FINGERCODE FOR FINGERPRINT RECOGNITION IN WAVELET TRANSFORM DOMAIN

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Abstract: FingerCode has been an effective representation for both the local and global information in fingerprints using their reference points. Wavelet transform is known to be a powerful tool for fingerprint enhancement and features extraction. In this paper, a novel method for fingerprint recognition using the FingerCode in wavelet transform domain is proposed. The proposed method includes a new reference point detection method in sub-images of the wavelet transform. Since the proposed method can be used for both feature extraction and pre-processing, conventional pre-processing algorithms can be eliminated from recognition steps and hence, it lowers the overall computational complexity of the recognition. Experimental results show that the proposed method is more accurate and reliable than a traditional FingerCode method.

1 INTRODUCTION

Traditionally, passwords (knowledge-based security) and badges (token-based security) have been used to restrict access to secure systems. However, security can be easily breached in these systems when a password is divulged to an unauthorized user or a badge is stolen by an impostor. The emergence of biometrics has addressed the problems that plague traditional identification or verification systems by using certain physiological or behavioural characteristics associated with an intended person, such as fingerprints, hand geometry, iris, retina, face, hand vein, facial thermo grams, signature, and voice-print. Biometric indicators provide uniqueness and have an edge over traditional security methods in that these attributes cannot be easily stolen or shared. Among all the biometric indicators, fingerprints has been proven as providing one of the highest level of reliability and extensively used in many applications, for example, in criminal investigations by forensic experts.

Three types of matching methods have been used for fingerprint recognition: correlation-based matching methods, minutiae-based matching methods (Jang and Yau, 2000 – Liu, et al., 2000), and texture-based (filter-based) matching methods (Jain, et al., 1999 - 2000, Sha, et al., 2003). In correlation-based matching methods, two fingerprint images for matching are superimposed and the correlation between corresponding pixels is computed for different alignments such as various displacements and rotations. Since the fingerprint representation coincides with the whole fingerprint image, these methods are quite time-consuming.

The most popular and widely used techniques for matching are minutiae-based matching methods. Methods in this type extract feature vectors from the two fingerprints as sets of points in the two-dimensional plane. They essentially consist of finding the alignment of minutiae points between the template and the input sets that result in the maximum number of minutiae pairing. However, a minutiae-based matching may not fully utilize significant components of the rich discriminatory information available in the fingerprints and it usually very time-consuming (Maltoni, et al., 2003).

The texture-based matching methods use features from the fingerprint ridge pattern such as local orientation and frequency, ridge shape, and texture information, which can be extracted more reliably than minutiae points. Filter-based matching is a type of the texture-based matching. The FingerCode (Jain, et al., 1999 – 2000) and its improved algorithms (Sha, et al., 2003) are shown to provide effective representations by extracting filtered features from the fingerprint image.

Wavelet transform have been used for fingerprint verification and recognition recently. Selvaraj et al

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(2003) proposed a method of matching between the input image and the stored template without resorting to exhaustive search using both the wavelet statistical features and wavelet co-occurrence features. However, it uses all the pixels in the wavelet sub-band image for the computation of the statistical features, and it is much time-consuming. Tico et al. (2001) suggested another matching algorithm using wavelet domain features. They used a feature vector of length 12 to represent a fingerprint image. The feature vector represents an approximation of the image energy distribution over different scales and orientations. Fung et al. (2004) proposed an improved approach of ref (Tico, et al. 2001). In their work, critical wavelet coefficients were selected to form a feature vector of a fingerprint image. However, the vector with 12 features is not sufficient to use all the information of a fingerprint image so that the recognition rate may not be appropriate for some applications. Lee W.K. et al. (1997) proposed an algorithm that extracts the dominant local orientation features in the wavelet transform domain. The performance of the algorithm is directly related to the accuracy of the detection of the local directions. Mokju et al. (2004) proposed an algorithm based on directional image constructed using the expanded Haar Wavelet Transform. In the work, they first obtain a directional image, and then quantize the directional image into a few grey-level values that represent a range of angle orientations. In this method, the quantizing process may be error-prone in computing the directional information.

To overcome the drawbacks of these methods, a new matching method is proposed in this work. We use a sophisticated FingerCode method in the wavelet transform domain for fingerprint recognition. In the work, FingerCode are extracted in the decomposed wavelet sub-band images instead of the original fingerprint image. There are two advantages to extract features from the wavelet sub-band images. Since the wavelet transform is a multi-resolution tool in signal processing, it can easily remove the high-frequency noise, usually contained in HH sub-band image. With this approach one can eliminate some pre-processing steps such as noise removing, binarization, thinning and restoration. In addition, the size of decomposed sub-band images is half of the original image, so that a matching method using features extracted from sub-band images can speed up the whole matching process comparing to other approaches.

The paper is organized as follows: In Section 2 The theory of FingerCode is briefly reviewed. The proposed recognition method is explained in Section 3 and its experimental results are shown in Section 4. The conclusion remarks are given in Section 5.

2 FINGERCODE

The FingerCode, introduced in ref (Jain et al., 2000), is a fixed length representation that can effectively capture both the local and global details in a fingerprint, with a bank of Gabor filters. The typical FingerCode generation process can be summarized in the following steps:

1. Locate the reference point and determine the region of interest for a fingerprint image.
2. Tessellate the region of interest, centered at the reference point, into a series of B (=5) concentric bands and divide each band into k (=16) sectors.
3. Normalize each sector to a predetermined constant mean M_0 (=100) and variance V_0 (=100).
4. Filter the region of interest in eight different directions using a bank of Gabor filters.
5. Computer the average absolute deviation from the mean (AAD) of grey level values in each of the 80 sectors for every filtered image. The collection of all the AAD features in each filtered image is defined as FingerCode.
6. Rotate the features in the FingerCode cyclically to generate five templates corresponding to five rotations ($\pm 45^0$, $\pm 22.5^0$, 0^0) of the original fingerprint image, thus to approximate the rotation-invariance;
7. Rotate the original fingerprint image by an angle of 11.25^0 and generate its FingerCode. Another five templates corresponding to five rotations are generated in the same way as step 6.
8. Match the FingerCode of the input fingerprint with each of the ten templates stored in the database to obtain ten matching scores. The final matching score is the minimum of the ten matching scores, which corresponds to the best matching of the two fingerprints.

In this paper, we use the reference point location method developed in ref (Sha, et al., 2003) for the original fingerprint image, which is known to be robust and rotation-invariance. The average orientation of each sector is also computed for the reference point.

3 THE PROPOSED ALGORITHM

The proposed algorithm for the fingerprint recognition consists of three main steps:

1. Apply the discrete wavelet decomposition to a fingerprint image.
2. Determine the reference point in the wavelet sub-images
3. Apply the FingerCode approach to the wavelet sub-images.

The first step is to apply the wavelet decomposition. Typically, Daubechies wavelet filters are reasonable tools for decomposing images (Mallat, 1998), here for simplicity, Db4 is chosen as the wavelet basis. We use Db4 wavelet to decompose the fingerprint image into 2 levels, the approximated sub-images LL1 and LL2 are shown as in Fig.1. We choose the approximated sub-image LL1 and LL2, and exclude LL3 or higher decomposed sub-images, since the size of higher-level decomposed sub-image is so small, and they hardly provide unique information as FingerCode features.

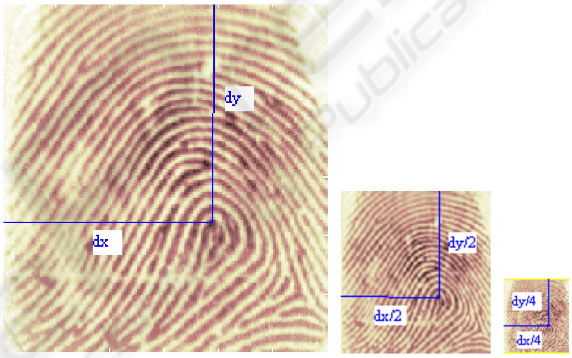
For the approximated sub-images, the ridges and valleys may not be clearly defined due to the approximation as in Fig. 1(b) and (c). Hence it is very hard to find reference points directly from these sub-band images using the traditional method. A new reference point detection method in the wavelet sub-images needs to be developed and described as the second step of the proposed method.

(a) (b) (c)

Figure: 1. (a), (b), (c) original image 101_7.tif (300×300) and its 1-level and 2-level decomposed sub-images LL1 and LL2 (Db4 wavelets used).

The second step is to determine the reference points from the wavelet sub-images. In here we proposed a new method based on the method in ref (Sha, et al., 2003). Since it is difficult to determine the reference point in sub-band images with less information, we first determine the reference point (dx, dy) in the original fingerprint image using the method in ref (Sha, et al., 2003). Then the algorithm finds the location of the reference point in the wavelet sub-images using the proportional location of the reference point in the original image. Since the decomposition of wavelet transform uses down-sampling in half, the size of the decomposed sub-image is a half size of the up-level image. If we find the coordinate of the reference point according to the left-top point (0,0) is (dx, dy) in the original image, then the coordinates of the reference point according to its left-top point can estimated as (dx/2, dy/2) and (dx/4,dy/4) in the LL1 and LL2 sub-images as shown in Fig.2 (b),(c) respectively.

The third step is using the FingerCode on the wavelet sub-images based on the method described in ref (Sha, et al., 2003). Since we locate the reference point in the wavelet domain, the FingerCode for fingerprint recognition can be straightforward.



(a) (b) (c)

Figure.2: (a), (b), (c) the detected reference point in the original image 101_7.tif (300×300) and its 1-level and 2-level decomposed sub-images LL1 and LL2 (Db4 wavelets used).

4 EXPERIMENTAL RESULTS

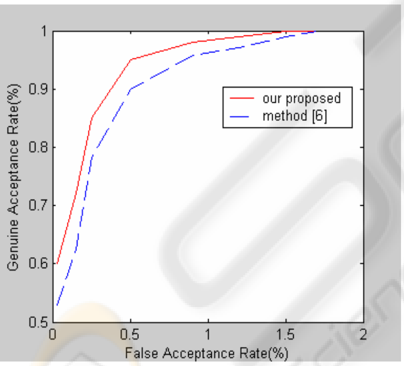
The fingerprint image database used in this work is the database of FVC2004 (http://bias.csr.unibo.it /fvc2004). Four distinct databases, provided by the organizers, constitute four benchmarks: DB1, DB2, DB3 and DB4. Each database contains 880 fingerprints for 110 fingers, each with 8 samples. The image format is the TIF with 256 grey levels. The images are uncompressed with a resolution of about 500dpi. The image size varies depending on the database. The orientation of fingerprint is approximately in the range [-30°, +30°] with respect to the vertical orientation.

Each fingerprint in the database is matched with all the other fingerprints in the 4 different databases. A matching is labelled correct if the matched pairs are determined as identical fingers. The recognition rate of FingerCode used on wavelet sub-images LL1 and LL2 are shown as Table 1. The recognition rate in LL1 is higher than in LL2 over all the databases. It can achieve 96.3% in the wavelet domain LL1 when we used the database DB1.

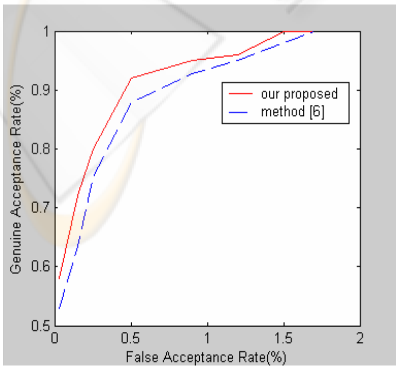
To compare the performance of the proposed method with a typical method, a receiver operating characteristic (ROC) is used. ROC is a plot of Genuine Acceptance Rate (GAR) against False Acceptance Rate (FAR). Fig.3. compares the ROCs of the method based on FingerCode in ref (Sha, et al., 2003) with the proposed algorithm on database DB1 and DB2. Since the ROC curve of our proposed algorithm is above the curve of method (Sha, et al., 2003), we consider our algorithm performs better than the method (Sha, et al., 2003) on these databases. For example, at a 0.5% FAR, the GAR of our proposed algorithm is 95.1%, while minutiae-based 90.3% on database DB1.

Table1: Comparison of the recognition rate in the wavelet domain LL1 and LL2 to different database DB1-4.

Database\wavelet domain	LL1	LL2
DB1	96.3%	95.1%
DB2	95.2%	94.8%
DB3	94.7%	91.7%
DB4	95.4%	93.6%



(a)



(b)

Fig.3. The ROC curve comparing the performance of the proposed methods with method (Sha, et al., 2003) based on (a) DB1, (b) DB2.

5 CONCLUSION

In this work, a novel method for fingerprint recognition using Fingercodes in the wavelet transform domain is proposed. One marked advantages of our proposed method is many conventional pre-processing such as smoothing, binarization, thinning and restoration are not necessary. Also, since the wavelet sub-band image size for processing is reduced comparing to the original image, the computational complexity is also lowered. Above all, experimental results show that the proposed method is outperforming the typical Fingercode method in terms of accuracy and reliability.

In addition, since the work is based on the sophisticated FingerCode technology and the reliable reference point detection algorithm in ref (Sha, et al., 2003), the proposed recognition algorithm can be robust to noise.

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