Fingerprint Recognition System based on Orientation and Texture features

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Abstract

Fingerprint recognition is one of the most well-known and publicized biometrics for personal identification. Fingerprints exhibit oriented texture-like patterns. The texture information of the fingerprint can be used for fingerprint matching. Gabor filters can optimally capture global and local texture information even from poor-quality or incomplete images. But Gabor filterbank-based approach use only texture information for fingerprint recognition and it is not robust to image distortion and rotation. In this paper, a hybrid fingerprint matching algorithm is developed for identifying the low quality fingerprint images by combining orientation features and the local texture pattern obtained using a bank of Gabor filters. The proposed matching approach is compared with the filterbank-based approach, and the proposed system produces a much improved matching performance by combining the orientation features to the filterbank-based features.

Keyword: Biometrics, fingerprints, fingerprint recognition, Gabor filters

1. Introduction

Biometric system is an imperative area of research in recent years. Biometrics is formed from the person's selected unique physical attributes which may be applied for the purpose of automated personal identification. The biometric system having two important utility 1) authentication or verification of people's identity and 2) identification in which person's identity is verified by biometric sign. The biometric systems consists different signs fingerprint, face, iris, hand, Palm etc. Out of these signs fingerprint is one of the oldest and most reliable sign used in identification systems.

Fingerprints of any individual are unique (even in the case of identical twins), remain the same over lifetime, and are easy to collect. A fingerprint pattern is composed of a sequence of ridges and valleys [1] which generally run parallel to each other in fingerprint. The ridges are dark lines while the valleys are the light areas between the ridges. The underlying ridge structure pattern can be analyzed on a global and local level. The global features mainly give an overall characteristic of the finger. 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, fingerprint matching and fingerprint alignment. Minutiae are the locations where a ridge becomes discontinuous. The structures of core point, minutiae, ridge and pore of the fingerprint are shown in Figure 1.

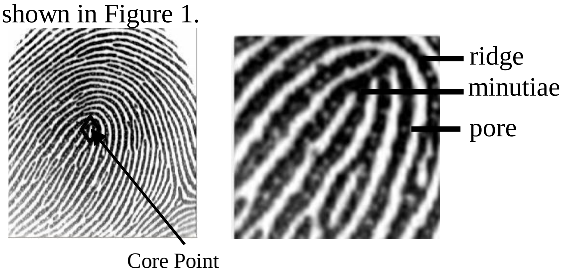

Figure 1. Fingerprint features (a) Core Point (b) minutiae, ridges and pores

In this research work, the fingerprint recognition is developed to identify the person according to the live scan fingerprint and fingerprint on NRC card. The fingerprints scanned from NRC card are shown in Figure 2 and its quality is very poor. The background pattern of image is very complex and can't be seen clearly the ridge line of the fingerprint. There are some difficulties to enhance the fingerprint ridge lines.

Figure 2. Low Quality fingerprints on NRC cards

Several methods of automatic fingerprint identification have been proposed in the literature. Minutiae based approach often gives satisfactory results for good quality images. But if, the quality of the image is poor, then minutiae extraction is a very difficult task and often gives incorrect results that are not acceptable for real time authentication applications. The minutiae sets may suffer from false, missed, and displaced minutiae, caused by poor fingerprint image quality and imperfections in the minutiae extraction stage [2].

Another class of finger-print matching algorithms doesn't use the minutiae features of the fingerprint. The texture features of the fingerprints are used for fingerprint matching.

In this paper, a hybrid fingerprint matching approach is proposed that combines orientation feature representation of the fingerprint with a Gabor-filter (texture-based) representation for matching purposes. The proposed system combines orientation feature matching to texture-based matching described in [7]. According to the experimental results, the proposed hybrid fingerprint matching algorithm is effective and efficient for both high and low quality fingerprints.

The rest of the paper is organized as follows: section 2 reports related works. In section 3 and 4, the overview of the proposed system and system methodology are described. Section 5 is experimental results. Finally, in section 6, the concluding remarks are given.

2. Related Works

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.

With the development of fingerprint identification, the state of the art application use the fingerprint ridge line features such as minutiae point and texture feature in order to obtain the improved fingerprint recognition system. Dadgostar et al., [3] initiated a fingerprint identification method in which features are extracted using Gabor filter and Recursive Fisher Linear Discriminant (RFLD) algorithms. Features extracted by Gabor filter are usually high dimensional. To reduce the dimension and also to extract more discriminant features, RFLD algorithm is used. Umair Mateen Khan et al., [4] discussed a fingerprint matching criteria. The features extracted from both minutiae based method and wavelet transformation based method are combined to get better results. Zhou Weina et al., [5] described an algorithm combining wavelet transform with prewitt edge detection for fingerprint verification. The fingerprint verification system is based on wavelet's supply of detail information and prewitt edge detection's stable characteristics in translation, scaling and rotation. Leon et al., [6] developed two algorithms for image enhancement and also, the invariant moments in verification phase. Fingerprint verification is considered using a combination of Fast Fourier Transform (FFT) and Gabor filters by image enhancement. A thinning algorithm is applied to get an image with the minimum thickness of one pixel. The feature vector is generated with the distance between minutiae, angle between minutiae and coordinates.

3. Overview of the Proposed System

The overview of the proposed fingerprint identification system is shown in Figure 3.

In the enrollment stage, the features of the fingerprint pairs acquired from both fingerprint scanner and NRC cards are stored in database with same index. The fingerprints used to test by using the proposed are acquired by fingerprint device (Hamster Eye-D).

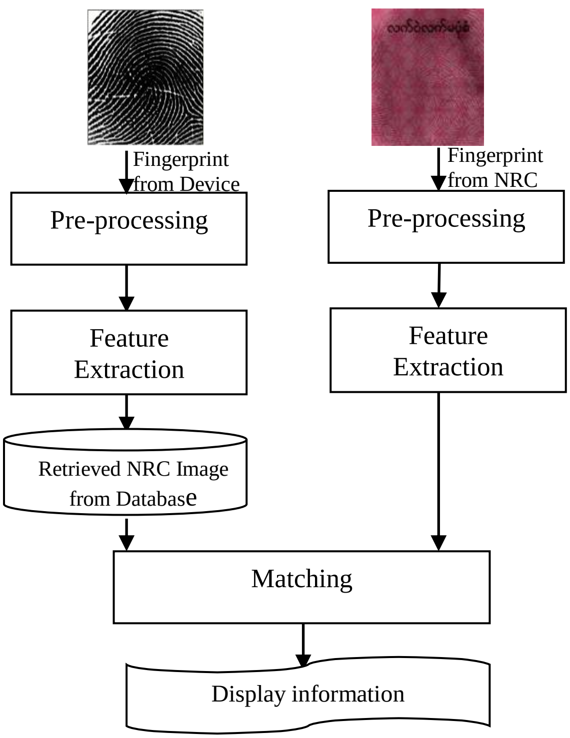

Figure 3. Overview of the Proposed System

For the identification stage, the fingerprint acquired from fingerprint device is preprocessed and features are extracted. The extracted features are matched with all device fingerprint images on database. If the input fingerprint matches with one of the fingerprints in the database, the NRC fingerprint in the same index with the matched fingerprint is retrieved. The retrieved NRC fingerprint is matched with the input NRC fingerprint. If the two fingerprints are the same, the NRC card holder is authentic and the related information is displayed.

4. System Methodology

4.1 Preprocessing

A fingerprint image is one of the noisiest of image types. This is due predominantly to the fact that fingers are our direct form of contact for most of the manual tasks we perform: finger tips become dirty, cut, scarred, creased, dry, wet, worn, etc. The image enhancement step is designed to reduce this noise and to enhance the definition of ridges against valleys.

Image preprocessing includes gray scale converting, segmentation. Segmentation is done to obtain Region of Interest (ROI) from background.

4.2 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. In this paper, the orientation features and the texture features derived by using the Gabor filters based algorithm proposed in [7] are used for fingerprint matching.

It is desirable to obtain representations for fingerprints which are scale, translation, and rotation invariant. Scale invariance is not a significant problem since most fingerprint images could be scaled as per the dpi specification of the sensors. In the proposed feature extraction scheme, translation is handled by a single reference point location during the feature extraction stage. The present implementation of feature extraction assumes that the fingerprints are vertically oriented. In reality, the fingerprints in our database are not exactly vertically oriented; the fingerprints may be oriented up to away from the assumed vertical orientation. This image rotation is partially handled by a cyclic rotation of the feature values in the FingerCode in the matching stage.

Fingerprint can be uniquely represented by its frequency content and orientation. Gabor filters can be used to extract this unique frequency and orientation information. Therefore, an input fingerprint image is filtered using this set of Gabor filters. A square tessellation, is then applied to each filtered image to examine the local response to the filter; a feature vector measuring average absolute deviation from mean (AAD), in the filtered images is next obtained. A collection of these feature vectors (over the tessellation) constitutes the Gabor texture pattern that is used to represent the fingerprint. Additional features, orientation features are stored as feature vector for fingerprint matching.

The five main steps in our feature extraction algorithm are

1) detect the orientation features of the fingerprint
2) determine a core or reference point and region of interest for the fingerprint image;
3) tessellate the region of interest around the reference point;
4) filter the region of interest in eight different directions using a bank of Gabor filters;
5) compute the average absolute deviation from the mean (AAD) of gray values in individual sectors in filtered images to define the feature vector or the FingerCode.

A. Ridge Orientation Detection

The term orientation image often refers to the determination of local ridge orientation in the fingerprint image. Reliable orientation extraction in low-quality regions is still an open problem and new approaches are often proposed in the literature. In proposed system, gradient based approach is used for extraction of ridge direction. 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 non-overlapping blocks of size *w*x*w*.

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 *w*x*w* sized block is calculated by:

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

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

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

B. Core Point Detection

Fingerprints have many conspicuous landmark structures and a combination of them could be used for establishing a reference point. We define the reference point of a fingerprint as the point of maximum curvature of the concave ridges in the fingerprint image.

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.

1) Orientation field *O* is defined as an *M x N* image, where *O(i,j)* represents the local ridge orientation at pixel *(i,j)*. An image is divided into a set of w x w non-overlapping blocks and a single orientation is defined for each block.
2) Initialize *A*, a label image used to indicate the core point.
3) For each pixel *(i,j)* in *O*, compute Poincare index and assign the corresponding pixels in *A* the value of one if Poincare index is between 0.45 and 0.51.The Poincare index at pixel *(i,j)* enclosed by a digital curve N,

which consists of sequence of pixels that are on or within a distance of one pixel apart from the corresponding curve, is computed as follows:

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

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

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

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

4) The center of block with the value of one is considered to be the center of fingerprint. 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. If more than one block has value of one, then calculate the average of coordinates of these blocks.

C. Gabor filter-based texture extraction

Gabor filters have both frequency-selective and orientation-selective properties and have optimal joint resolution in both spatial and frequency domains.

Different steps in texture extraction are as follows:

1) ROI extraction: Tessellate the region of interest centered at the reference point. The region of interest is divided into a series of B concentric bands and each band is sub-divided into k sectors (B = 5, k = 16). Thus, a total of 16×5=80 sectors (S_0 through S_{79}).

2) Normalization: The region of interest in each sector is normalized separately to a constant mean and variance before filtering. Normalization is done to remove the effects of sensor noise and finger pressure differences. Let *I(x, y)* denote the gray intensity value of the pixel at position (x, y), M_i, and V_i, be the estimated mean and variance of the sector block S_i respectively and N_i *(x , y)*, the normalized gray-level value at pixel (*x*, *y*). For all the pixels in sector S_i, where M_O and V_O are the desired mean and variance values, respectively, the normalized image is given by following formula:

$$N_i(x,y) = \begin{cases} M_0 + \sqrt{\frac{V_0 \times (I(x,y)-M_i)^2}{V_i}}, if\ I(x,y) > M_i \\ M_0 - \sqrt{\frac{V_0 \times (I(x,y)-M_i)^2}{V_i}}, otherwise \end{cases} \qquad (5)$$

3) Image Filtering: A 2-D Gabor filter can be viewed as a complex plane wave modulated by a 2-D Gaussian envelope. These filters can be used for extracting local frequency and orientation information. By tuning a Gabor filter to a specific frequency and direction, the local frequency and orientation information can be obtained. Thus, they are useful for extracting texture from fingerprint images. An even symmetric Gabor filter has following general form in the spatial domain [7].

$$G_{\theta,f}(x,y) = \exp\left\{\frac{-1}{2}\left[\frac{x'^2}{\delta_x{}^2} + \frac{y'^2}{\delta_y{}^2}\right]\right\}\cos(2\pi\ fx') \qquad (6)$$

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

where *f* is the frequency of the sinusoidal plane wave at an angle θ with the *x* axis, and δ_x, δ_y are the standard deviations of the Gaussian envelope along the *x* and *y* axes, respectively. The normalized region of interest in a fingerprint image is convolved with each of these eight filters to produce a set of eight filtered images. For extracting texture information at various orientations of the Gabor filter, the parameters $(f, \delta_x, \delta_y, \theta)$ are set to following values:

a) The frequency, *f*, corresponds to the inter-ridge distance in a fingerprint image. For the 500 dpi images, the average inter-ridge distance is approximately 10 pixels. Hence, f = 0.1 [7].

b) The bandwidth of the Gabor filter is determined by standard deviation values δ_x and δ_y. Based on empirical data, both these values are set as 4 [7].

c) Eight different orientations are examined. These correspond to θ values of 0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135° and 157.5° respectively.

D. Gabor Feature Vector

Let $F_{i\theta}(x,y)$ be the θ-direction filtered image for sector S_i. Now for $\forall$ i $\in$ {0, 2, 3,...., 79} and $\theta \in$ {0°,22.5°,45°, 67.5°, 90°, 112.5°, 135°, 157.5°}, the feature values are the average absolute deviations from the mean defined as [7],

$$F_{i\theta} = \frac{1}{n_i}\left(\sum_{n_i}\left|F_{i\theta}(x,y) - P_{i\theta}\right|\right) \qquad (7)$$

where n_i is the number of pixels in S_i and $P_{i\theta}$ is the mean of pixel values of $F_{i\theta}(x,y)$ in sector S_i. Thus, the average absolute deviation of each sector is calculated for all eight filtered images. The feature vector of the size (80 x 8) thus obtained, called as 'Gabor texture pattern' is used to find normalized Gabor matching. The proposed feature extraction algorithm is shown in Figure 4.

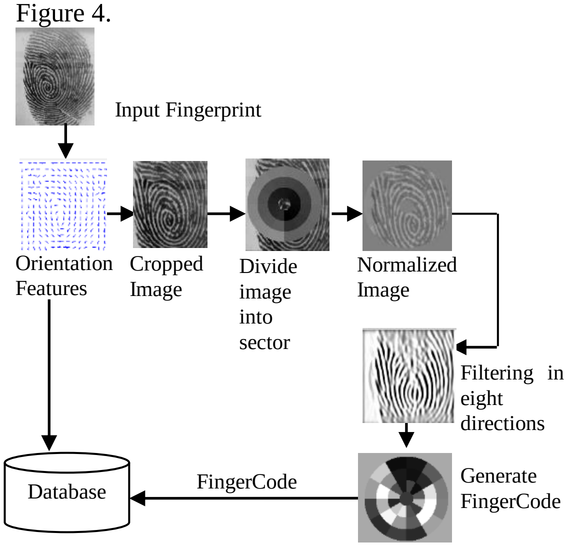

Figure 4. Proposed feature extraction algorithm

4.3 Matching

A. FingerCode Matching

Fingerprint matching is based on finding the Euclidean distance between the corresponding FingerCodes. The final matching distance score is taken as the minimum of the scores, i.e., matching of the input FingerCode with each of the fingerprint templates in the database. This minimum score corresponds to the best alignment of the two fingerprints being matched.

B. **Orientation Matching**

To compare two fingerprint orientation fields, the first step is alignment of these two fingerprints. It can be done by using the core point or reference point to align the fingerprints.

In the matching step, the correlation between two aligned orientation fields, A and B, is computed as below. Let **Ω** denotes the intersection of the two effective regions after alignment, and N is the total number of points in **Ω**. The matching score between two orientation fields is defined as

$$s(A,B) = \frac{1}{N}\sum_{(i,j)\in\Omega}\delta(i,j) \qquad (8)$$

In (13), $\delta(i,j)$ is the difference between the orientation values at the point,(i,j) in image A and B, which is formulated as follows:

$$\delta(i,j) = \begin{cases} \delta_0(i,j),\ldots if \delta_0(i,j) \le \frac{\pi}{2} \\ \pi - \delta_0(i,j),\ldots otherwise \end{cases} \qquad (9)$$

and $\delta_0(i,j)$ is defined as

$$\delta_0(i,j) = \left|\theta_A(i,j) - \theta_B(i,j)\right| \qquad (10)$$

where $\theta_A(i,j)$ and $\theta_B(i,j)$ are the direction of point, (i,j), in image A and B. If the matching score $s(A,B)$ is higher than a certain threshold, we say the two orientation fields are "matched".

Matching scores of FingerCode and orientation algorithms are fused using sum rule to give a final matching score. The minimum score corresponds to the best alignment of the two fingerprints being matched. If the input fingerprint is one of the fingerprints in database, the stored NRC fingerprint in the same index with matched fingerprint is retrieved and matched with the input NRC fingerprint by using the proposed system. The extraction of features from NRC card is shown in Figure 5. If the matching is success, the NRC card holder is authentic and registered person.

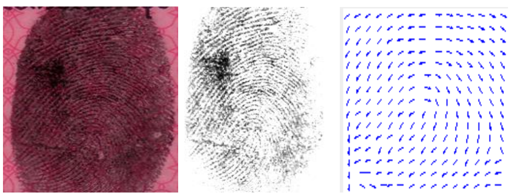

Figure 5. Fingerprints from NRC card (a) Original fingerprint (b) Extracted image from background(c) Orientation features

4.4 Score level fusion

The matching scores generated by comparing the Gabor feature sets and orientation features are combined in order to generate a single matching score. While a variety of strategies may be used to fuse these scores, here following sum rule is used [8]. Let Gabor Matching Score (GMS) and Orientation Matching Score (OMS) indicate the matching scores obtained using Gabor feature matching and orientation feature matching, respectively. Then, the final matching score (FMS), is computed as

$$FMS = \alpha \times GMS + (1-\alpha) \times OMS \qquad (11)$$

where, $\alpha \in [0,1]$. Here, α is set as 0.5.

5. Experimental Results

The proposed system is tested on our own database that consists of 150 (75×2) fingerprint images captured using an optical fingerprint scanner (Hamster Eye-D). Each fingerprint has two different impressions of the same finger. In enrollment stage, the features of the live scan fingerprint and fingerprint from NRC card of the same identity are stored in the database. For the identification stage, the input fingerprint is preprocessed. And, the fingercode and orientation features are extracted and matched with each of the fingerprints in the database. If the two fingerprints are matched, the NRC fingerprint of the matched fingerprint is extracted and matched with the input NRC fingerprint. If the two NRC fingerprint matched, the input fingerprint is recognized as a genuine attempt, else an imposter.

The performance of the proposed hybrid fingerprint matching system is compared with the filterbank-based fingerprint matching algorithm proposed in [7] that utilizes only texture information for representing the fingerprint.

To test the performance of the proposed system, we first implement the filterbank-based fingerprint matching system that uses only texture features. The database is then processed using the implemented system.

We then add the orientation features with the new algorithm to compute the oriented FingerCode. The same database is again processed. Each test fingerprint image is matched with all the other fingerprints in the database.

The only filterbank-based matching algorithm is not robust to identify when the quality of the fingerprint is low. More importantly, reference point is falsely detected when the reference points are too close to the edge of the image and it is not rotation-invariant. In addition, the orientation features of the fingerprint are utilized in this system that is rotation-invariant. The proposed approach outperforms the filterbank-based approach over a wide range of FAR values. For example, at a 1% FAR, the hybrid matcher gives a Genuine Accept Rate of 98%while the only filterbank-based matcher gives a Genuine Accept Rate of 95%. The genuine accept rates (GAR) of the two matchers at two values of false accept rate (FAR) are shown in Table 1. The Receiver Operating Characteristic (ROC) curves for Filterbank-based and the proposed system matchers are shown in Figure 6.

Table 1.GAR of the two matchers

Matcher	GAR at 1% FAR	GAR at 0.1% FAR
Filterbank-based	95 %	83%
Proposed approach	98 %	90%

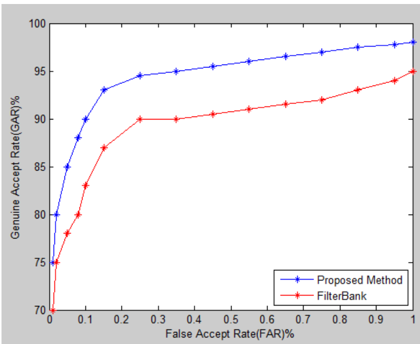

Figure 6. ROC curve

6. Conclusion

The hybrid fingerprint matching scheme that utilizes both orientation and texture information available in the fingerprint have presented. A bank of Gabor filters is used to extract features from the tessellated cells of the template and input images. Additional features such as the orientation of the fingerprints is detected and matched. According to the experimental results, additional orientation matching improved the accuracy of the fingerprint recognition system. The proposed matching algorithm is effective and efficient for low quality and rotated images.

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