An Efficient Approach to Recognize Fingerprints

Muhammad Sheikh Sadi, Md. Nazim Uddin, Abdul Ahad and Ariful Haque
Department of Computer Science & Engineering
Khulna University of Engineering & Technology, Khulna-9203, Bangladesh
Email: sheikhsadi@gmail.com, nazim.cse.kuet@gmail.com

Abstract—Fingerprint analysis is typically based on the position and pattern of detected singular points in the fingerprint images. These singular points (cores and deltas) represent the characteristics of local ridge patterns, determine the topological structure (i.e., fingerprint type) and largely influence the orientation field. A core-delta relation is used as a global constraint for the final selection of singular points. This paper proposed an approach for singular points detection and then recognizes fingerprints based on singular points position and their relative distances. Experimental results show that the approach is efficient and robust, giving better results than existing dominant approaches.

Index Terms—Fingerprint recognition, Singular points, Poincare index, Core, Delta.

I. INTRODUCTION

The need for person identification is increasing more and more in the business world for transactions and industrial security. Generally, password system was one of the most used methods for this kind of security in past years. Besides, many other code systems were also used. But, these systems are easily breakable and also changeable. So, the importance of permanent and unbreakable personal identification arises significantly. Fingerprints are formed before birth, during the development of the hands. Fingerprints aren’t actually formed in the skin, but are caused by ridges in the flesh underneath the skin. Their development is partially random, and can be affected by health issues, sometimes distorting them or eliminating them altogether. Genetics plays some part in their formation, but even identical twins (who have identical DNA) have different fingerprints. As a result, fingerprint recognition approaches become very reliable and robust for personal authentication.

There are mainly two kinds of features used in fingerprint matching: local features and global features. Two most known local characteristics, called minutiae, are ridge ending and ridge bifurcation, while global features are singular points, namely core and delta. Generally, singular points are used to classify fingerprint images to reduce the search space for recognizing. But it is also possible to recognize fingerprints using singular points. The accurate detection of the singular points (cores and deltas) is an important and difficult task in fingerprint classification and recognition. The number of cores and deltas and the relative position between these points can be used for fingerprint classification and recognition.

In this paper, a fingerprint recognition approach, based on singular points detection is proposed. And then the recognition of fingerprint is performed. This method of recognition can be performed with the rotation of image, because the variance and standard deviation for singular points positions to recognize fingerprints has been used. The calculation of standard deviation reduces the error. The singular points extraction is performed using three sequential steps- image filtering, directional image extraction, Poincare indexes computation and singular point extraction. And then the recognition is performed for those fingerprints.

II. RELATED WORKS

In recent years, many approaches have been proposed for developing fingerprint recognition systems. Generally, those are characterized by three main steps: image acquisition, biometric signature extraction, matching between the acquired biological signature and the stored related one.

Singular candidate method uses both the local and global features of the ridge distribution with the aim of achieving high reliability in singularity detection [1], [2]. It sometimes gives false candidate region. So, it is necessary to run another process to detect and eliminate this false candidate region. In this method, noisy images can also be extracted finding singular points. Here, angles are taken using average of ridge lines. Thus, it is difficult to find out the exact location of the singular points. In Intersection based method, the singular point is viewed as the intersection of certain lines. Ramo et al. proposed a method in which singular points are taken as the intersections of transition lines [3]. Transition lines are defined as the lines on which the orientation vectors change their signs. The singular point viewed as the intersection of certain transition lines. Thus, these intersect points may not give accurate result always. This method also needs high quality images. Noisy images may cause wrong intersect points, thus wrong singular points. Poincare Index method is easy to understand and implement [4], [5]. However it may lead to false detection in noisy images. Additional preprocessing (smoothing the orientation) or post-processing (combining other information such as quality check and segmentation) is required to reduce the false detection.
Fingerprint recognition systems can be divided into two main classes. The first class of systems use micro-features (minutiae) points for matching fingerprints [6], [7], while the second class of systems use macro-features for classification tasks, like directional images. Fingerprint minutiae extraction is very critical, complex and time consuming. Consequently, different dedicated software algorithms had already been proposed [8]. These algorithms show high computational costs, high execution time, and sophisticated image enhancement phases.

III. EXTRACTING SINGULAR POINTS AND RECOGNIZING FINGERPRINTS

The paper proposes reliable singular point extraction for both low and high quality images and then recognizing fingerprints in lesser time based on singular points orientation and their relative distances. The methodology is composed of two main phases: (i) Singular point Extraction, and (ii) Fingerprint Recognition.

With more details, the first phase (i.e. Singular point Extraction) is composed of three sequential steps:

- Directional image extraction
- Poincare indexes calculation
- Singular points detection
- Removing spurious singular points

The second phase (i.e. Fingerprint Recognition) deals with:

- Types and numbers of singular points
- Relative distance, variance and standard deviation calculation for multiple singular points
- Calculating distance between singular point and average midpoint of the fingerprint image, and analyze the surrounding area of the singular point in case of single singular point.

These steps are outlined shortly as follows.

A. Singular point Extraction

Singular points extraction is performed based on the Poincare indexes associated to the fingerprint directions matrix. At first the directional image is generated from fingerprint image. Then the singular points are extracted using Poincare-index [5] and removed the spurious singular points. The flow diagram of singular point extraction is shown in Fig. 1.

The directional image extraction phase is composed by four sequential tasks showed in Fig. 2.

In the directional image, every element represents the local ridges orientation of the original grey-scale image of fingerprints. In this paper 10x10 pixel blocks are considered for calculating gradients. Each \( \theta(i,j) \) element of direction image represents the angle between the fingerprint ridge and a horizontal line.

\[
\theta(i,j) = (\tan^{-1}(D_x(i,j)/D_y(i,j))) / 2 + 90^\circ \quad \text{(1)}
\]

Where, \( D_x(i,j) = G_x^2 - G_y^2 \) and \( D_y(i,j) = 2G_xG_y \)

Let, \( (x, y) \) denote the direction of the pixel \( (i, j) \) in an \( M \times N \) fingerprint image. The Poincare Index at pixel \( (i, j) \) which is enclosed by a digital curve (with \( N \) points) can be computed as follows:

\[
Poincare(i,j) = \frac{1}{2\pi} \sum_{k=0}^{N-1} \Delta(k) \quad \text{(2)}
\]

Where, \( \Delta(k) = \left\{ \begin{array}{ll} \delta(k) & \text{if } |\delta(k)| < \frac{\pi}{2} \\ \delta(k) + \pi & \text{if } |\delta(k)| \geq \frac{\pi}{2} \\ \pi - \delta(k) & \text{otherwise} \end{array} \right. \)

\[
\delta(k) = \theta(x_{(k+1)modN}, y_{(k+1)modN}) - \theta(x_k, y_k)
\]

And it goes in a counter-clockwise direction from 0 to \( N-1 \). In our experiment, we always choose radius 3 and 5 to confirm there’s no other singularities in the close curve.
Fig. 3 is the sketch map of close curve. And the Poincare index of close curve d0d1d2d3d4d5d6d7d0 radius 3 is:

\[
Poincare_1(i, j) = \frac{1}{2\pi} \sum_{k=0}^{7} |d_k - d_{(k-1)\mod 8}|
\]

Similarly, the Poincare index of close curve D0D1D2D3D4D5...D15D0 radius 5 is:

\[
Poincare_2(i, j) = \frac{1}{2\pi} \sum_{k=0}^{15} |D_k - D_{(k+1)\mod 16}|
\]

The Poincare index at pixel (i, j) is calculated, which can present not only the rotation angles, but also the rotation direction of the vector in the vector field exactly [10].

If Poincare (i, j) = 0.5, the point is a core point;
If Poincare (i, j) = -0.5, the point is a delta point;
Otherwise, the point is not a singular point.

Only when, the Poincare_1 = 0.5 or -0.5, then Poincare_2 will be calculated. Otherwise, there is no need to calculate Poincare_2. After calculating Poincare_2, if Poincare_1 = Poincare_2, then singular point detected is effective, else, the point candidate will be deleted.

<table>
<thead>
<tr>
<th>D0</th>
<th>D15</th>
<th>D14</th>
<th>D13</th>
<th>D12</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>d0</td>
<td>d7</td>
<td>d6</td>
<td>D11</td>
</tr>
<tr>
<td>D2</td>
<td>d1</td>
<td>(i,j)</td>
<td>d5</td>
<td>D10</td>
</tr>
<tr>
<td>D3</td>
<td>d2</td>
<td>d3</td>
<td>d4</td>
<td>D9</td>
</tr>
<tr>
<td>D4</td>
<td>D5</td>
<td>D6</td>
<td>D7</td>
<td>D8</td>
</tr>
</tbody>
</table>

Fig. 3. Sketch map of close curve

The blocks which may contain singularities are detected. Then the Poincare Index at pixel (i,j) which is enclosed by a digital curve of 8 or 16 pixels can be compute in the detected blocks as shown in Fig. 3. The direction yards from d0 to d7, is calculated first as Poincare_1. Then Poincare_2 is calculated in the direction yards from D0 to D15.

Many previous researchers have shown that Poincare Index-based methods can usually detect nearly all true singular points when the Index is computed along small region boundaries, but this also leads to much spurious detection. If a larger region is chosen, true singular points will be easy to miss. In order to remove spurious detections while preserving a good detection rate, the paper proposes a feature extended from the Poincare Index, which can provide more discriminating features and can be used to verify the trueness of detection after using Poincare Index calculation.

The Poincare Index is defined as the sum of the orientation differences along a closed circle (in this paper, its radius is chosen as both 3 and 5). The Poincare Index is only the sum of difference of angles in the closed curve counter-clockwise. It contains no information about the structure of difference of angles, i=1, 2, 3, ..., N - 1, and it cannot describe the singular point completely. So, when there are creases, scars, smudges or damped prints in the fingerprint images, the Poincare Index method will easily result in many spurious singular points. Post-processing steps are therefore usually necessary.

This paper uses a simple heuristic rule during post-processing: in a very small region (a circular region with a radius of 10 pixels), if there is more than one core (or delta), an average core (or delta) can be computed. Otherwise, single core (or delta) points will be eliminated, because those points are false singular points as shown in Fig. 4.

B. Fingerprint Recognition

After extracting singular points the fingerprint recognition phase is proposed. In Fig. 5 the logical steps of the recognition algorithm steps are depicted. The algorithm receives as input the spatial coordinates of core and delta points and returns the similarity index between the database image and the processed fingerprint image. Initially, some constraints must be satisfied to realize a successful correct recognition. At first, the number of singular points is compared. If number of singular points is same, then the types of singular points are compared. If these conditions satisfied then next comparison will be performed. The logical schema of fingerprint recognition is shown in Fig. 5.

If the two fingerprint images have at least two singularity points then a particular topologic comparison between the singularity regions with minimum distance (d1, d2) for each image, will be performed. The comparisons are the following: the first is to compare the types of singularity points contained in the considered regions; the second consists in the distance (d3, d4) between every pairs of points as shown in Fig. 6.
But this comparison doesn’t always give accurate result. Because the fingerprint image may be rotated, in such case we need to consider other constraints. Hence, the variance and standard deviation are calculated to measure the relative distances among the singular points.

In case of single singular point, at first the average mid-point of the fingerprint is calculated, then its distance from the singular point is calculated.

### IV. EXPERIMENTAL RESULTS

The proposed approach is applied in many fingerprint images. 75 images were selected randomly from NIST-4, proposed approach successfully extracted 86 core points out of 90 and 5 false core points are detected, the accuracy rate reaches 95.56%. For the delta point, it detects 40 true and 4 false delta points out of 42; the accuracy rate is 95.24%. The result is summarized in **TABLE I**.

<table>
<thead>
<tr>
<th>Singular points</th>
<th>Total</th>
<th>Missed</th>
<th>False</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>90</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Delta</td>
<td>42</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

This paper compares the proposed detection algorithm with some conventional singular point detection algorithms. Since, the proposed approach is developed from the Poincare Index, so three widely used Poincare Index-based algorithms are choosen for comparison, including Yin’s algorithm [4], Peng’s algorithm [10] and Chikkerur’s algorithm [11].

In the proposed approach, core missing rate is 4.44% and false core points rate is 5.55%. For delta extraction 4.76% missing rate and 9.52% false delta rate is found. In average proposed method gives better result than other methods. The comparison results are shown in Fig. 7.

Existing singular points detection methods only extract singular points, don’t recognize fingerprints. So, in the proposed method the work has been extended to recognize fingerprints. The proposed approach is applied in FCV2004 fingerprint image database for recognizing fingerprints. The overall accuracy rate of fingerprint recognition is found 91.56%. The applied fingerprint images has been divided in three types- rotated images, displaced images and changed size images. Their individual accuracy rates are calculated. The rotated images give 88.01%, displaced images give 90.07% and changed size images give 96.6% accuracy.
V. CONCLUSIONS

In this paper, an approach is presented and discussed in the development and implementation of a structural fingerprint recognition system. The key fingerprint features used in this recognition system are the Core and the Delta. So, the proposed approach cannot recognize fingerprints in case of arc fingerprints, where no singular point existed. The proposed approach works on noisy fingerprint images as well as, also works for rotated images. However, the available optical and photoelectric sensors give high quality fingerprint images with a well defined core and delta points, if they are present.

REFERENCES


Muhammad Sheikh Sadi received B.Sc. Eng. in Electrical and Electronic Engineering from Khulna University of Engineering and Technology, Bangladesh in 2000, M.Sc. Eng. In Computer Science and Engineering from Bangladesh University of Engineering and Technology, Dhaka, Bangladesh in 2004, and completed PhD from the department of Electrical and Computer Engineering of Curtin University of Technology, Australia in 2010. He is currently serving as an associate professor in the department of Computer Science and Engineering, Khulna University of Engineering and Technology, Bangladesh. He teaches and supervises undergraduates and postgraduate theses in topics related to Embedded Systems, Pattern Recognition, Digital System Design, and Soft Errors Tolerance etc. He has published around 25 papers and book chapters in his area of expertise. Muhammad Sheikh Sadi is a member of the IEEE since 2004.

Md. Nazim Uddin received M.Sc. Eng. in Computer Science and Engineering from Khulna University of Engineering and Technology, Bangladesh in 2012. He is the Member of The Institute of Engineers, Bangladesh (IEB) and Associate Member of Bangladesh Computer Society (BCS). His current research interests are in Embedded Systems, Pattern Recognition, Soft Errors Tolerance and System Modeling. He has published in his area of expertise.

Abdul Ahad received B.Sc. Eng. in Computer Science and Engineering from Khulna University of Engineering and Technology, Bangladesh in 2010. His research areas of interest are Pattern Recognition, Security Enhancement, Software Architecture, and Database Engineering. He is currently working as a software engineer in Dimik Infotech Ltd., Dhaka, Bangladesh. He has published a research paper in a peer reviewed conference in the area of Fingerprint Recognition.

Mohd. Ariful Haque received B.Sc. Eng. in Computer Science & Engineering from Khulna University of Engineering and Technology, Bangladesh in 2010. He is currently serving as a software engineer at ADN Telecom Limited, Bangladesh. His research areas of interest are Pattern Recognition, Security Enhancement, Software Architecture, and Database Engineering. He has published a research paper in a peer reviewed conference in the area of Fingerprint Recognition.