FINGERPRINT FEATURE EXTRACTION: A REVIEW

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Abstract

A Brief review of fingerprint feature extraction has been described here. This paper specifically discuss about the scheme for the extraction of Gabor feature and minutia feature. The performance of fingerprint verification system based on above features is analyzed.

Keywords: Verification, Identification Gabor features, Minutiae

1. Introduction

Among all the biometrics, fingerprint is most convenient, reliable, hence extensively used by forensic experts in criminal investigations. Fingerprints are believed to be unique across individuals, and across fingers of the same individual [1]. Even identical twins having similar DNA, are believed to have different fingerprints. Because of this, there is increased use of automatic fingerprint verification systems in civilian as well as in law-enforcement applications.

The uniqueness of a fingerprint is determined by the topographic relief of its ridgestructure and the presence of certain ridge anomalies termed as minutiae points. Typically, the global configuration defined by the ridge structure is used to determine the class [2,3] of the fingerprint, while the distribution of minutiae points are used to match and establish the similarity between two fingerprints [4,5]. Automatic fingerprint identification systems that match a query print against a large database of prints (which can consist of millions of prints), rely on the pattern of ridges in the query image to narrow their search in the database (fingerprint indexing), and on the minutiae points to determine an exact match (fingerprint matching). The ridge flow pattern itself is seldom used for matching fingerprints.

Fingerprint matching techniques can be broadly classified as being minutiae-based or correlation-based. Minutiae-based techniques attempt to align two sets of minutiae points and determine the total number of matched minutiae [6,7,4]. Correlation-based techniques, on the other hand, compare the global pattern of ridges and furrows to see if the ridges in the two fingerprints align [8,9]. The performance of minutiae-based techniques rely on the accurate detection of minutiae points and the use of sophisticated matching techniques to compare two minutiae sets, which undergo non-rigid transformations. The performance of correlation-based techniques is affected by non-linear distortions and noise present in the image.

Unfortunately the minutiae-based approach contains many time consuming steps and relies heavily on the quality of input image. In fingerprint images, however, minutiae are not always clear even though the information of ridge directions and inter-ridge distances is preserved.

In this paper we will discuss the feature extraction techniques and their performance in person authentication.

2. Feature Extraction

The most common features are minutiae, there are more than 10 types of minutiae, out of which ridge endings and ridge bifurcation are the most commonly used for verification/Identification. The filters with rotation and spatial frequency selectivity like Gabor filters have proved their utility in extracting the features of an oriented texture.

2.1 Orientation field

Fingerprint image is an oriented texture. The orientation field of a fingerprint image represents the directionality of ridges. The local dominant orientation is computed as an optimal estimate of direction vectors at each pixel in a local window. Orientation field is useful in the process of feature extraction as well as in post processing. Fingerprint image typically divided into number of non-overlapping blocks and an orientation representative of the ridges in the block is assigned to the block based on analysis of grayscale gradients in the block. The block size depends on the inter-ridge distance i.e. it should include at least one ridge and one valley in a block. The block orientation could be determined from the pixel gradient orientations based on averaging, voting or optimization. The orientation field is given by

$$\theta(i,j) = 0.5\tan^{-1}\left(\frac{v_x(i,j)}{v_y(i,j)}\right) \qquad \text{---(1)}$$

where

$$v_x(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=i-\frac{w}{2}}^{i+\frac{w}{2}} 2G_x(u,v)G_y(u,v) \qquad \text{------(2)}$$

$$v_y(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=i-\frac{w}{2}}^{i+\frac{w}{2}} \left(G_x^2(u,v)G_y^2(u,v)\right) \qquad \text{------(3)}$$

Where, w is the size of block or cell. G_x and G_y are the gradient magnitudes in x and y directions respectively. The orientation field of a typical fingerprint image is shown in figure 1. Orientation field is useful in extracting both the minutiae features and Gabor filter based features.

2.2 Gabor features

In this paper the scheme proposed by Arun Ross and etal [10] for Gabor base feature map extraction has been discussed.

A 2D Gabor filter can be thought of as a complex plane wave modulated by 2D Gaussian envelope. These filters optimally capture both local orientation and frequency information1 and their development was motivated by observing the linear response of the receptive field in simple striate cortex cells. By tuning a Gabor filter to a specific frequency and direction, the local frequency and orientation information can be obtained. Thus, they are suited for extracting texture information from images. An even symmetric Gabor filter h s the following general form in the spatial domain

$$G_{\theta,f}(x,y) = \exp\left\{-1/2\left[\frac{x'^2}{\delta_x^2} + \frac{y'^2}{\delta_y^2}\right]\right\}\cos(2\pi f x') \qquad --(4)$$

where

$$x' = x\cos 6 + y\sin 6$$

$$y' = x\cos\theta - y\sin\theta$$

where f is the frequency of the sinusoidal plane wave at an angle θ with the x-axis, and δx and δy are the standard deviations of the Gaussian envelope along the x and y axes, respectively. For extracting the response of the ridge at various orientations of the Gabor filter, the parameters (f, δx and δy) are set to the following values

(i) The frequency, f, corresponds to the inter-ridge distance in fingerprint images. For example the 300 × 300 (500 dpi) images obtained using the Veridicom sensor, the average inter-ridge spacing is about 8 pixels. Hence, f = 1/8 = 0.125.

(ii) The selection of the standard deviation values, δx and δy, involves a trade-off. Larger values are more robust to noise, but will not capture ridge information at a fine level. Smaller values, on the other hand, are less robust to noise in the image, but capture ridge information very well. Based on empirical data.

(iii) Gabor filter are tuned to eight different orientations 0, 22.5, 45, 67.5, 90, 112.5, 135, 157.5 degrees.

The fingerprint image after enhancement passed [11] through the tuned Gabor filters. The convolution in frequency domain increases the speed of computation. The Gabor filtered fingerprint images are shown in figure 2.

$$G(i,j) = F^{-1}\left(F(I(x,y)) \otimes F(G_{\theta,f}(x,y))\right) \qquad ---(5)$$

where $I(x,y)$ is a enhanced fingerprint image while $G_{\theta,f}(x,y)$ is a tuned Gabor filter.

The filtered images are divided into square blocks or cells, which is called as square tessellation. The variance of pixel intensities in each cell across all filtered images is used as feature vector. Those tessellated cells that contain a certain proportion of background pixels are labeled as background cells and the corresponding feature value is set to 0.

Ridge feature map is given by

$$R = \left\{\sigma_{m,n}^{2}(i,j)\right\} \qquad --(6)$$

Where

$\sigma_{m,n}^{2}(i,j)$ – variance of block

The ridge feature map R is used for verification.

The feature from Gabor filter output other than variance are magnitude response, only real component etc:, as explained in [12].

2.3 Minutiae feature extraction

The most commonly used minutiae for verification are ridge bifurcation and ridge endings. The method proposed by Nalini Ratha and etal [13] has been discussed here.

The fingerprint is viewed as a flow pattern with definite texture. An orientation field of the flow texture is computed as described in section 2.1. The overall feature extraction algorithm is divided into

i. Preprocessing and segmentation

ii. Thinning and feature extraction

iii. Postprocessing

i. Preprocessing and segmentation

The preprocessing and segmentation is used to obtain the ridge segmented binary fingerprint image from the original gray scale fingerprint image. Following steps are involved in preprocessing and segmentation

a. Foreground and background segmentation

b. Ridge segmentation

c. Directional smoothing of ridges

A fingerprint image typically consists of region of interest i.e. ridge and valleys with blurred area patterns and smudgy patches. The fore ground needs to be segmented from the background. For this the variance of gray levels in a direction orthogonal to the orientation of each block. The region of interest exhibits very high variance in a direction orthogonal to orientation and low variance along the ridges. The background exhibits uniform variance. In other words background has low variance in all directions. Foreground is segmented by selecting a proper value of variance as threshold. Threshold may be local or global.

Consider the window with its projection in a direction orthogonal to the orientation. The ridge pixel attains local maxima (peak) in a direction orthogonal to orientation. Two neighboring pixels on either side of the peak are also retained along a direction perpendicular to the orientation field. Before projecting, the image the image is smoothed using a 1-dimensional averaging mask on each line oriented along a direction orthogonal to orientation of the window. The ridge pixels are assigned value 1, while remaining pixels 0.

The directional smoothing is applied to the detected ridges. A 3 by 7 mask of values all 1 is placed along the direction of each window. If the count of all 1 exceeds 25% of total then the ridge point is retained. The size of the window is decided emerically.

ii. Thinning and feature extraction

The binary image is thinned to have one pixel fingerprint image using skeletonization, which results in to spurious minutiae. The skeleton needs to be smoothed before minutiae point to be located. The box shaped morphological filter with size 3 by 3 with all 1 is used for smoothing.

The minutiae points are located in a 3 by 3 block. If a pixel consists of at least three neighbors, then its ridge bifurcation And a ridge ending has only one neighbor. A Post processing stage filters the false minutiae

iii. Postprocessing

Postprocessing stage eliminates spurious points based on structural and spatial relationship of the minutiae like ridge break, spike elimination and boundary effects.

Various stages of minutiae extraction process are shown in figure 3.

3. Performance analysis of AFIS

The performance of Gabor feature based automatic fingerprint verification system and minutiae based system is analyzed here.

The performance of AFIS heavily depends on the alignment. The minutiae based verification system heavily depends on the input quality of fingerprint image, the segmentation technique, performance of thinning algorithm, it is found that at minimum value of false acceptance rate the genuine acceptance rate is less compared to the Gabor feature based AFIS [10]. The Gabor based AFIS performs in a better way though the quality of input fingerprint image is poor. The minutiae based algorithms may be suitable for applications in embedded AFIS, as space required for minutiae storage is less. Depending on the application of AFIS (i.e. limits in FAR and FRR) the feature extraction technique may be adopted or both minutiae and Gabor features are commonly used as described in [10].

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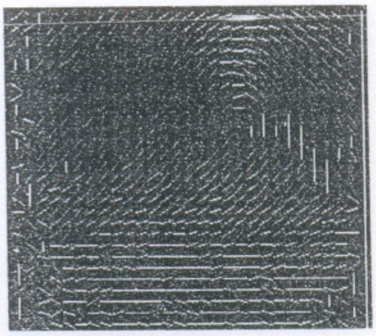

Figure 1. Orientation field of typical fingerprint image

Figure 2. Gabor filtered fingerprint images in eight different orientations

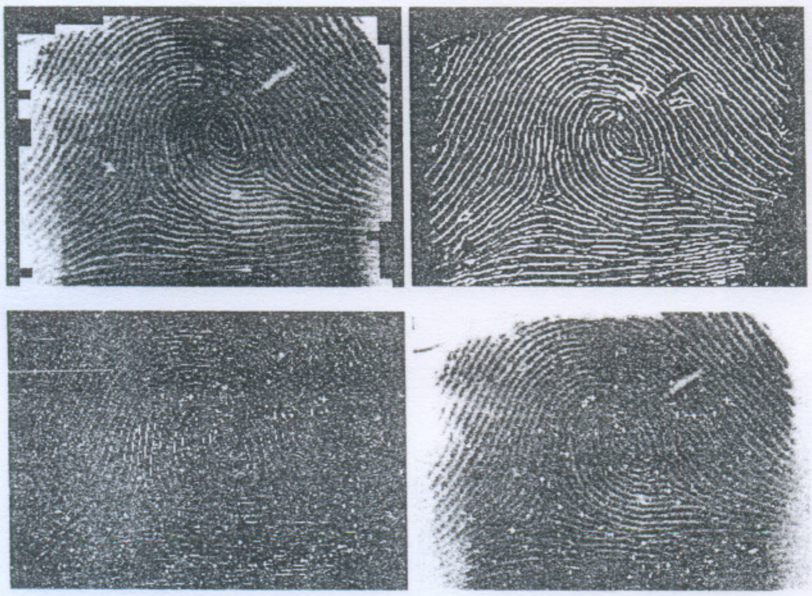

Figure 3. Various stages of minutiae detection
Region of interest, ridge segmentation, thinning, and minutiae located fingerprint image