

FINGERPRINT VERIFICATION SYSTEM: A NON-MINUTIAE BASED APPROACH

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ABSTRACT

In this paper, a new method for fingerprint verification, based on the features extracted from both spectrum and direction domains of fingerprints, is introduced. In this method, the spectrum of fingerprint is divided to sectors with equal number of pixels and for each sector, the respected average and standard deviation is calculated. The resulting feature vector for any fingerprint is used to calculate the distance measure of two fingerprints. Also a value is assigned to the similarity of the Block Directional Field (BDF) of two fingerprints. The fusion of the above mentioned distance and similarity of BDF's is used to verify an input fingerprint image. This method does not need any preprocessing step and due to simplicity, the speed of verification is high. Also, in spite of other image-based methods, this method does not need any reference point to be detected. The experiments show better results for verification accuracy in comparison with the most important methods presented in the literature.

Keywords: Fingerprint Verification, Block Directional Field, Spectrum.

1. INTRODUCTION

Fingerprint is one of the most important biometric for people verification. This is mainly due to the two properties of fingerprints, i.e. immutability and uniqueness. There are various methods for verification of fingerprints. The most important of them is to identify and match local visible features of fingerprints called minutiae and hence the name, minutiae-based approaches. These methods require extensive preprocessing operations in order to reliably

extract the minutiae features. The preprocessing operations include image enhancement, orientation flow estimation, ridge segmentation, ridge thinning and minutiae detection [1,2,3,4]. Also, a minutiae purification stage must be added in order to reduce the number of false minutiae erroneously detected in noisy fingerprint images. Image-based approaches do not use minutiae features for fingerprint matching. They are usually applied onto gray-scale fingerprint image without preprocessing, and hence, they may achieve higher computational efficiency than minutiae-based methods [5,6]. But image-based methods generally need a reference point (core point) to be detected and when such a point is not found in the captured fingerprint image, the methods fail [3]. In this paper, we propose an image-based method for fingerprint verification. In this method, verification is achieved with a fusion of spectral and directional features and does not need any reference point to exist and detected.

The paper is organized as follows. This introduction serves as the first section. The following section presents feature extraction in both spectrum and direction domains. Experimental results are shown in section 3, and finally a brief conclusions section will summarized the paper.

2. PROPOSED METHOD

The proposed method uses directional and spectral features and hence feature extraction from both frequency domain and BDF must be explained

2.1. Feature Extraction from Spectrum

The magnitude of two dimensional Fourier Transform of an image is called spectrum. A fingerprint image along with its frequency spectrum is shown in figure 1. The global direction of the



Figure 1: a fingerprint and its spectrum.

spectrum is orthogonal to that of the fingerprint image because the frequency information is orthogonal to directional ridge information of fingerprints. In order to extract suitable features from the frequency spectrum, it is divided to sectors with equal number of pixels as shown in figure 2. Each sector is around of one of the directions (0, 22.5, 45, 67.5, 90, 112.5, 135, and 157.5). We call these directions, 1st, 2nd, ..., 8th direction, respectively. For each sector, the respected values of average and standard deviation are calculated. Due to the central symmetry property of spectrum, only half of the spectrum is used for feature extraction. For each fingerprint image, two feature vectors, one for averages and the other, for standard deviations of sectors are extracted. Two images; one is transformed horizontally or vertically with respect to the other, have the same feature vectors. Let u_{sdij} and u_{avij} be the standard deviation and average values of sector j from direction i of one fingerprint and v_{sdij} and v_{avij} be the standard deviation and average value of sector j from direction i of another fingerprint, then:

$$d_{sdi} = \sqrt{\sum_{j=1}^m (u_{sdij} - v_{sdij})^2} \quad (1)$$

$$d_{avi} = \sqrt{\sum_{j=1}^m (u_{avij} - v_{avij})^2} \quad (2)$$

$$d_{sd} = \sum_{i=1}^8 d_{sdi} \quad (3)$$

$$d_{av} = \sum_{i=1}^8 d_{avi} \quad (4)$$

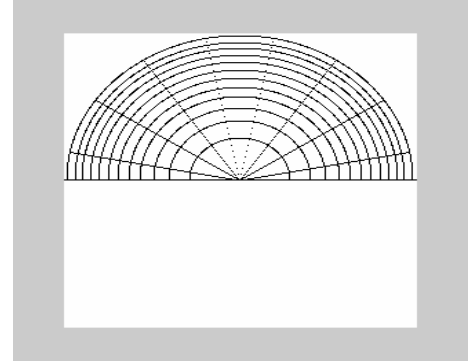


Figure 2: division of spectrum to sectors with equal surfaces.

Then d_{sd} and d_{av} will be two measures of how the two fingerprints similar to each other. A criterion for similarity of two fingerprints may be defined as either of the mentioned distances to be less than a threshold. Experimental results show that for a fixed value of threshold, choosing d_{av} ; compared to d_{sd} , gives lower FAR. For this reason and in order to FAR and FRR together be as small as possible, the following criterion has been considered:

$$d_{av} \leq t_2 \quad \& \quad d_{sd} + d_{av} \leq t_1 \quad (5)$$

Where in (5), threshold values t_1 and t_2 are obtained empirically.

2.2. Similarity Measuring Using BDF

Block Directional Field (BDF) is an image that shows the direction of fingerprint ridges. Directions are changed to the nearest direction belongs to one of the eight directions (0, 22.5, 45, 67.5, 90, 112.5, 135, and 157.5) so that the final directions have discrete values. The name BDF comes from the fact that the original fingerprint image is divided to square blocks and the dominant direction of ridge in each block is stored in a matrix making the BDF. A fingerprint and its BDF is shown in figure 3. In this research, the method used in [7] is applied to calculate BDF. In order to assign a value to the similarity of BDF's of fingerprints, a BDF of one fingerprint is translated horizontally and vertically with respect to BDF of other fingerprint image and in either case the number of matched blocks that have the same direction, is counted. Consider the case with maximum number of matching block with the same directions. The value obtained for the counts measures the similarity of the fingerprint images and we call it MBO. With the above definition for MBO, one may calculate it from the

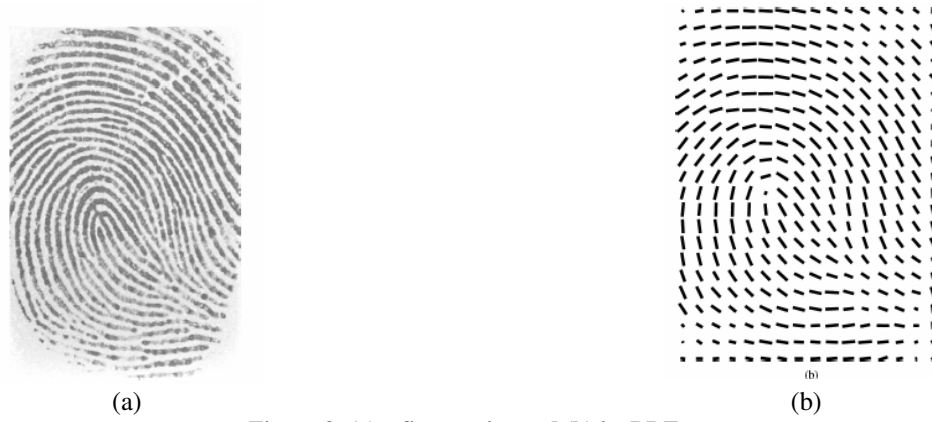


Figure 3: (a) a fingerprint and (b) its BDF.

following relation:

$$MBO =$$

$$\max_{i,j} \left\{ \sum_{il,jl} \delta [f_1(il+i, jl+j) - f_2(il, jl)] \right\} \quad (6)$$

Where f_1 and f_2 are the BDF 's of two fingerprints. δ Function is 1 when its argument is zero and it is zero elsewhere. As a criterion for the similarity of two fingerprints, it is necessary for MBO to be larger than a threshold. On the other hand, when the two fingerprints are identical, shift of one fingerprint with respect to the other, can be obtained by:

$$(I, J) =$$

$$\arg \left\{ \max_{i,j} \sum_{il,jl} \delta [f_1(il+i, jl+j) - f_2(il, jl)] \right\} \quad (7)$$

The values for the shift in terms of no. of pixels can easily be calculated by multiplying I, J by the block size (W for a $W \times W$ block). The two images of the same fingerprint may be *partially* (not totally) overlapped and hence it is better to normalize MBO in such cases. DEG_SIM is defined as:

$$DEG_SIM = \frac{MBO}{NOV} \quad (8)$$

In (8), NOV is the total number of blocks in the overlapped region, in the case of maximum number of matched blocks with the same directions. The criterion for the similarity is as follows:

$$MBO \geq t_3 \quad \text{or} \quad DEG_SIM \geq t_4 \quad (9)$$

Where in (9), the values t_3 and t_4 are obtained empirically.

2.3. Information Fusion

In order to combine the results of sections 2.1 and 2.2, one may take the two fingerprints are identical if (5) or (9) holds. This reduces FRR, but increases FAR. On the other hand, if one assumes two fingerprints are identical if (5) and (9) hold, FAR is reduced, but FRR is increased. Therefore, the two fingerprints are assumed to be identical if the following criterion is met:

$$\begin{aligned} & (d_{av} \leq t_2 \ \& \ d_{sd} + d_{av} \leq t_1) \quad \text{OR} \\ & \{ (d_{sd} + d_{av} \leq t_5 \ \& \ d_{av} \leq t_6) \ \text{AND} \\ & (MBO \geq t_3 \ \text{or} \ DEG_SIM \geq t_4) \} \end{aligned} \quad (10)$$

Where $t_5 > t_1$ and $t_6 > t_2$. This Criterion means that two fingerprints with similar spectral features is assumed to be identical. Otherwise and with similarity in direction domain, the two fingerprints is supposed to be the same only if they have similar spectral features with larger thresholds applied on similarity criterion for spectrum. The reason for this is that reduction of *FRR* does not cause *FAR* to increase.

3. Experimental Results

In order to evaluate the fingerprint verification system developed by (10), we used fingerprint database presented in [8]. These images are from 21 fingerprints, each having 8 images so that the total number of images is 168. The size of the images is 256×256 . System evaluation is achieved according to [9]. 192 bytes features are extracted for the

Table 1: one point of ROC curves with their threshold values.

METHOD	t_1	t_2	t_3	t_4	t_5	t_6	FRR(%)	FAR(%)
SPECTRUM-BASED	0.6E4	0.28E4	----	-----	-----	-----	23.6	0.45
(SPECTRUM+DIRECTION)-BASED	0.6E4	0.28E4	130	0.6	1E4	0.6E4	18.4	0.45

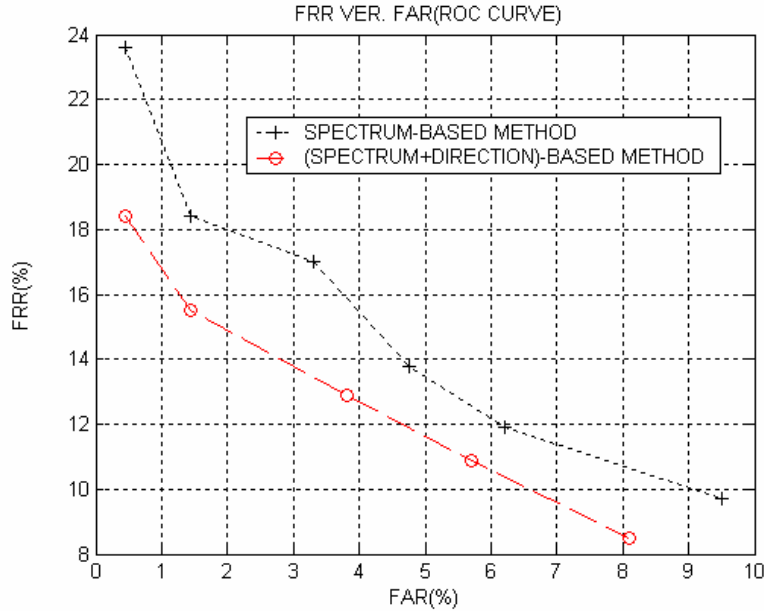


Figure 4: ROC curve for the proposed method.

average and standard deviation of sectors. The block size for BDF extraction has been 16×16 so that 96 bytes is also reserved for directional features. As a result, 288 bytes are used to represent each fingerprint image in our proposed verification system.

ROC curve for the proposed system is shown in figure 4. There are two curves in this figure. The first one (called spectrum-based) uses only spectral features and the second (called (spectrum+direction)-based) uses (10) to verify an input fingerprint. The second curve has 3% to 5% improvement for FRR relative to the first curve at a fixed value of FAR. Therefore directional information improves the overall performance.

A point of ROC curve with the respected threshold values for both methods at a fixed and low value of FAR is shown in table 1. This point clearly shows performance improvement when using (10) as the verification criterion.

In [10], a method for fingerprint verification using texture features is presented. This method is based on applying 8 Gabor filters on the fingerprint image in a limited area around the core point and then extracting texture features. The main condition for this method is to find a core point in acquired fingerprint region. For the database used, there are only 104 images from 13 individuals that have core points in a suitable position for extracting the features. Therefore we evaluated this method with only 104 images. To do this, a subimage of 64×64 pixels around the core point is divided into 8×8 non-overlapping blocks and the features are extracted. The system EER (occurs when $FAR = FRR = EER$) has been obtained 9.9%. However, for the proposed system with all 168 images, EER is 8.3%. Therefore the proposed system has better performance than [10]. It is the noticeable characteristic of the proposed system that does not need the core point so that all available data has been used for system evaluation.

4. CONCLUSIONS

A new method for fingerprint verification system has been proposed. This method is based on the fusion of spectral and directional features. The method has improved performance in terms of EER relative to the method reported in the literature. The proposed method is simple so that the verification speed is high. The method does not need any reference point to exist and detected. Also we did not apply any preprocessing step to the input fingerprint. We have extracted the features using all pixels of fingerprint image in spite of the methods proposed in the literature that extract features in a limited region around the core point.

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