Texture Feature based Fingerprint Recognition for Low Quality Images

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Abstract:
Fingerprint-based identification is one of the most well-known and publicized biometrics for personal identification. Extracting features out of poor quality prints is the most challenging problem faced in this area. In this paper, the texture feature based approach for fingerprint recognition using Discrete Wavelet Transform (DWT) is developed to identify the low quality fingerprint from inked-printed images on paper. The fingerprint image from paper is very poor quality image and sometimes it is complex with fabric background. Firstly, a center point area of the fingerprint is detected and keeping the Core Point as center point, the image of size w x w is cropped. Gabor filtering is applied for fingerprint enhancement over the orientation image. Finally, the texture features are extracted by analyzing the fingerprint with Discrete Wavelet Transform (DWT) and Euclidean distance metric is used as similarity measure. The accuracy is improved up to 98.98%.

Keywords- Biometrics, features, wavelets, Discrete Wavelet Transform, Euclidean distance

1. INTRODUCTION

Biometrics is formed from the person's selected unique physical attributes which may be applied for the purpose of automated personal identification. Among them, fingerprint recognition is considered one of the most reliable technologies and has been extensively used in personal identification [1]. A distinctive feature of fingerprint lies in the high degree of difficulty in terms of forgery, coupled with the fact that fingerprints are unique to each person. In fact, fingerprint provides an outstanding source of entropy, which makes it an excellent candidate for security applications. Users cannot pass their fingerprint characteristics to others as easily as they do with their cards or passwords [2–4].

The pattern of valleys and ridges on human fingertips forms the fingerprint image. Analyzing this pattern at different levels reveals different types of global and local features. A global feature normally provides a special pattern of ridges and valleys including singularities or singular point (SP). The most used singularities are core and delta. While the core is usually defined as a point on the inner most ridge, the delta is known as the center point where three different flows meet. The SP provides important information used for fingerprint classification [5,6], fingerprint matching [7,8] and fingerprint alignment [9,10]. The local feature known as minutiae is also considered important for fingerprint matching. The major minutiae features of fingerprint are: ridge ending, bifurcation. The ridge ending is the point at which a ridge terminates. Bifurcations are points at which a single ridge splits into two ridges. Depending on the quality of the fingerprint image, the prominent features can be extracted. For high quality fingerprint images, the sweats, pores features can be used for matching.

Generally, methods for extracting and matching fingerprint features can be classified into three categories; minutiae-based, correlation-based and ridge feature-based. In minutiae-based approaches, a minutia detected in a fingerprint image can be characterized by a list of attributes that includes the minutia position, the minutia direction, and the type of minutia (ending or bifurcation). The minutiae sets may suffer from false, missed, and displaced minutiae, caused by poor fingerprint image quality and imperfections in the minutiae extraction stage. In the correlation-based approach, global patterns of ridges and valleys are compared to determine whether two fingerprints are aligned [11,12]. Performance of correlation-based techniques is normally affected by non-linear distortions and noise present in the image. In the ridge feature-based approach, the spatial relationship and geometrical attributes of the ridge lines, shape features, global and local texture information are used for fingerprint matching.

In proposed system, fingerprint texture information is used for fingerprint recognition. This paper presents an algorithm for fingerprint verification based on Gabor filter and Discrete Wavelet Transform features. In order to remove noise and to get the true ridge structure, Gabor filtering method is applied for fingerprint enhancement from the cropped image according to the core point and DWT features are extracted from fingerprint; finally, Euclidean distance between the feature vectors will be calculated to perform similarity matching and tests have been made on the algorithm effect in Matlab.

The paper is organized into the following sections. Section 2 is an overview of related works. The system methodology is described in Section 3. Section 4 is the experimental results and performance analysis. Finally, in section 5, the concluding remarks are given.

2. RELATED WORK

There has been a lot of work in various types of fingerprint identification. Based on our survey related to fingerprint classification, it has been observed that most of the existing works are aimed to classify the fingerprint database based on the minutiae sets, singular points and other techniques. Most systems detect minutiae points as fingerprint features and these points are used for matching. Minutiae extraction is very difficult if the quality of image is poor. Recently, Arivazhagan et al. [14] proposed a fingerprint verification using Gabor wavelets and co-occurrence matrices. A finger code is the main theme in Arivazhagan approach. Similarly, Yazdi et al. [15] also employed the co-occurrence matrices for the purpose of classifying fingerprint image.Reddy et. al., [16] presented fingerprint denoising using both wavelet and Curvelet Transforms. The search-rearrangement method performs better than minutiae based matching for fingerprint binary constraint graph matching since implicit alignment of two fingerprint images are not required.

Jianjiang Feng [17] proposed descriptor-based minutiae matching algorithm emphasis on minutiae descriptors and the computation of matching scores. The work presented in S.LinLin [13] used wavelet domain features to recognize fingerprints. The 64-subband structure of the FBI fingerprint compression standard is used to directly extract the wavelet features of the fingerprint image without preprocessing. A.Pokhriyal [18] used pseudo Zernike moments (PZMs) and wavelet transforms to extract the global and local features of fingerprint. PZMs are robust to noisy images, invariant to rotation and have a good image reconstruction capability. PZMs have been used for global analysis and so they are used to extract global features. Wavelets are good at local analysis and so they help to extract local features.

2. SYSTEM METHODOLOGY

The overview of the proposed system is as shown in Fig 1.

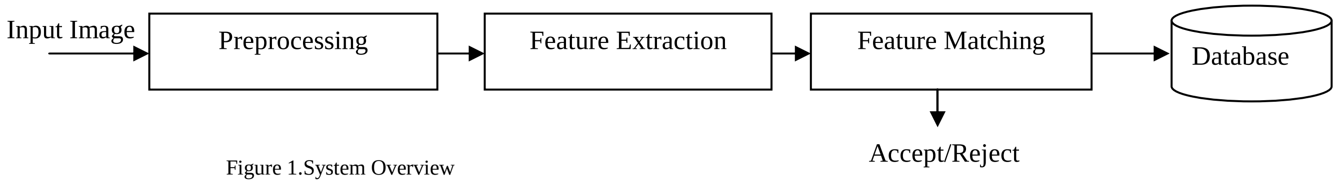


Figure 1.System Overview

In proposed system, for each training fingerprint image, a center point (core point) area of the fingerprint is detected from the orientation image to crop the region of interest. The orientation maps are used to predict the ridge line pattern. The Gabor filter is applied for image enhancement. The fingerprint features are extracted using DWT and stored into the database.

During the testing phase, features will be extracted from the scanned image from printed paper and are matched with the corresponding features stored earlier. Distance based matching is used for similarity measure.

3.1 Fingerprint Orientation Estimation

The term orientation image often refers to the determination of local ridge orientation in the fingerprint image. A fingerprint field orientation map is defined as a collection of two-dimensional direction fields. It represents the directions of ridge flows in regular spaced grids. The value of an orientation field at a given pixel is the angle that the fingerprint ridges form with the horizontal axis in a small neighborhood around that pixel. The simplest and the most natural approach for computing orientation field is based on the gradient values. Because of the computational effort and the presence of noise, the orientation field is usually computed in a small neighborhood instead of at each pixel.

Another approach to compute the orientation field that differs from this image-based approach is the model-based approach (e.g. zero-pole model [19], [20], [21]), which uses the location of singular points to estimate the orientation field based on a model. In the inked fingerprint case, since the images are usually of poor quality, it is very difficult to estimate the orientation field based only on the image itself which makes the model-based orientation field unreliable. The gradient-based approach is very useful for inked fingerprint.

The gradients of gray intensity of fingerprints are estimated to obtain reliable ridge orientation. The following steps are applied for finding orientations (Hong et al., 1998).

Let θ be defined as the orientation field of a fingerprint image. $\theta(x,y)$ is the least square estimate of the local ridge orientation at the block centered at pixel (x,y). Firstly, divide the fingerprint image into no-overlapping blocks of size *wxw*.

Compute the gradients $\partial_x(x,y)$ and $\partial_y(x,y)$ of each pixel (x,y) corresponding to the horizontal and vertical directions. The Sobel operator is employed in this work.

The local orientation of the (x,y) centered *wxw* sized block is calculated by:

$$V_y(x,y) = \sum_{u=x-W/2}^{x+W/2} \sum_{v=y-W/2}^{y+W/2} 2\partial_x(u,v)\partial_y(u,v) \quad (1)$$

$$V_x(x,y) = \sum_{u=x-W/2}^{x+W/2} \sum_{v=y-W/2}^{y+W/2} \partial^2{}_x(u,v) - \partial^2{}_y(u,v) \quad (2)$$

Compute again the local ridge orientation:

$$\theta(x,y) = \frac{1}{2}\tan^{-1}\frac{V_y(x,y)}{V_x(x,y)} \quad (3)$$

3.2 Core Point Detection

In consideration of image deformation and distortion due to different humidity and uneven force of fingers in the fingerprint image collection and to reduce amount of calculation, it is necessary to take the area near the centre point where the image quality is higher as the region of interest (ROI). In this paper, the core point of the fingerprint image is detected by calculating the Poincare Index value and then, the area near the centre point is extracted to be the ROI of the feature extraction. This method is the most classical, intuitive and simple algorithm to detect singular points. It is based on the mathematical model of the fingerprint and detects the centre point of the fingerprint by calculating the Poincare Index value in the fingerprint orientation field and then, the area near the centre point is extracted to be the ROI of the feature extraction.

A digital closed curve, *N*, around each pixel is used to compute the Poincare index as defined below:

$$Poincare(x,y) = \frac{1}{2\pi}\sum_{k=0}^{N-1}\Delta(k) \quad (4)$$

$$\Delta(k) = \begin{cases} \delta(k) if \ |\delta(k)| < \frac{\pi}{2} \\ \pi + \delta(k) if \delta(k) \le -\frac{\pi}{2} \\ \pi - \delta(k) otherwise \end{cases}$$

$$\delta(k) = \theta(x_{(k+1)\bmod N}, y_{(k+1)\bmod N}) - \theta(x_k, y_k)$$

where θ is the orientation field, and $x_{(k+1)}$and $y_{(k+1)}$ denote coordinates of the k^{th} point on the arc length parameterized closed curve *N*.

Poincaré index is computed by summing up the difference in the direction surrounding the block P. For each block P_j, we compute the angle difference from 8 neighboring blocks along counter-clockwise direction. If the sum of difference is 180°, it is the core point. In case of two or more central points detected, then, a larger smoothing parameter shall be selected to carry out wave filtering over the orientation image until the only central point is detected.

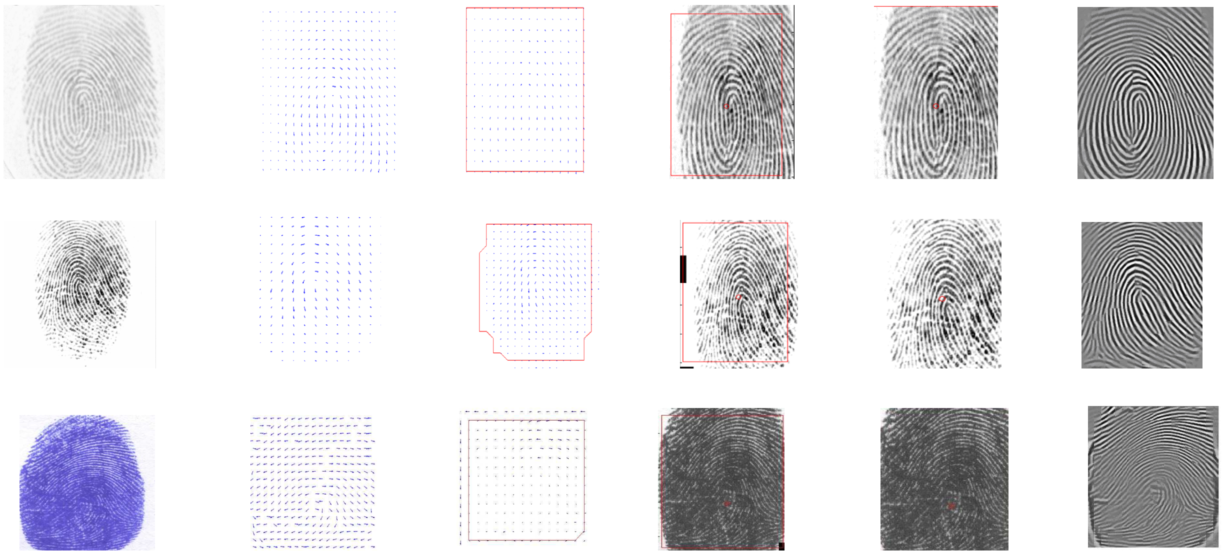
3.3 Gabor Filtering

The robustness of the recognition system depends on its ability to enhance poor quality images. Majority of the techniques are based on the use of contextual filters whose parameters depend on the local ridge frequency and orientation. The ridges and valleys in a small local neighborhood have well defined local frequency and local orientation properties [22]. A set of band pass filters can remove the undesired noise and preserve true ridge structures. Fingerprint enhancement methods based on the Gabor filter have been widely used to facilitate various fingerprint applications such as fingerprint matching and fingerprint classification. Gabor filters have both frequency-selective and orientation-selective properties and have optimal joint resolution in both spatial and frequency domains. Gabor filters are used to remove the noise and preserve true ridge/valley structures.

One useful characteristic of fingerprints is that they are known to have well defined local ridge orientation and ridge frequency. Therefore, the enhancement algorithm takes advantage of this regularity of spatial structure by applying Gabor filters that are tuned to match the local ridge orientation and frequency. Based on the local orientation and ridge frequency around each pixel, the Gabor filter is applied to each pixel location in the image. The effect is that the filter enhances the ridges oriented in the direction of the local orientation, and decreases anything oriented differently. Hence, the filter increases the contrast between the foreground ridges and the background, which effectively reducing noise. The filter applied at each pixel *(x, y)* has the form:

$$g(x,y{:}\theta,f) = e^{\left(\frac{-(x+y)^2}{2\delta^2}\right)}\cos[2\pi.f.(x.\sin\theta + y.\cos\theta)] \quad (5)$$

where θ and f are the corresponding local orientation and frequency.

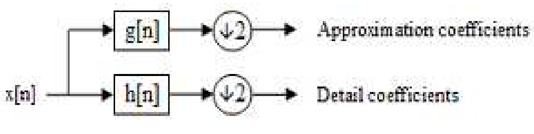


(a) (b) (c) (d) (e) (f)

Figure 2.Preprocessing Steps (a)Original Image (b) Orientation Image (c) Region of Interest (ROI) (d) Detected Core point(e) Cropped Image (f) Enhanced Image

3.4 Discrete Wavelet Transform

Wavelet transform (WT) represents image as a sum of wavelets on different resolution levels. The power of the WT is that it offers high temporal localization for high frequencies while attempts good frequency resolution for low frequencies. Thus, WT is a good tool to extract local features of the image. The hierarchical wavelet transform uses a family of wavelet functions and its associated scaling functions to decompose the original signal/image into different sub bands. The decomposition process is recursively applied to the sub bands to generate the next level of the hierarchy.



This shows one level DWT. An image *f(x,y)* whose forward discrete transform can be expressed in the form of following general relation :

$$W_{\varphi}^{i}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{X=0}^{M-1}\sum_{Y=0}^{N-1}f(x,y)\psi_{j,m,n}(x,y) \quad (6)$$

$$W_{\varphi}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{X=0}^{M-1}\sum_{Y=0}^{N-1}f(x,y)\varphi_{j_0,m,n}(x,y) \quad (7)$$

where, i = {H, V, D} and j0 is an arbitrary starting scale. Wφ(j0,m,n) coefficients define the approximation details of image *f(x,y)* at scale jo. $W^{i}_{\varphi}(j_0,m,n)$ coefficients add horizontal, vertical and diagonal details of image *f(x,y)* at scale j0. In our proposed approach we have applied the wavelets on the cropped image and extracted the features from the cropped image around the Core Point. In this paper, we have used level 2 daubechies transform. Daubechies deals with problems associated with JPEG compression and random additive noise.

3.5 Feature Extraction

Feature extraction is concerned with the quantification of texture characteristics in terms of a collection of descriptors or quantitative feature measurements, often referred to as a feature vector. Feature extraction with DWT starts the input image to a 2-level discrete wavelet transform decomposition. At each level, the wavelet transform decompose the given image in to three directional components, i.e., horizontal, diagonal and vertical detail sub bands in the direction of 0, 45 and 135 respectively apart from the approximation (or) smooth sub band. Standard deviation and the energy based techniques are applied independently on each of the sub-band information. The standard deviation is then calculated from the horizontal, vertical and diagonal details referred by $\{d_j^1\ d_j^2\ d_j^3\}$.Following equation is used for standard deviation:

$$\sigma_k = \frac{1}{M \times N} \sum_{i=1}^{N} \sum_{j=1}^{N} E\left[W_k(i,j) - \mu_k\right] \quad (8)$$

where, $W_k(i,j)$ is the k^{th} wavelet decomposed sub-band. $M \times N$ is the wavelet decomposed sub-band. μ_k is the mean value of k^{th} decomposed sub-band. Similarly energy function is given by Eq.9.

$$Energy = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} \left| X(m,n) \right| \quad (9)$$

where $X(m,n)$ is a discrete function whose energy is to be computed.

3.6 Matching

Distance based classifier has been used in the proposed system for the purpose of recognition. Relative distances of each Feature Vector are compared with the stored Feature Vectors. Euclidean distance metric given by Eq.10 is used to compute the similarity or match value for given pair of features. Zero distance implies a perfect match, and feature tends towards mismatch as the distance increases.

$$D_{(x,y)}^{Eucli} = \sqrt{\sum_{i=0}^{N} (x_i - y_i)^2} \quad (10)$$

4. EXPERIMENTAL RESULTS

The database used in the experimentation consists of 300 different fingerprint images acquired from inked images on paper. All images in the database were 256×256 in size. Each fingerprint image is enhanced and segmented by cropping the fixed size around the Core Point. DWT is used as the analysis tool. Daubechies wavelet is used as the mother wavelet and two level db10 is used as it gives high compression and removes random additive noise.

Furthermore, the effectiveness of the proposed system is also tested on the FVC 2000 database. FVC2000 is a popular and public fingerprint image database; however, many of its fingerprint images are damaged by local image noise.

To verify the system, the receiver operating characteristic (ROC) curve and equal error rate (EER) are used to evaluate the performance of the proposed method. The ROC curve is a false acceptance rate (FAR) versus false rejection rate (FRR) curve. For a given distance threshold, FRR and FAR can be calculated.

Different thresholds are taken to perform tests according to the proposed method and multiple sets of FRR and FAR values are obtained; the FRR and FAR graph of relation is drawn. Fig 5 represents the ROC results, which measures the accuracy of fingerprint matching process and shows the overall performance of an algorithm. The EER is the point where a false acceptance rate and the false rejection rate are equal in value. The smaller the EER is, the better the algorithm. From Fig 3, we can see that the performance of our algorithm is good and the EER is 2.80%.

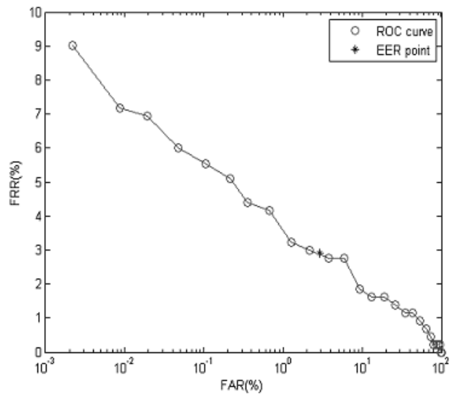


Figure 3.ROC curve

5. CONCLUSION

This paper proposes a novel method to identify enhanced fingerprint images using Discrete Wavelet Transform (DWT) to compute the fingerprint features. Image quality is directly related to the final performance of automatic fingerprint authentication systems. Good quality fingerprint images need only minor preprocessing and enhancement for accurate feature detection algorithm. But low quality fingerprint images need substantial preprocessing to increase contrast, and reduce different types of noises. In reality, the quality of the fingerprint images scanned from paper is low, thus for this reason, gabor filters are applied to enhance the images. The experimental results have demonstrated that the proposed algorithm exhibits encouraging performance for identifying the enhanced fingerprint images.

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The biometric is the study of physical or behavioral characteristics used for the identification of a person. These characteristics of a person include the features like fingerprints, face, hand geometry, voice and iris biometric features. These biometrics features can be used for authentication purpose in computer based security systems. Among these features, fingerprints are widely used in biometric techniques for automatic personal identification. Fingerprint-based identification is one of the most well-known and publicized biometrics for personal identification. Extracting features out of poor quality prints is the most challenging problem faced in this area. In this paper, the texture feature based approach for fingerprint recognition using Discrete Wavelet Transform (DWT) is developed to identify the low quality fingerprint from inked-printed images on paper. The fingerprint image from paper is very poor quality image and sometimes it is complex with fabric background. Firstly, a center point area of the fingerprint is detected and keeping the Core Point as center point, the image of size w x w is cropped. Gabor filtering is applied for fingerprint enhancement over the orientation image. Finally, the texture features are extracted by analyzing the fingerprint with Discrete Wavelet Transform (DWT) and Euclidean distance metric is used as similarity measure. The proposed system has been evaluated on both our database of over 300 images acquired from inked images on paper and FVC 2000 database. According to the experimental results, the proposed system can detect accurate core point and enhancement algorithm gives the satisfactory results. To verify the system, the receiver operating characteristic (ROC) curve and equal error rate (EER) are used to evaluate the performance of the proposed method. From the experiments, we can see that the performance of our algorithm is good and the EER is 2.80%.