Wavelet Features Based Fingerprint Verification

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Shweta U. Bagadi, Asha V. Thalange, and Giridhar P. Jain

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Shweta U. Bagadi [#1], Asha V. Thalange [*2], Giridhar P. Jain [*3]
[#] Electronics Engg. Department,
Walchand Institute of Technology, Solapur; Solapur University, India.
[1] shwetabagadi@yahoo.com
[*] Electronics and Telecommunication Engg. Department,
Walchand Institute of Technology, Solapur; Solapur University, India
[2] ashathalange@yahoo.co.in
[3] gpjain_bv@rediffmail.com

Abstract— In this work; we present a automatic fingerprint identification system based on Level 3 features. Systems based only on minutiae features do not perform well for poor quality images. In practice, we often encounter extremely dry, wet fingerprint images with cuts, warts, etc. Due to such fingerprints, minutiae based systems show poor performance for real time authentication applications. To alleviate the problem of poor quality fingerprints, and to improve overall performance of the system, this paper proposes fingerprint verification based on wavelet statistical features & co-occurrence matrix features. The features include mean, standard deviation, energy, entropy, contrast, local homogeneity, cluster shade, cluster prominence, Information measure of correlation. In this method, matching can be done between the input image and the stored template without exhaustive search using the extracted feature. The wavelet transform based approach is better than the existing minutiae based method and it takes less response time and hence suitable for on-line verification, with high accuracy.

Keywords—fingerprint verification, wavelet transform, automatic fingerprint identification system (AFIS)

I. Introduction

Accurate automatic personal identification is becoming more and more important to the operation of our increasingly electronically inter-connected information society. Traditional automatic personal identification technologies, which are in use such as Personal Identification Number (PIN), ID card, key, etc., to verify the identity of a person, are no longer considered reliable enough to satisfy the security requirements of electronic transactions. All of these techniques suffer from a common problem of their inability to differentiate between an authorized person and an impostor who fraudulently acquires the access privilege of the authorized person. Biometrics is a rapidly evolving technology which uniquely identifies a person based on his/her physiological or behavioral characteristics such as finger prints, hand geometry, iris, retina, face, hand vein, facial thermo grams and voice print.. Among all biometric indicators, finger prints have one of the highest levels of reliability. A finger print can be viewed as an oriented texture pattern. For sufficiently complex oriented texture such as fingerprints, invariant texture representations can be extracted by combining both global and local discriminating information in the texture which forms the basis of proposed work [5]. Firstly, the Discrete Wavelet Transform (DWT) features are used for Fingerprint characterization and verification. Secondly, the co-occurrence features computed out of the sub bands of wavelet transformed images are used for fingerprint verification .This is done as the chances of correct verification will be considerably improved if higher order statistical features are used, as they will normally have good discriminating ability than the lower order one. Fingerprint image's, statistical features such as mean and standard deviation are extracted from the approximation and from the detail regions of DWT decomposed images, at different scales [5,7]. The various combinations of the above statistical features are applied for fingerprint verification and a set of best feature vectors are chosen. In order to improve the success rate of verification, the co-occurrence matrix is calculated for original image, approximation and detail sub-bands of 1- level DWT decomposed images and additional features are extracted. These additional features are combined with the above chosen best wavelet statistical feature sets for verification.

II. Proposed System

The objective of the proposed work is to extract the statistical & co-occurrence features of fingerprint image using Discrete Wavelet Transform & compare them with the stored features for verification.

Figure 1 shows the system block diagram of proposed work.

The whole work is implemented in two steps, fingerprint training and fingerprint verification. Initially the know test database is used to extract the features and to create the feature library. Further from the unknown fingerprint images, the features are extracted and compared with the features in the library for verification. In order to improve the accuracy it is proposed to find co-occurrence matrix features as mentioned in detail below in the proposed process [4, 5].

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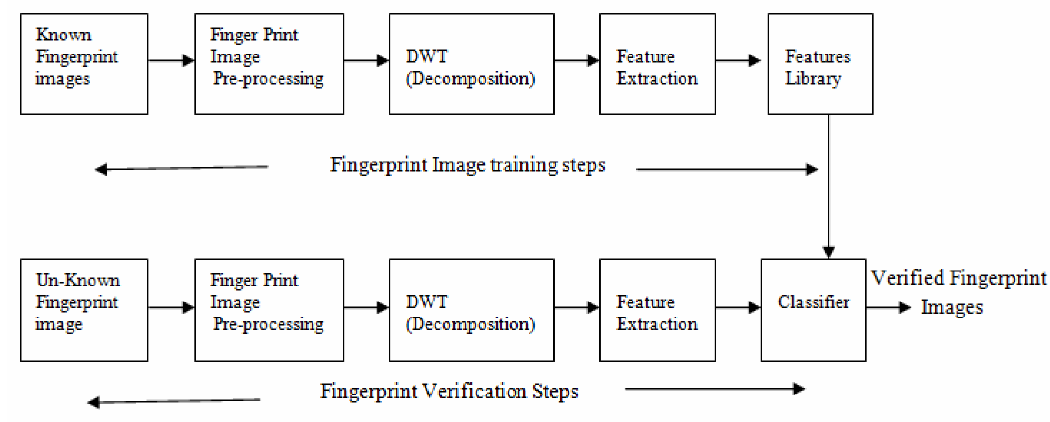


Figure 1 System Block Diagram

A. *Details of Proposed Process*

In the proposed work the process of fingerprint verification is subdivided into a number of processing modules which can be identified as:

- Data acquisition
- Pre-processing
- Feature Extraction
- Comparison and Verification

1) Data Acquisition: With the help of optical sensors fingerprint images are extracted for generating the database. The database is further divided into two groups for training and for testing process. These will be further used for pre-processing and finally feature extraction is done using wavelet transform.

2) Fingerprint Image Pre-Processing:

2.1 Fingerprint Image enhancement: - This is done to make the image clearer in order to make further operations easy. Since the fingerprint images acquired from sensors or other Medias are not assured with perfect quality, the enhancement methods, for increasing the contrast between ridges and furrows, for connecting the false broken points of ridges due to insufficient amount of ink, are very useful to keep a higher accuracy in fingerprint recognition. Two Methods are adopted in fingerprint recognition system: the first one is Histogram Equalization; the next one is Fourier Transform [1, 7].

Histogram equalization is to expand the pixel value distribution of an image so as to increase the perceptional information. The original histogram of a fingerprint image has the bimodal type as shown in Figure 2 and the histogram after the histogram equalization occupies all the range from 0 to 255 as shown in Figure 3 and the visualization effect of an image is enhanced as shown in Figure 4.

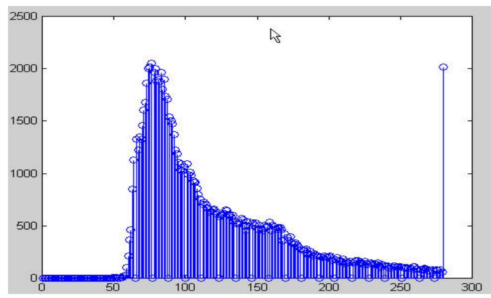


Figure 2 Original histogram of a fingerprint image

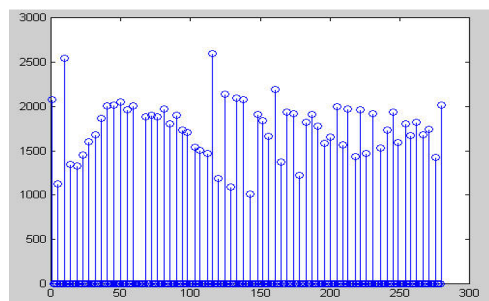


Figure 3 Histogram after equalization

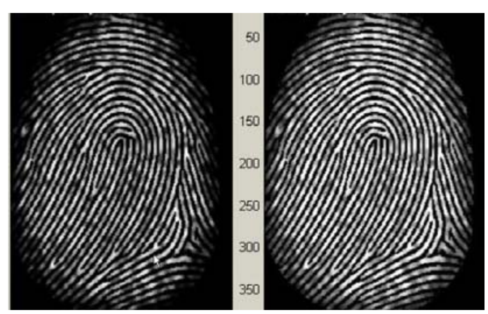


Figure 4 Histogram Enhancement.
Original Image (Left), Enhanced image (Right)

In the Fingerprint Enhancement by Fourier Transform method the image is divided into small processing blocks (32 by 32 pixels) and the Fourier transform is performed according to equation (1).

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

For $u = 0, 1, 2, ..., 31$ and $v = 0, 1, 2, ..., 31$.

In order to enhance a specific block by its dominant frequencies, we multiply the FFT of the block by its magnitude a set of times. Where the magnitude of the original FFT equals abs (F (u, v)) which equals $|F(u, v)|$.

Enhanced block is obtained according to equation (2).

$$g(x,y) = F^{-1}\{F(u,v) \times |F(u,v)|^{k}\} \quad \text{------(2)}$$

Where $F^{-1}(F(u,v))$ is obtained by equation (3).

$$f(x,y) = \frac{1}{MN}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v) \times \exp\left\{j2\pi \times \left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \quad \text{-------(3)}$$

for $x = 0, 1, 2, ..., 31$ and $y = 0, 1, 2, ..., 31$.

The k in equation (4) is an experimentally determined constant, which we choose k=0.45 to calculate. While having a higher "k" improves the appearance of the ridges, filling up small holes in ridges, having too high a "k" can result in false joining of ridges. Thus a termination might become a bifurcation. Figure 5 presents the image after FFT enhancement.

2.2 Fingerprint Image Binarization:- This 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 colour while furrows are white.[2]

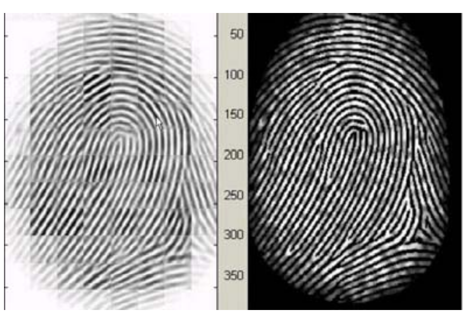


Figure 5 Fingerprint enhancement by FFT
Enhanced image (left), Original image (right)

2.3 Fingerprint Image Segmentation:- In general, only a Region of Interest (ROI) is useful to be recognized for each fingerprint image. Thus image segmentation is done. The image area without effective ridges and furrows is first discarded since it only holds background information. Then the bound of the remaining effective area is sketched out since the minutias in the bound region are confusing with those spurious minutias that are generated when the ridges are out of the sensor.

3) Feature Extraction: Feature extraction is done in both fingerprint training and as well as during fingerprint verification [4, 5]. The steps involved in Fingerprint training and Fingerprint verification is as mentioned below.

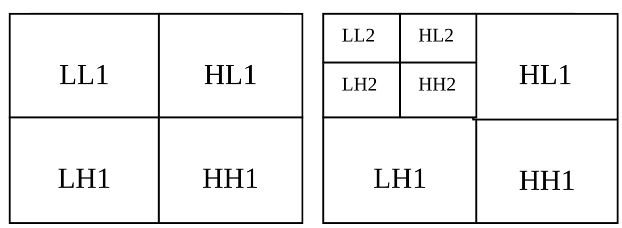
In the fingerprint training, the known fingerprint images are decomposed using DWT and the filter used is Daubechies-tab 4 filter. For decomposition-Mallat Tree Decomposition Algorithm is used. Then, the wavelet statistical features such as mean and standard deviation of approximation are extracted using the Eqns. (4) and (5) respectively and stored in features library.

$$\text{Mean (m)} = \frac{1}{N^2}\sum_{i,j=1}^{N} p(i,j) \quad \text{----- (4)}$$

$$\text{Standard Deviation (sd)} = \sqrt{\frac{1}{N^2}\sum_{i,j=1}^{N}[p(i,j)-m]^2} \quad \text{------ (5)}$$

Where, p (i, j) is the transformed value in (i, j) for any sub-band of size N x N.

The Discrete Wavelet Transform (DWT) is identical to a hierarchical sub band system where the sub bands are logarithmically spaced in frequency and represent octave-band decomposition [7,5].The image is actually decomposed i.e., divided into four sub bands and critically sub sampled by applying DWT as shown in Figure 6(a). These sub bands labelled LH1, HL1 and HH1 represent the finest scale wavelet coefficients i.e., detail images while the sub band LL1 corresponds to coarse level coefficients i.e., approximation image. To obtain the next coarse level of wavelet coefficients, the sub band LL1 alone is further decomposed and critically sampled. This results in two-level wavelet decomposition as shown in Figure 6(b).



(a) One- level (b) Two-level
Figure 6 Image Decomposition

Similarly, to obtain further decomposition, LL2 will be used. This process continues until some final scale is reached. The features obtained from these wavelet transformed images are used for fingerprint verification and identification. Detail sub-bands of three level decomposed images are calculated as features. Using this procedure, from any fingerprint image, the features up to k-level sub-bands are computed and stored in the features library.

Where, k =0, 1, 2…

These are further used in fingerprint verification phase. In order to improve the correct verification rate, further, it is proposed to find co-occurrence matrix features for detail sub-bands of 1-level DWT decomposed images (i.e., LL1, LH1, HL1 and HH1), called wavelet co occurrence features. The various co-occurrence features such as contrast, energy, entropy, local homogeneity, cluster shade, cluster prominence and maximum probability, are calculated from the co-occurrence matrix C(i,j) using the equations mentioned below[5,3].

$$\text{Contrast} = \sum_{i,j=1}^{N} (i-j)^2 \; C(i,j) \qquad \text{------(6)}$$

$$\text{Energy} = \sum_{i,j=1}^{N} C^2\,(i,j) \qquad \text{------(7)}$$

$$\text{Entropy} = -\sum_{i,j=1}^{N} C(i,j) \log_2 C(i,j) \qquad \text{------(8)}$$

$$\text{Local Homogeneity} = \sum_{i,j=1}^{N} \frac{1}{1+(i-j)^2}\, C(i,j) \qquad \text{------(9)}$$

$$\text{Cluster Shade} = \sum_{i,j=1}^{N} (i - M_x + j - M_y)^3 \; C(i,j) \qquad \text{-----(10)}$$

$$\text{Cluster prominence} = \sum_{i,j=1}^{N} (i - M_x + j - M_y)^4 \; C(i,j) \qquad \text{------ (11)}$$

$$\text{Information measure of correlation} = \frac{(Entropy - H_{xy})}{\max(H_x, H_y)} \qquad \text{------(12)}$$

Where

$$M_x = \sum_{i,j=1}^{N} i \; C(i,j) \qquad \text{-----(13)}$$

$$M_y = \sum_{i,j=1}^{N} j \; C(i,j) \qquad \text{------(14)}$$

$$H_{xy} = -\sum_{i,j=1}^{N} C(i,j) \; log \; [S_x(i) \; S_y(j)] \qquad \text{-----(15)}$$

$$H_x = -\sum_{i,j=1}^{N} S_x(i) \; log \; [S_x(i)] \qquad \text{------(16)}$$

$$H_y = -\sum_{i,j=1}^{N} S_y(j) \; log \; [S_y(j)] \qquad \text{------(17)}$$

$$S_x(i) = \sum_{j=1}^{N} C(i,j) \qquad \text{------(18)}$$

$$S_y(j) = \sum_{i=1}^{N} C(i,j) \qquad \text{------(19)}$$

4) Fingerprint Comparison and Verification : Here, the fingerprint images, is decomposed using DWT and a similar set of wavelet statistical and co-occurrence matrix features are extracted and compared with the corresponding feature values stored in the features library using a distance vector formula D(i)[3,5].

$$D(i) = \sum_{j=1}^{No\ of\ features} abs[\, f_j(x) - f_j(i) \,] \qquad \text{-----(20)}$$

Where, fj(x) is the features of unknown fingerprint

fj(i) is the features of known ith fingerprint in the library.

Then, the unknown fingerprint is verified as i^{th} fingerprint, if the distance D(i) is minimum among all fingerprints, available in the library.

III. Future Scope

Various combinations of feature extraction methods along with the different classifying engine can be used to enhance the accuracy and the performance of the system.

IV. Conclusion

It is concluded that the rotation invariant finger print representations can be extracted by combining both wavelet statistical and wavelet co occurrence features and the overall success rate is improved when wavelet statistical features of three level of DWT decomposed sub-bands are used with wavelet co-occurrence features corresponding to single level DWT decomposed sub-bands.

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