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An Improved Method for Matching of Fingerprint Features

M.Marimuthu

Coimbatore Institute of Technology, Coimbatore, India

A.Kannammal

Coimbatore Institute of Technology, Coimbatore, India

Abstract

In this paper, we analyse the fingerprint recognition computational time against the query fingerprint and stored user fingerprint template for authentication. Fingerprints are permanent and unique. The two most prominent local characteristics of the fingerprint are ridge ending and bifurcation. Fingerprint undergoes for pre-processing and post-processing to enhance the quality of fingerprint and to remove false minutiae to achieve high recognition rate. It is also perceived that effective distance calculation method decreases the computational time. Our proposed method outperforms comparing to the existing distance calculation method. The algorithm was tested on FVC (2002) database and achieved better performance.

Keywords--- Fingerprint feature, Matching, Pre-processing, Post-processing

1. Introduction

Biometrics plays an important role in providing security and authentication to the genuine user and the imposter. Among all the biometric (face, fingerprints, hand geometry, iris, retina, signature, voice print, facial thermogram, hand vein, gait, ear) fingerprint-based identification is one of the most mature and proven technique [1,3]. It also highly explored in academic and research areas [2]. In an Automatic Fingerprint Verification System (AFVS), the goal is to match the user template with the enrolled template in the database. Ridge ending is the point where a ridge ends abruptly and bifurcation is the point where a ridge forks or diverges into branch ridges [3]. A good quality fingerprint typically contains about 40-100 minutiae. Traditional security system lies between token and the password. Once token is stolen or password is revealed then security becomes more vulnerable and it affects the entire security system.

The general diagram of a fingerprint verification system (FVS) is depicted in Fig. 1. As shown, fingerprint matching is the final step in AFVS.

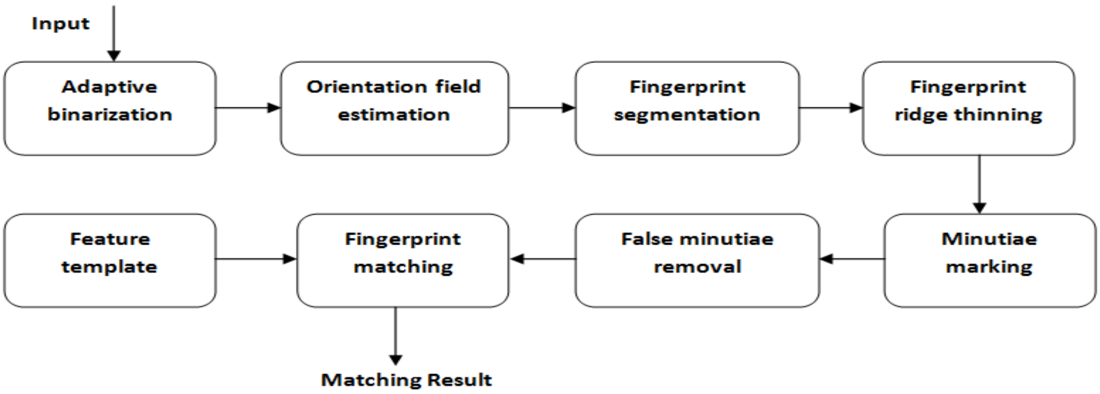

Figure 1: General diagram of Automatic Fingerprint Verification System.

Fingerprint matching can be class be classified into 3 different types [5,10]:
1. Correlation-based matching
2. Pattern-based matching
3. Minutiae-based matching

Correlation-based matching

In this type two fingerprint images are superimposed and the correlation between corresponding pixels is computed for different alignments [5].

Pattern-based (or image-based) matching

This method is entirely differs from the previous one, matching is performed based on the global features like (singular point, delta, arch, whorl and loop) of a fingerprint image with the previously stored template. This requires that the images to be aligned in same orientation. To do this, the algorithm picks a central point in the fingerprint image and centers on that [5, 6]. The template contains the type, size and orientation of patterns within the aligned fingerprint image. The newly enrolled fingerprint image is graphically compared with the stored template to determine the degree to which they match.

Minutiae-based matching

This technique is the most popular and widely used by the people [5, 7]. Fig. 2. depicts the local features of the fingerprint. Query fingerprint image undergoes for pre-processing and minutiae points are extracted and stored as sets of points in the three-dimensional plane. Further these new minutiae sets are compared with the existing template. Minutiae-based matching essentially consists of finding the alignment between the template and the query minutiae sets that result in the maximum number of minutiae pairings.

Figure 2: (a) two important local features (b) Other features

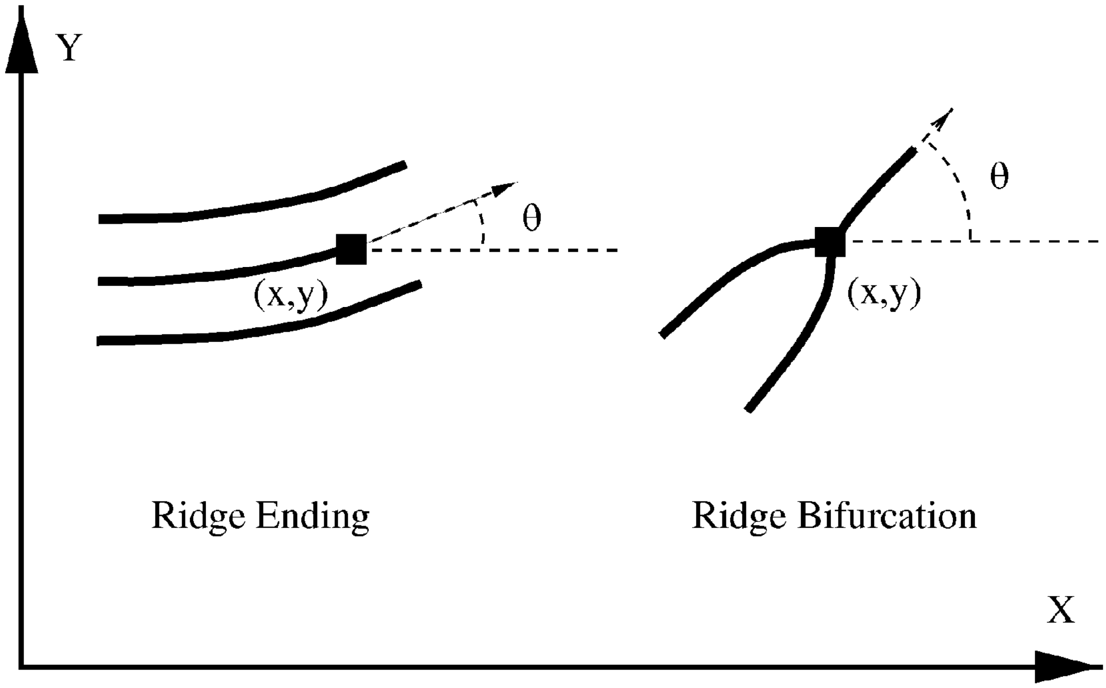

Figure 3: Local features with theta value [9]

The rest of the paper is as follows. The following section 2 briefly discuss about fingerprint pre-processing. The proposed technique is presented in Section 3.

The experimental results are shown in Section 4 and finally conclusion is presented in Section 5.

2. Fingerprint Pre-processing

Fingerprint image acquired from the user undergoes for various pre-processing and post-processing activities in order to remove the noise and to achieve high recognition rate. Noise occurs in fingerprint image due to less ink or over ink. Less amount of ink which introduces fake and ridge breaks between ridges in the fingerprint and over ink generates enclosure between two ridges.

First step is to apply adaptive binarization to convert the grayscale image into black and white image; later orientation is used to calculate the ridge flow directions. Next segmentation is used to separate the foreground image from the background of the fingerprint image for further operation. Ridge thinning is applied to segmentation image to convert one pixel wide of the image for minutiae marking.

Finally Minutiae points are marked in fingerprint and false minutiae points are eliminated from the minutiae set. Query fingerprint is compared against with stored user template and matching performance is calculated with the help of threshold, user might be authenticated for accessing the service or rejected to avoid further processing.

A. Adaptive binarization

Fingerprint Image binarization is a method to transform the 8-bit gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for valley. After the operation, ridges in the fingerprint are highlighted with black color while valleys are white. A locally adaptive binarization method is performed to binarize the fingerprint image in order to reduce the size of the 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 (16x16) to which the pixel belongs.

B. Orientation Field Estimation

The orientation image represents an intrinsic property of the fingerprint images and defines invariant coordinates for ridges and valleys in a local neighbourhood. The orientation field of a fingerprint image defines the local orientation of the ridges contained in the fingerprint. The orientation estimation is a fundamental step in the enhancement process as the subsequent Gabor filtering stage relies on the local orientation in order to effectively enhance the fingerprint image.

C. Segmentation

Segmentation is done to extract fingerprint image from background image. In AFVS, the processing of the fingerprint image background is not necessary and consumes more processing time in all stages. Cropping or cutting out the region that contains the fingerprint feature which minimizes the number of operations on the fingerprint image. A new boundary values and modified gradient-based method for fingerprint segmentation is proposed in [8]. Steps for this method are summarized as follows:

1 Divide the input image I(i,j) into non-overlapping blocks with size $k \times k$.
2 Use histogram equalisation to enhance the contrast between background and foreground image.
3 Use a 3x3 median filter to reduce the noise in background of the image.
4 Compute the gradients $\partial_x(i,j)$ and $\partial_y(i,j)$ at each pixel (i,j) which is the center of the block.
5 Compute the mean values M_x and M_y for x and y components of the gradient using equations 1 and 2 respectively

$$M_x = \frac{1}{k^2}\sum_{i=-k/2}^{k/2}\sum_{j=-k/2}^{k/2}\partial_x(i,j) \quad (1)$$

$$M_y = \frac{1}{k^2}\sum_{i=-k/2}^{k/2}\sum_{j=-k/2}^{k/2}\partial_y(i,j) \quad (2)$$

6 Compute standard deviation for both *Mx* and *My* using equations 3 and 4.

$$std_x = \sqrt{\frac{1}{k^2}\sum_{i=-k/2}^{k/2}\sum_{j=-k/2}^{k/2}(\partial_x(i,j) - M_x(I))^2} \quad (3)$$

$$std_y = \sqrt{\frac{1}{k^2}\sum_{i=-k/2}^{k/2}\sum_{j=-k/2}^{k/2}(\partial_y(i,j) - M_y(I))^2} \quad (4)$$

7 Compute the gradient deviation using equation 5.

$$grddev = std_x + std_y \quad (5)$$

8 Select a threshold value empirically. If *grddev* is greater than threshold value, the block is considered as foreground otherwise it belongs to background.

D. Ridge Thinning

The final image enhancement step typically performed prior to minutiae extraction is thinning. Ridge Thinning is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide [11]. This skeleton image is then used in the minutiae extraction Thinning is normally only applied to binary images, and produces another binary image as output. The skeletonisation method is guaranteed to produce a connected skeleton.

E. Minutiae Extraction

A most important in fingerprint processing is to reliably extract minutiae from the fingerprint images. The minutiae extraction technique that has been implemented is based on the widely-employed crossing number method. The segmented image is thinned, as a result of which a ridge is only one pixel wide. The minutiae points are thus those which have a pixel value of one (ridge ending) as their neighbour or more than two ones (ridge bifurcations) in their neighbourhood. Crossing number of pixel 'p' is defined as half the sum of the differences between pairs of adjacent pixels defining the 8-neighbourhood of 'p'. Mathematically, it is calculated using the below equation[12].

$$CN(p)=\frac{1}{2}\sum_{i=1}^{8} val(p_{imod8}) - val(p_i - 1) \quad (6)$$

Where to are the pixels belonging to an ordered sequence of pixels defining the 8-neighbourhood of p, and val (p) is the pixel value. Crossing numbers 1 and 3 correspond to ridge endings and ridge bifurcations respectively.

F. False Minutiae Removal

False Minutia Removal eliminates the spurious minutiae which were introduced by the earlier processing steps. For example, false ridge breaks due to insufficient amount of ink and ridge cross connections due to over inking are not totally eliminated [13]. False minutiae are island, lake, hook, bridge, spur and crossover, trifurcation, opposed bifurcation and opposed ridge ending [14, 15]. These false minutiae will significantly affect the accuracy of the system and these are removed. Finally, the x,y position along with theta position of the marked minutiae are stored in a text file and these values are used for matching fingerprint.

3. Proposed method

Our proposed method deals with the Minutiae extracted from fingerprint image. Suppose the stored minutiae sets $\boldsymbol{P} = \{p1, p2, \cdot\ \cdot\ \cdot\ , pi\}$ and query minutiae sets $\boldsymbol{Q} = \{q1, q2, \cdot\ \cdot\ \cdot\ , qj\}$ to be matched are composed of i and j points respectively ($i \geq j$). Below equations P(x,y,z) and Q(x,y,z) are used to calculate the location distance and orientation distance between the stored and query minutiae sets.

$$P(x,y,z) = [((x_{p1}-x_{q1})^2 + (y_{p2}-y_{q2})^2+(z_{p3}-z_{q3})^2) + ((x_{p1}-x_{q1})^2 + (y_{p2}-y_{q2})^2 +(z_{p3}-z_{q3})^2) \cdot\ \cdot\ \cdot ((x_{pN}-x_{qN})^2 + (y_{pN}-y_{qN})^2+(z_{pN}-z_{qN})^2)] \quad (7)$$

$$Q(x,y,z) = [((x_{p1}-x_{q1})^2 + (y_{p2}-y_{q2})^2+(z_{p3}-z_{q3})^2) + ((x_{p1}-x_{q1})^2 + (y_{p2}-y_{q2})^2+(z_{p3}-z_{q3})^2) \cdot\ \cdot\ \cdot ((x_{pN}-x_{qN})^2 + (y_{pN}-y_{qN})^2 +(z_{pN}-z_{qN})^2)] \quad (8)$$

Finally Euclidean distance is used for calculating the similarity between two fingerprint images.

$$dis(Mp,Mq)=\sqrt{P-Q} \quad (9)$$

4. Experimental Result and Analysis

The performance of our proposed technique is tested on a public-domain database FVC2002 [17], which contains 40 different gray-scale fingers and 8 impressions of each finger(40x80=320 fingerprints). The images in DB1, DB2, DB3 and DB4 are 388x374, 296x560, 300x300, 288x384 and each fingerprints have a resolution of 500 dpi. Matlab 7.10.0 is employed to perform image enhancement , direction estimation, thinning, Minutiae marking and false minutiae removal. From the below Table 1 our proposed method requires less computation time comparing to the existing method[16], for matching the fingerprint.

Table 1. Evaluation of Computational Time

FVC2002	Existing method [16]	Proposed method
DB1	0.26ms	0.22ms
DB2	0.22ms	0.21ms
DB3	0.22ms	0.21ms
DB4	0.22ms	0.21ms

5. Conclusion

In this paper a novel modified method is proposed to reduce the computational time for matching against the query fingerprint and stored fingerprint template for authentication. First fingerprint processing steps are discussed. False minutiae removal stage is very important to increase the matching rate. Finally experimental results are compared with the existing method and our proposed method significantly reduces the computational time. As a future work this paper further can be extended with different biometrics and also with different multimodal biometrics.

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