. Minutiae based techniques produce the fingerprint by its local features, like termination and bifurcation when minutiae points match between two fingerprints, so fingerprint are match. This approach has been genuinely studied, and it is the backbone of the current available fingerprint recognition products.
- **Pattern Matching or Ridge Feature based Technique -** Feature extraction are established on series of ridges as averse to different points which design the basis of pattern matching techniques over minutiae extraction. Minutiae points can be change by wear and tear and the main drawback are that these are acute to proper adjustment of finger and need large storage for templates.
- **Correlation based Technique -** Correlation based technique is used to match two fingerprints, the fingerprint are adjusted and computed the correlation for each corresponding pixel. They can match ridge shapes, breaks etc. Main disadvantages of this method are its computational complication and less tolerance to non-linear distortion and contrast variation.

- **Image based Technique -** This technique attempt to do matching which based on the global features of an all fingerprint images.

2. Model

2.1. Definitions

- Fingerprint : Impression of a finger acquired from digital scanners.
- Minutiae : Ridge bifurcations and ridge ending in fingerprint image.
- Core : Centre of the loop or pattern in fingerprint image. It is located where the innermost recurve begins and curve to exit the same way they came in.
- Delta : It is the area of pattern where there is a triangulation or a dividing of ridges.
- Sensitivity : The ability of the algorithm to detect the true minutiae and is represented as 1 – missed minutiae / ground truth number minutiae.
- Spurious Minutiae : It is the type of error that falsely identifies a noisy ridge structure as minutiae.
- Missed Minutiae : It is the type of error that occurs in failing to detect the existing minutiae when it is obscured by surrounding noise, scars or poor ridge structures.
- False Minutiae : Points which have been incorrectly identified as minutiae.

2.2. False Matching Ratio (FMR)

It is the probability that the system will decide to allow access to an imposter is given in an equation

$$FMR = \frac{\text{False Matches}}{\text{Im poster Attempts}} \quad \text{---------} (1)$$

The imposter attempts are implemented by matching each input image with all the template images. False match was recorded for each imposter attempt when the matching score was greater than the established threshold.

2.3. False Non Matching Ratio (FNMR)

It is the probability that the system denies access to an approved user is given in an equation (2)

$$FNMR = \frac{\text{False Non Matches}}{\text{EnrolleAttempts}} \quad \text{----------} (2)$$

Enrollee attempts are implemented by matching each input image with corresponding template image, hence it is one-to-one matching. A False Non-match was recorded when the matching score between an enrollee and its template was less than the established threshold.

2.4. Matching Score

It is used to calculate the matching score between the input and template data is given an equation (3)

$$\text{Matching score} = \frac{\text{Matching Minutiae}}{\text{Max(NT, NI)}} \quad \text{-----} (3)$$

Where NT and NI represent the total number of minutiae in the template and input matrices respectively.
By this definition, the matching score takes on a value between 0 and 1. Matching score of 1 and 0 indicates that data matches perfectly and data is completely mismatched respectively.

2.5. FPR

Figure 1 gives the block diagram of FPR which is used to match the test fingerprint with the template database using Minutia Matching Score.
Fingerprint Image: The input fingerprint image is the gray scale image of a person, which has intensity values ranging from 0 to 255. In a fingerprint image, the ridges appear as dark lines while the valleys are the light areas between the ridges. Minutiae points are the locations where a ridge becomes discontinuous. A ridge can either come to an end, which is called as termination or it can split into two ridges, which is called as bifurcation. The two minutiae types of terminations and bifurcations are of more interest for further processes compared to other features of a fingerprint image.

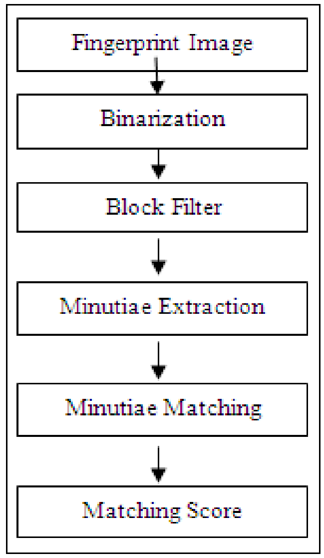

Figure 1: Block Diagram of FPR

2.6. Binarization

The pre-processing of FPR uses Binarization to convert gray scale image into binary image by fixing the threshold value. The pixel values above and below the threshold are set to ‘1’ and ‘0’ respectively. An original image and the image after Binarization are shown in the Figure 2.

Figure 2: (a) Original Fingerprint (b) Binarized image

2.7. Block Filter

The binarized image is thinned using Block Filter to reduce the thickness of all ridge lines to a single pixel width to extract minutiae points effectively. Thinning does not change the location and orientation of minutiae points compared to original fingerprint which ensures accurate estimation of minutiae points. Thinning preserves outermost pixels by placing white pixels at the boundary of the image, as a result first five and last five rows, first five and last five columns are assigned value of one. Dilation and erosion are used to thin the ridges. A binarized Fingerprint and the image after thinning are shown in Figure 3.

Figure 3: (a) Binarized FP, (b) thinning

2.8. Minutiae Extraction

The minutiae location and the minutiae angles are derived after minutiae extraction. The terminations which lie at the outer boundaries are not considered as minutiae points, and Crossing Number is used to locate the minutiae points in fingerprint image. Crossing Number is defined as half of the sum of differences between intensity values of two adjacent pixels. If crossing Number is 1,2 and 3 or greater than 3 then minutiae points are classified as Termination, Normal ridge and Bifurcation respectively is shown in figure4.

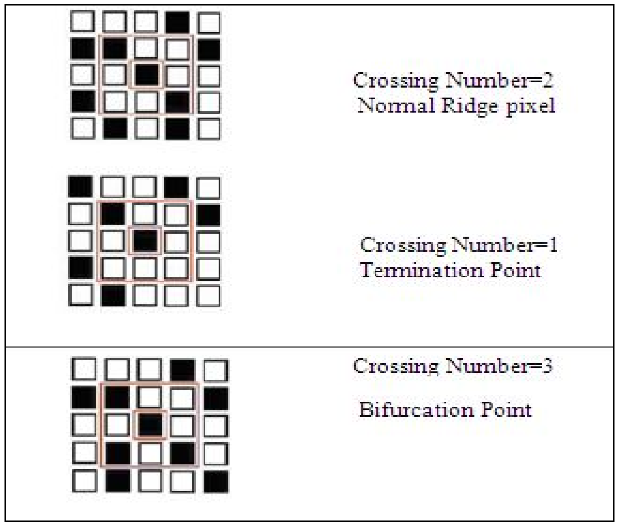

Figure 4: Crossing Number and Type of Minutiae

To calculate the bifurcation angle, we use the advantage of the fact that termination and bifurcation are dual in nature. The termination in an image corresponds to the bifurcation in its negative image hence by applying the same set of rules to the negative image, we get the bifurcation angles. Figure 5 shows the original image and the extracted minutiae points. Square shape shows the position of termination and diamond shape shows the position of bifurcation as in figure 5

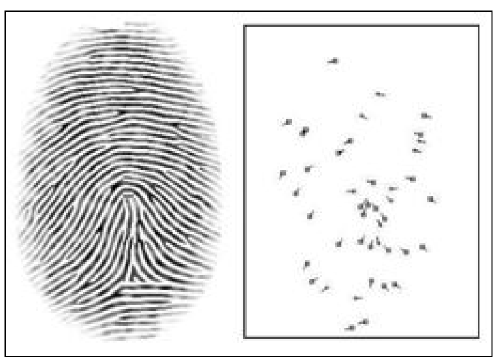

Figure 5: (a) Gray-scale Fingerprint, (b) Minutiae Points

2.9. Minutiae Matching

To compare the input fingerprint data with the template data Minutiae matching is used. For efficient matching process, the extracted data is stored in the matrix format. The data matrix is as follows. Number of rows: Number of minutiae points.

Number of columns: 4

- Column 1: Row index of each minutia point.
- Column 2: Column index of each minutia
- Column 3: Orientation angle of each minutia

Column 4: Type of minutia. (A value of '1' is assigned for termination, and '3' is assigned for bifurcation).

During the matching process, each input minutiae point is compared with template minutiae point. In each case, template and input minutiae are selected as reference points for their respective data sets. The reference points are used to convert the remaining data points to polar coordinates. The Equation is used to convert the template minutiae from row and column indices to polar coordinates in Equation (4).

$$\begin{pmatrix} r_k^T \\ \varphi_k^T \\ \theta_k^T \end{pmatrix} = \begin{pmatrix} \sqrt{\left[row_k^T - row_{ref}^T\right]^2 + \left[col_k^T - col_{ref}^T\right]^2} \\ \tan^{-1}\left(\dfrac{row_k^T - row_{ref}^T}{col_k^T - col_{ref}^T}\right) \\ \theta_k^T - \theta_{ref}^T \end{pmatrix} \quad (4)$$

Where, for a template image,
r_k^T = radial distance of k[th] minutiae.
φ_k^T = radial angle of k[th] minutiae.
θ_k^T =orientation angle of k[th] minutiae.
row_{ref}^T , col_{ref}^T = row index and column index of reference points currently being considered. Similarly the input matrix data points are converted to polar coordinates using the below Equation (5).

$$\begin{pmatrix} r_m^I \\ \varphi_m^I \\ \theta_m^I \end{pmatrix} = \begin{pmatrix} \sqrt{\left[row_m^I - row_{ref}^I\right]^2 + \left[col_m^I - col_{ref}^I\right]^2} \\ \tan^{-1}\left(\dfrac{row_m^I - row_{ref}^I}{col_m^I - col_{ref}^I}\right) + rotatevalues\,(k,m) \\ \theta_k^T - \theta_{ref}^T \end{pmatrix}$$

Rotate values (k, m) represents the difference between the orientation angles of *Tk* and *Im* . *Tk* and *Im* represent the extracted data in all the columns of row *k* and row *m* in the template and input matrices, respectively.

3. Algorithm

Problem definition**:** Given the test Fingerprint Image the objectives are,

- Pre-processing the test Fingerprint.
- Extract the minutiae points.
- Matching test Fingerprint with the database.

It gives the algorithm for fingerprint verification, in which input test fingerprint image is compared with template fingerprint image, for recognition.
Algorithm of FPR:
Input: Gray-scale Fingerprint image.
Output: Verified fingerprint image with matching score.

- Fingerprint is binarized
- Thinning on binarized image
- Minutiae points are extracted. Data matrix is generated to get the position, orientation and type of minutiae.
- Matching of test fingerprint with template

Matching score of two images is computed, if matching score is 1 images are matched and if it is 0 then they are mismatched.

4. Performance Analysis and Results

For performance analysis, we considered large fingerprint database images having different patterns such as fingerprint left loop, right loop, whorl and arch.
Table gives the comparison of False Non Matching Ratio (FNMR) and False Matching Ratios (FMR) for existing method of Fingerprint Recognition Fuzzy Neural Network (FRFNN) and proposed method of Fingerprint Recognition using Minutia Score Matching method (FPR). It is observed that the False Non Matching Ratio for both the methods is zero and False Matching Ratio for existing method is 0.23 whereas for the proposed method FPR is 0.026.

	FRFNN	FPR
FNMR	0.00	0.00
FMR	0.23	0.026

Table 1: Comparison of FNMR and FMR for FRFNN and FPR

5. Conclusion

In this paper, we presented Fingerprint matching using FPR. The pre-processing the original fingerprint involves image binarization, ridge thinning, and noise removal. Fingerprint Recognition using Minutia Score Matching method is used for matching the minutia points. The proposed method FPR gives better FMR values compared to the existing method. Usually a technique called minutiae matching is used to be able to handle automatic fingerprint recognition with a computer system.

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