SIFT based Fingerprint Corepoint Localization

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Abstract:. The detection of singular points (core and delta), accurately and reliably, is very important for classification and matching of fingerprints.This paper presents a new approach for core point detection based on Scale Invariant Feature Transform (SIFT) operation. Firstly, SIFT points are extracted, then reliability and ridge frequency criteria are applied to reduce the candidate point required to make a decision on the core point. Finally a suitable mask is applied to detect an accurate core point. Experiments on FVC2002 and FVC2004 database show that our approach locates a unique reference point with high accuracy.Results have been compared with existing methods in terms of accuracy of core point detection. To make the algorithm reliable, a simple point based matching has been implemented.

Keywords: Biometrics; Fingerprint; Corepoint; SIFT.

1. Introduction

Biometric recognition refers to the use of distinctive physiological and behavioral characteristics, called biometric identifiers for the authentication of individuals [Ma03]. Fingerprint recognition has been widely used in both forensic and civilian applications. Compared with other biometrics features, fingerprint-based biometrics is the most proven technique. Fingerprints are the oldest and most widely used biometric trait because of their universality and distinctiveness. With the increase in the number of commercial systems based on fingerprints, new features and algorithms are being developed.

A pattern of valleys and ridges constitute the fingerprint image. Analyzing this pattern at different levels reveals different types of global and local features. The important singularities are core and delta which are global features. 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 core and delta points are land mark points whose locations are consistent across different impressions of the same user. Therefore, their positions can be used as reference to align the prints. The singular points provide important information used for the fingerprint alignment, matching and classification. Consistent extraction of these features is crucial for fingerprint recognition. The region around a core point is one that contains maximum unique information in a fingerprint, thus adding to its importance.

The outline of the paper is as follows: Section 2 gives a review of previous work done on core point detection in fingerprints. The proposed core point detection based on SIFT features is discussed in Section 3. Experimental results and analysis are described in Section 4. Section 5 gives conclusions and future scope.

2. Literature Review

Many approaches have been investigated for accurately determining the location of singular points. A practical method based on Poincare index is proposed by Kawagoe and Tojo [KT84]. This depends upon the observation that singularities are termed as loop, whorl and delta corresponding to the core point index value of 180°, 360° and -180° respectively. Another Poincare method for locating singular point is proposed by Bazen and Gerez [BG02]. But in noisy and low quality images, Poincare method detects false singularities. Karu and Jain [JK96] iteratively smooth the ridge orientation through averaging until a valid number of singularities is detected by Poincare index.

A majority of the existing techniques try to locate the core point by making use of the ridge orientation of a fingerprint. Srinivasan and Murthy [MS92] have used local histogram of the orientation image to extract the singularities, their method is able to discriminate between the loop and delta singularities. Koo and Kot [KK01] employ a multi resolution approach to determine the singularities with single pixel accuracy. Nilson and Bigun [BN03] approach is based on complex filtering. Singular points are extracted from the complex ridge orientation field estimated from the global structure of a fingerprint. Complex filters, applied to the orientation field in multiple resolution scales, are used to detect the symmetry and the type of symmetry. The direction of curvature is used for the coarse core point detection and GR(geometry of region) technique is used for the fine detection using candidate analysis with an extended relational graph in Ohtusuka et al. [Oh08]· Both the local and global features of the ridge orientation field are extracted to achieve reliable extraction of core and delta. Zhou et al. [CGZ09] have proposed the Difference of Orientation values along a Circle (DORIC) feature to remove the spurious singular point after the initial detection using the Poincare index. An optimal combination of singular points is used to minimize the difference between the original orientation field and the model based orientation field reconstructed using the singular points. Khalil et al. [Kh10] have developed an algorithm for the singular point detection based on the fingerprint orientation field . A two stage algorithm for core point detection in fingerprint images is presented by Tejas et al. [DJS09] in which the first stage determines the presence of a core point based on ridge component identification followed by the unwanted component elimination and core segment detection. A method to detect the exact(single) point from the approximate core and delta region using the fuzzy reasoning is proposed by Kundu et al. [KKM11].

3. Proposed Method

3.1. Preprocessing

The fingerprint image can be electronically scanned with ranges of resolution. However, the generally accepted one is that of 500 dpi. The quality of the acquired images may vary in the location and the clarity of the image itself. The uncertainty due to the first factor can be remedied by fixing the finger position while scanning the fingers. In the second case, the image quality is highly dependent on the finger condition. The enhancement process, therefore, tries to level-up the image condition to the state where it can be processed with high degree of success. The discontinuous ridge and abrupt ends in ridges, the noise due scars is corrected using adaptive interpolation and extrapolation [1] from Peter Kovesi's Matlab functions[4]. They mention several attributes to each set of points like frequency in neighborhood, reliability for interpolation etc.[4] Enhancement also includes Short Time Fourier Analysis [2] is performed as in [CG05]. The enhancement process removes ridge discontinuities that would otherwise interfere in the accurate location of the singular points and recreates the distorted ridges.

3.2. Scale Invariant Feature Transform

Scale Invariant Feature Transform (SIFT) was originally developed for the general purpose object recognition. SIFT detects stable feature points in an image and performs matching based on the descriptor representing each feature point. The features are selected to be invariant to scale and rotation, and they provide robust matching across a substantial range of affine distortion, addition of noise and partial change in the lighting [Lo99]. The steps in the generation of SIFT features are discussed by D.G. Lowe in [Lo99].

3.3. SIFT point extraction

Scale space is constructed with three samples per scale as per [Lo99]. The size of the Gaussian filter is taken as 3(sig for finding the Difference-of-Gaussian images. Threshold for the Difference of the Gaussian is to 0.005 to minimize the detections on the background of the fingerprint. We get an absolute value of two Difference-of-Gaussian images. For finding the local maxima and minima each sample point is compared with its eight neighbors in the current image and nine neighbors in the scale above and below the blurred Gaussian images. This step extracts SIFT feature points as shown in Fig.2(b) .

3.4. Keypoint localization

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[1] Refer to testfin.m in the library of functions. The parameters used for freq1 (frequency of ridges) and reliability(reliability of interpolation) and orientim(Orientation image).
[2] STFT is directly applied to the raw image before any kind of processing. http://www.cubs.buffalo.edu

In the image shown in Fig.2(a), some new ridges having the shape of the closed loop similar to a core point are formed. Based on the reliability and frequency of ridges, a threshold is used to remove noisy and spurious keypoints. The keypoints which have reliability [3] greater than 0.4 and ridge frequency greater than 0.5 are selected.

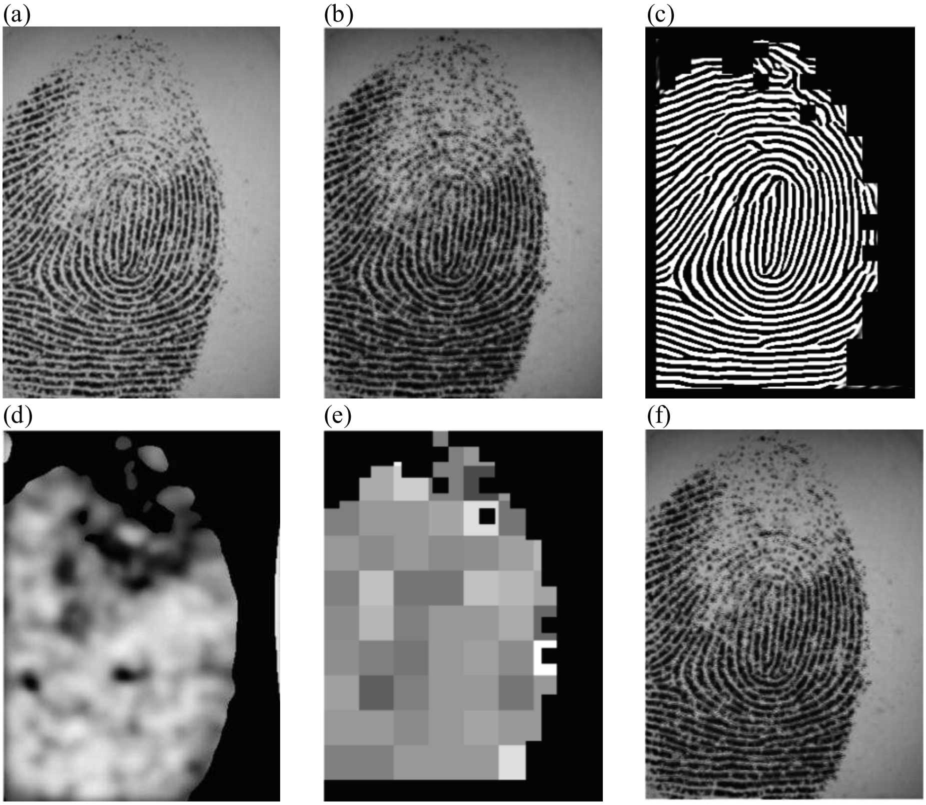

Fig. 2.(a) Original Image (b) SIFT points extracted (c) Ridge enhanced image (d) Reliability Image (e) Ridge Frequency Image (f) Reduced SIFT points

In Fig.2(d) it can be seen that reliability in the upper region is low (blackish region), while at the centre it is quite high. Fig.2(e) shows that the background frequency is zero, therefore threshold for frequency is set to 0.5. After this step the number of keypoints is reduced as shown in Fig 2(f). We can clearly see that the ridges extrapolated over a white background have a much lower reliability as compared to minute discontinuities that exist in the center.

3.5. Orientation assignment

The least square estimation method is used here to compute the orientation image as in [Ja00]. The steps for calculating the orientation at pixel (i,j) are as follows:

1. Divide the input fingerprint image into non-overlapping blocks of size W x W.

2. For each pixel in the block, compute $\partial x(i,j)$ and $\partial y(i,j)$ which are gradient magnitudes in the x and y direction respectively.

3. Estimate the local orientation at pixel(i,j) using

$$V_x(i,j) = \sum_{u=i-W/2}^{i+W/2} \sum_{v=j-W/2}^{j+W/2} 2\partial x(u,v)\, \partial y(u,v) \tag{5}$$

$$V_y(i,j) = \sum_{u=i-W/2}^{i+W/2} \sum_{v=j-W/2}^{j+W/2} \partial_x^2(u,v)\partial_y^2(u,v) \tag{6}$$

$$\theta(i,j) = \frac{1}{2}\tan^{-1}\frac{V_y(i,j)}{V_x(i,j)} \tag{7}$$

Where $\theta(i,j)$ is the least square estimate of local orientation at the block centered at pixel(i,j).

4. Smooth the orientation field in a local neighborhood using a Gaussian filter. The orientation image is firstly converted into a continuous vector,defined as:

$$\phi_x(i,j) = \cos(2\theta(i,j)) \tag{8}$$

$$\phi_y(i,j) = \sin(2\theta(i,j)) \tag{9}$$

Where ϕ_x and ϕ_y are the x and y components of the vector field respectively.

5. Perform the Gaussian smoothing as follows:

$$\phi_x'(i,j) = \sum_{u=-\frac{w_\phi}{2}}^{\frac{w_\phi}{2}} \sum_{v=-\frac{w_\phi}{2}}^{\frac{w_\phi}{2}} G(u,v)\,\phi_x(i-uw, j-vw) \tag{10}$$

$$\phi_y'(i,j) = \sum_{u=-\frac{w_\phi}{2}}^{\frac{w_\phi}{2}} \sum_{v=-\frac{w_\phi}{2}}^{\frac{w_\phi}{2}} G(u,v)\phi_y(i-uw, j-vw) \tag{11}$$

Where G is a Gaussian low pass filter of size w_ϕ x w_ϕ.

6. The final smoothed orientation image field O at pixel (i,j) is defined as:

$$O(i,j) = \frac{1}{2}\tan^{-1}\frac{\phi_y'(i,j)}{\phi_x'(i,j)} \tag{12}$$

3.6. Core Point Localization

The sine component of the orientation image $O(i,j)$ is

$$\varepsilon(i,j) = sin(O(i,j)) \tag{13}$$

The sine component of the orientation field is multiplied by a semicircular region consisting of segments RI and RII as shown in Fig.3(a), at every SIFT point calculated above with (i,j) denoting the SIFT point. Region I consists of 1 and Region II consists of -1 [Ja00]. Matrix of dimension to the effect is built by declaring the remaining points zero. Empirically using random test images, a matrix of size 15x15 was found most suitable for locating the core point. All of the elements obtained after the filter operation are summed. The maximum value obtained after all these operations is taken as the reference point. Fig. 3(b) shows reference point located in the fingerprint image.

Equation for Region RI: $\{x^2 + y^2 - r^2 < 0,\ y >= 0,\ x^2 - y^2 > 0\}$

Equation for Region RII: $\{x^2 + y^2 - r^2 < 0,\ y >= 0,\ x^2 - y^2 < 0\}$

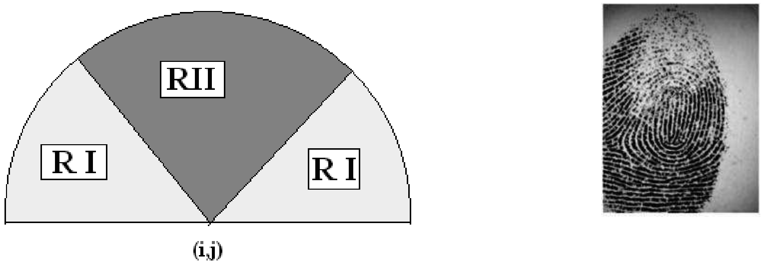

Fig.3 (a) Semicircular Filter (b) Core point located in Fingerprint image

3.7. Cropping

After locating the reference point, the region of interest (ROI) around the reference point is cropped. The reason for cropping is that test fingerprints will always be good, hence only one iteration of the fingerprint algorithm will suffice, but in a comparison based solution, a cropped image will be eliminate the backgrouund noise , leading to detection of corepoints within 10 pixel distance. If we use a fixed window size to extract ROI, then the fingerprint images having core points at the edges will include the background region which does not carry any useful information, as shown in Fig 4.

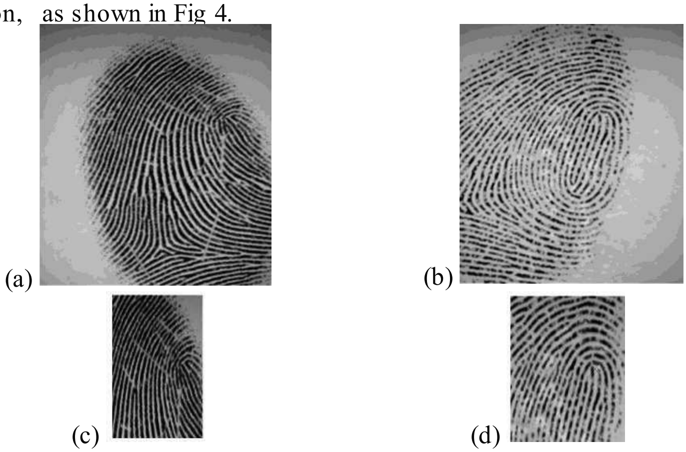

Fig. 4. (a and b) Original image (c and d) Cropped image

To overcome this problem the window size for cropping is varied according to the extent of the background .This is done using the SIFT points extracted earlier. To set the boundary of the window we find the maximum and minium of the x and y co-ordinates of the SIFT points. Different conditions are set to deal with all possible cases so that the core point is included in the region of interest and the background area is minimized. Cropped images are shown in Fig.4(c and d).

4. Experimental Results and Analysis

The benchmark databases, FVC2002 and FVC2004, are used for the state-of-the-art algorithm in fingerprint recognition, where the finger impressions are acquired using capacitive and optical sensors. Both the databases contain images of 100 different persons with 8 impressions per finger. The images in FVC2002DB1A are captured with an optical sensor at 500dpi and each image is 388x374 pixels wide. The images in FVC2004 DB1A, DB2A captured with optical sensor at 500 dpi are 640x480 and 328x364 pixels wide respectively. The images in FVC2004 DB3A are captured using thermal sweeping sensor at 512 dpi and are 300x480 pixels wide. The images in FVC2004DB4A, obtained by synthetic generator, are 288x384 pixels wide at about 500dpi.

The typical image in FVC2002 for which core point has been accurately detected are shown in Fig.5(a and b) and the failure cases where the core point has not been detected are shown in Fig.5(c and d) The algorithm is tested on 773 images from FVC2002DB1A, discarding 27 images as in these images shown in Fig. 5(e and f),the core point does not exist or the quality of the fingerprint is poor or the singularity is missing as in the case of plain arch.Fig.5(g and h) show the core point detected in the tented arch images. The proposed method is able to find the core points and checked for their validity with an accuracy of 99.47% as in Table 1.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

Fig.5. FVC2002 (a and b) Correct Corepoint Detection (c and d) Failure Cases (e and f) Rejected images (g and h) Tented Arch Images

The images of FVC2004 DB4A shown in Fig.6 (a, b) have their core points correctly located and the failure cases are shown in Fig.6 (c, d). The total number of images tested is 742 out of 800 so, 58 images were rejected as shown in Fig.6 (e, f).The algorithm is able to detect core point with an accuracy of 99.46%. The core points detected in the tented arch images are shown in Fig.6 (g) but the plain arch type images have no core points as observed by Maio etal. (2003) as shown in Fig.6 (h).

(a)

(b)

(c)

(d)

(e) 

(f) 

(g) (h)

Fig.6. FVC2004 (a and b) Correct Corepoint Detection (c and d) Failure Cases (e and f) Rejected images (g and h) Tented Arch and Plain Arch

The results of the core point detection algorithm are shown in Table 1, with and without the arch images of database FVC2002 DB1A and FVC2004. Optimal core point detection method in [CJ07] gives an accuracy of 93% on FVC2002.

The success rate of detection of core point on FVC2002 DB1A is 87% by Poincare index method, 78.6% by the extended relational graph method and 91.7% by the singular candidate method [Oh08].The proposed method yields an accuracy of 99.47% on FVC2002DB1A which is higher than that of the existing methods.

FVC2004 database is a very difficult benchmark with many intra-class variations accompanied by large scale distortion, which is a well known problem among fingerprints as discussed in [LN07].The accuracy obtained on the corepoint detection in both FVC2002 DB1A and FVC2004 databases is tabulated in Table 1.

Table1.Core point detection accuracy

FVC2002 DB1A	**Whole Database**	**With arch**	**Without arch**
Total images	800	800	800
Discarded	-	20	20+16arch=36
Images considered	-	780	764
Failure Cases	-	12	4
Successful Core detection	768	768	760
Accuracy	**768/800=96%**	**768/780=98.46%**	**760/764=99.47%**
FVC2004 DB1A	**Whole Database**	**With arch**	**Without arch**
Total images	800	800	800
Discarded	-	13	13+40arch=53
Images considered	-	787	747

Failure Cases	-	25	10
Successful Core Detection	762	762	737
Accuracy	**762/800=95.25%**	**762/787=96.9%**	**737/747=98.6%**
FVC2004 DB2A	**Whole Database**	**With arch**	**Without arch**
Total images	800	800	800
Discarded	-	18	18+40arch=58
Images considered	-	782	742
Failure Cases	-	51	13
Successful Core Detection	731	731	729
Accuracy	**731/800=91.375%**	**731/782=93.48%**	**729/742=98.25%**
FVC2004 DB3A	**Whole Database**	**With arch**	**Without arch**
Total images	800	800	800
Discarded	-	29	29+42arch=71
Images considered	-	771	729
Failure Cases	-	55	40
Successful Core Detection	716	716	689
Accuracy	**716/800=89.5%**	**716/771=92.9%**	**689/729=94.5%**
FVC2004 DB4A	**Whole Database**	**With arch**	**Without arch**
Total images	800	800	800
Discarded	-	16	16+42arch=58
Images considered	-	784	742
Failure Cases	-	46	4
Successful Core Detection	738	738	738
Accuracy	**738/800=92.25%**	**738/784=94.1%**	**738/742=99.46%**

5. Conclusion and Future Scope

This paper develops an efficient algorithm to consistently locate a core point on the fingerprints in the wake of several problems. The proposed method uses SIFT points detected on the fingerprint image as the possible candidates for the determination of core point. SIFT method eliminates the noisy and spurious points, thus minimizing the possibility of false core point detection. It has been observed that even in the extreme case of core points located at the edges of the fingerprints the proposed method is able to detect the core point. Presently, work is around for extracting other types of features for efficient authentication because the conventional minutiae pose a lot of problems.

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