Extracting and Enhancing the Core Area in Fingerprint Images

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Summary

An automatic fingerprint identification system (AIFS) plays a major role in forensic applications such as criminal identification, ATM card verification, etc. The fingerprint enhancement is essential in the issues of AIFS to ensure robust performance. This paper describes the design and implementation of fingerprint enhancement in two stages: extraction of high ridge curvature area (core) and enhancing the core block. This enhancement algorithm is concentrated on enhancing the block, around the core block for two reasons 1) Rich minutiae exist close around the core point. 2) Absence of delta point in certain fingerprint images. This feature of enhancing core block is essential for fast and robust performance of fingerprint verification / identification. The high ridge curvature area is extracted using the local ridge orientation and the enhancement is based on the estimated local ridge orientation and frequency. The system has been tested on a variety of fingerprint images even of very poor quality and the results showed remarkable performance. Experimental results showed that fingerprint enhancement algorithm is best suited for the verification with high accuracy. The complete fingerprint enhancement procedure takes on an average of about three seconds which is remarkably good.

Key words:
enhancement, fingerprint, Gabor filter, orientation field, singular point.

1. Introduction

Automatic fingerprint identification system, one of the most demanding biometric technology, depends upon high quality fingerprint images. Due to the variations in impression conditions, skin conditions, ridge configuration, etc certain acquired fingerprint images are of poor quality. Therefore enhancement of the fingerprint images is necessary to improve the clarity of the ridge structures.

In order to enhance the fingerprint, a set of discriminating features are extracted from the fingerprint images. The uniqueness can be well-defined by the local characteristics in ridge and valley. High ridge curvature is one of the ridge curvature is one of the ridge characteristics which occur where the local ridge orientation changes very rapidly (i.e. core or delta) the core is the endpoint of the innermost curving ridge while delta is the confluence point of there different flow direction. Most of the fingerprint enhancement algorithms consider the singular points along with the orientation field to enhance the fingerprints. The first step in such algorithms is estimating the orientation field. The orientation field is reliably estimated using the methods based on neural networks [12], gradient based approach [1], [2] and filter based approaches [3]. The filter based approaches are not as accurate as gradient based because of limited number of filters.

Secondly singularities are detected generally based on the poincare index of squared directional fields [4-6]. In this method, as the size of the closed curve is crucial it may lead to spurious detection of singularities or missed singularities. In [10] a ratio of two sines of direction field in two adjacent regions is used to detect singularities.

Finally for fingerprint enhancement, several attempts have been made. In [6] the fingerprint enhancement is based on the singularities. In [3], the directional filter are used for fingerprint enhancement. In [7], the enhancement is done in scale space.

In this paper, a fast fingerprint enhancement algorithm is developed, which efficiently improves the clarity of ridges based on the estimated ridge orientation and frequency. It is possible that there could be images with no delta point [8] or delta point outside the print [9]. Therefore this paper is concentrated on extracting only the core block, as most of the ridge characteristics like ridge endings, bifurcations are present in the core block (center).

This paper is organized as follows. In section 2, the high ridge curvature is extracted using the proposed algorithm. The algorithm for enhancing the high ridge curvature area using the estimated ridge frequency and by applying the filter is mentioned in the section 3. Experimental results performed on a variety of fingerprint images are described

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in section 4. Finally the conclusion is summarized in section 5.

1. Extraction of high ridge curvature area

In this system, the method proposed in [10],[14] is used to estimate the high ridge curvature area. The algorithm is used as follows.

1) Determine the x and y magnitudes of the gradients (Gx and Gy) at each pixel.

2) Apply the 2D Gaussian Low Pass Weiner filter, to reduce noise from the fingerprint image, on the x and y gradients.

3) Divide the input image in to blocks of size w × w

4) With each block, compute the slope orthogonal to the local orientation of each block using the equation

$$\theta(i,j)=\frac{1}{2}\tan^{-1}\left(\frac{\sum_{u=i}^{i+w-1}\sum_{v=j}^{j+w-1}2\partial_x(u,v)\partial_y(u,v)}{\sum_{u=i}^{i+w-1}\sum_{v=j}^{j+w-1}(2\partial_x^2(u,v)\partial_y^2(u,v))}\right)+\frac{\Pi}{2} \quad (1)$$

where ∂_y ∂_x (u,v), ∂_y (u,v) represents gradient magnitudes at each pixel in x and y directions respectively. $\theta(i,j)$ is the direction of the block centered at pixel (i,j).

5) The blocks with slope values ranging from 0 to ∏/2 are located. Then trace a path down until you encounter a slope that is not ranging from 0 to pi/2 and mark that block.

6) The block that has the highest number of marks will compute the slope in the negative y direction and output on x and y position which will the core point.

7) A new core block is formed around the core point which is further enhanced in the next section.

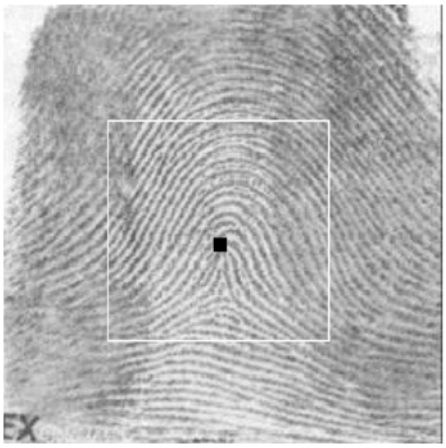

Fig 1. high ridge curvature area

2. Enhancing high ridge curvature area

Core point is the inner point normally in the middle of the fingerprint. Where as delta point is normally at the lower left and right hand of the fingerprint. Therefore the chance for the absence of delta point is possible.

In close around the core point there exists rich minutiae information than others, which is necessary for the fingerprint verification/identification[12]. Hence we have focused on enhancing the core block of the fingerprint image.The enhancement consist of

a) Determining ridge frequency across the core block

b) Apply filter to enhance the pattern of ridges.

2.1 Ridge frequency estimation

The grey levels along ridges and valleys can be modeled as sinusoidal shaped wave along the direction normal to the local ridge orientation. Utilizing this wave, the ridge frequency can be estimated. According to [1], valid ridge frequencies lie within [1/31, 1/25] for 500dpi images.

1) Divide the normalized image G into blocks of size w × w.

2) For each block, centered at pixel (i , j) oriented window (l × w) is computed.

3) the X-Signature X[0],X[1],…X[l-1] for each block (i, j) is calculated using

$$X[k] = \frac{1}{w}\sum G(u,v) \qquad k = 0,1,....l-1 \qquad (2)$$

where

$$u = i + \left(d - \frac{w}{2}\right)\cos O(i,j) + \left(k - \frac{l}{2}\right)\sin O(i,j)$$

$$v = j + \left(d - \frac{w}{2}\right)\sin O(i,j) + \left(\frac{l}{2} - k\right)\cos O(i,j)$$

4) The ridge frequency is then computed as

$$f(i,j) = \begin{cases} \dfrac{1}{T(i,j)}, & \text{if well defined sinusoidal wave is obtained} \\ 0 \quad , & \text{if no consecutive peaks are detected or if the frequency is out of threshold} \end{cases} \qquad (3)$$

Where T(i , j) is the average number of pixel between two consecutive peaks.

B. Filtering

Fingerprints have local parallel ridges and valleys with well defined frequency and orientation. Gabor filters is a very useful tool for analysis in spatial or frequency domain [13]. Gabor filters have both frequency selective and orientation selective properties [1]. Gabor filters can remove noise and preserve the true ridge and valley structures thus showing good performance.

The general form of the filter is

$$h(x,y:\phi,f) = \exp\left\{-\frac{1}{2}\left[\frac{x_\phi^2}{\partial_x^2} + \frac{y_\phi^2}{\partial_y^2}\right]\right\}\cos(2\pi f x_\phi) \qquad (4)$$

where

$$x_\phi = x\cos\phi + y\sin\phi,$$

$$y_\phi = -x\sin\phi + y\cos\phi,$$

where ϕ is the orientation of Gabor filter ,f is the frequency of sinusoidal plane wave, and ∂_x and ∂_y are the space constants of the Gaussian envelope along x and y axes respectively.

The filter is then applied to the normalized image to obtain the enhanced image.

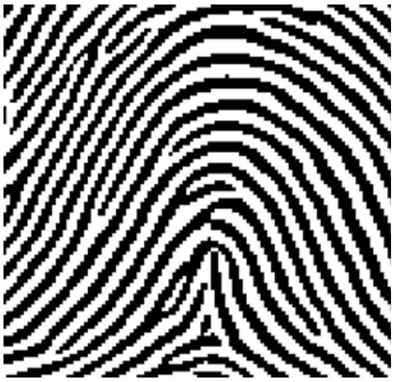

Fig 2. enhanced image of the high ridge curvature area

$$E(i,j) = \begin{cases} 255 & if R(i,j) = 0 \\ \displaystyle\sum_{u=-w_g/2}^{w_g/2}\sum_{v=-w_g/2}^{w_g/2} h(u,v:O(i,j),F(i,j)G(i-u,j-v), & otherwise \end{cases} \qquad (5)$$

where G is the normalized fingerprint image, O is the orientation image, F is the frequency image.

3. Experimental results

I validated the methodology presented here on a database of 200 fingerprint images. I compared the performance of the extraction of high ridge curvature area algorithm presented in section II with that of poincare index. The method presented here showed a remarkable performance than the poincare's as shown in fig 3a,3b. In poincare index method, the smoothening parameter have to be modified for fingerprint images in order to reduce the false detections. Fig 3 (c,d,e,f) shows the performance of our algorithm in good and poor quality images. This enhancement algorithm showed good performance even on poor quality images.

4. Conclusion

The resulting algorithm is shown to extract the high ridge curvature area efficiently and enhance a variety of fingerprints even of poor quality. The probabilities of false detections are considerably reduced. This method of enhancing fingerprints could be incorporated further efficiently in the fingerprint verification, identification and classification to ensure robust performance.

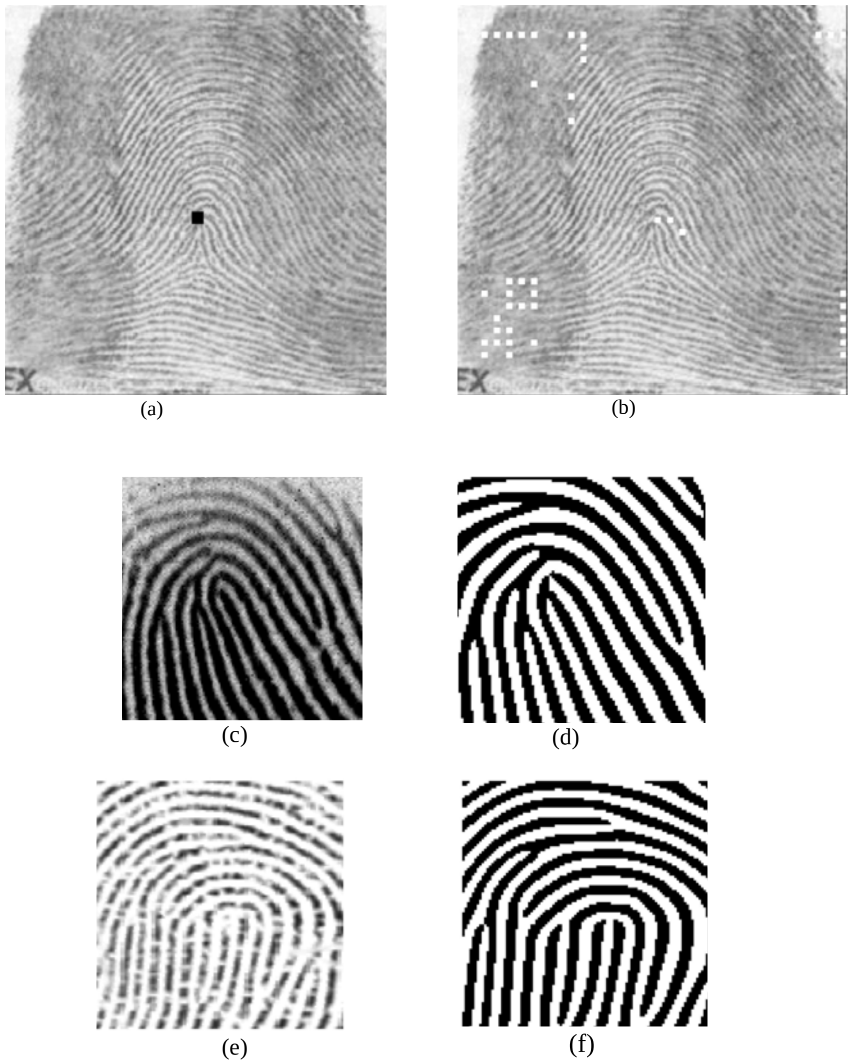

Fig 3 (a) core point extraction using the proposed method, (b) core point extraction using poincare index method, (c) good quality image, (e) low quality image, (d) (f) enhanced (c)(e) images respectively

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