A Survey on Singular Points Detection Technique

Fadzilah Ahmad
Department of Computer Graphics and Multimedia
Faculty of Computer Sciences and Information System
Universiti Teknologi Malaysia
Tel. +607-553-5315, fax. +607-5565044
fadzilah.fa@gmail.com

Dzulkifli Mohamad
Department of Computer Graphics and Multimedia
Faculty of Computer Sciences and Information System
Universiti Teknologi Malaysia
Tel. +607-553-5315, fax. +607-5565044
dzulkifli@utm.my

ABSTRACT
Fingerprint classification is an important task for any large scale fingerprint recognition system. The high precision of detecting core point is crucial for most fingerprint classification operations. This paper provides an overview of the most well-known techniques for singular points detection fingerprint classification based on these singularities. The main purpose of singular points detection is to use as reference points for fingerprint matching and classification. Generally, accurate and efficient singular points detection considerably affects the overall fingerprint identification system. A various method of singular points detection has been examined starting with Kawagoe and Tojo from 1984. Since then, there are many new approaches introduced. Most of the approaches proposed by the researchers for the singular points detection operate on the fingerprint ridge orientation image. On the other hand, this paper focuses to present the precise way for detection of singular points and dealing with accurate performance for fingerprint classification systems.

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General Terms
Algorithms, Performance, Theory.

Keywords
Fingerprints, Classification, Singular Points, Orientation image

1. INTRODUCTION
Fingerprint has been widely applied as a personal identification. Due to reliability and uniqueness features. In fingerprint, there are two kinds of features: the global feature and local feature. The global feature includes the ridge orientation map, core and delta locations, while the local feature form by minutiae points. Singular points are the most important global features that contain the significant global information which play an important role in fingerprint pattern classification [1] and fingerprint matching [2].

One of the features of fingerprint identification and verification is singularity (see Figure 1). The accuracy of singularity extraction basically depends on the quality of images. Therefore, in order to improve the identification and verification process, we need to enhance the fingerprint image. The poor quality of fingerprint image makes efficient singularity extraction algorithm degrades rapidly and we cannot identify the singular points area efficiently. A majority of techniques that used to enhance the fingerprint images are based on the use of contextual filters whose parameters depend on the local ridge frequency and orientation. The filters themselves may be spatial [3] [4] or based on Fourier domain analysis [5] [6].

Singular points are the discontinuities in the orientation field of fingerprint. Core and delta points are examples of two different types of singular points as can be seen from Figure 1. The core point is defined as the top most point on the innermost upward recurving ridge [7] and delta point is defined as the point of bifurcation (in a delta-like region) on a ridge splitting in two branches which extend to encompass the complete pattern area [7].

Figure 1. The fingerprint image with core and delta points

Core and delta points both have distinctive features. However, core point is mostly used as reference points for fingerprint matching and classification [8] rather than the delta point. Therefore, in order to align the fingerprint images which used in minutiae algorithm, core point position can be used as a reference point. Most fingerprint identification system used reference point to extract fingerprint features. Consequently, accurate and consistent reference point detection considerably affects the overall fingerprint identification system.

2. SINGULARITY DETECTION CHALLENGES
There are several challenges to detect the singularities of fingerprint images. These are the important issues that may potentially be solved by incoming researchers. Some problems will arise due to the difficulty in extracting the singularities information from the noisy fingerprint images and sometimes not all fingerprints have valid singular points. Random noise and other effects caused by the skin conditions such as dry,
sweaty, dirty, and diseased can cause errors in the fingerprint images.

The number and positions of the singularities play an important role in most fingerprint classification systems. Since this method heavily relies on singularities, it may not be very successful due to lack of availability of such information in partial fingerprint images, which are singular points left outside the prints.

Another related issue dealing with singularity detection problem is the quality of fingerprint images. The challenge faced in singularity detection that deals with poor quality image is loss of singular points. A poor quality fingerprint image is low in contrast, not always well defined and hence they can not be correctly detected. Therefore, several pre-processing stages are required in order to raise the quality of fingerprint images.

3. PREVIOUS WORK

It is a common trend in fingerprint reference point detection algorithm to used Poincare index (PI) as an approach to detect the core point. This method simply computed the PI of each block by summing up the direction changes along a closed digital curve of the block. Previous researcher as a [9][8][10][1] proposed Poincare index method as an elegant and practical method to detect the core point location. Instead of using PI as a main technique to locate singular points, it also can judge the type of singular points.

Generally, most of the approaches proposed by the researchers for the singularity detection operate on the ridge orientation image. In order to locate the position of singular points accurately, we should compute the reliable orientation field of fingerprint images and make full use of this property. However, to improve the reliability of orientation field image is still a challenging task because of the noise or poor quality of fingerprint image. Poincare index method may lead with this problem as it is ease to be affected by the noise of orientation field image and may detect the false singularities (see Figure 2). In view of the matter, an interesting implementation of Poincare index method for locating singular points was proposed by [11].

![Figure 2](image)

Figure 2. a) A poor quality fingerprint; b) the singularities of the fingerprint in a) are extracted through the Poincare method (circles highlight the false singularities); c) the orientation image has been regularized and the Poincare method no longer provides false alarms [12].

Multi-resolution approach is one of another technique to determine singularities as initiated by [13]. On the other hand, early exploration of multi-resolution approach to locate the singularities of fingerprint images was proposed by [2]. This method based on the orientation image of a maximum ridge curvature [14]. The presence of noise in fingerprint image will affect the process to compute the curvature which is sensitive to noise of orientation field image; therefore this method does not work well for poor quality fingerprint images. As stated in [15], multi-resolution approach can not find the accurate core point location and still hard to decide the size of the reference points region.

Since singular points is defined as the points those discontinuities in the orientation field, many researchers extracted the singular points location by using the orientation field images. Another approach that used orientation field to detect the singular points was proposed by [16]. The authors implemented complex filtering technique with multi-resolution scales. This method is time consuming, but it is very hard to give good localization of singular points location.

Chui-Hyun Park et al. [17] introduced an efficient reference point detection algorithm by using the orientation pattern labeling. This method is not efficient to fingerprint rotation and its result for plain arch fingerprint is inferior to that of the method that proposed by Jain et al [2]. Manhua Liu et al. [18] used the multiscale-analysis approach to locate singular points efficiently and consistently for all types of fingerprint images. This approach relies on the reliability of orientation field of fingerprint images. Another reference point localization technique proposed by [14] based on hierarchical analysis of orientation coherence. However, method needs the consistency of the local orientations to get accurate location of singular points. By improving these features, the authors proposed an orientation smoothing method to attenuate the noise of orientation field and compute the reliable orientation field.

In fact, the enhancement process of the fingerprint images is required in order to improve the clarity of the ridge structures. As stated in [19], Gabor filter is applied for enhancing the image using the estimated ridge frequency. The authors proposed a novel method for fingerprint reference localization by calculating the reliability of the enhanced image. Manhua Liu et al. [18] calculate the reliability to measure the accuracy of the orientation. Another authors, [20] also used the reliability as threshold value for the image.

From our study, we can conclude that there are four main approaches to allocate the singular points [21] namely mathematical model representation, statistical approaches, method based on the Fourier transform and method based on fingerprint structures. According to [22] [23], the representation of an accurate model for fingerprint images is a difficult task due to presence of noise in fingerprint images. Method that based on the statistical approaches can not adapt themselves to different image characteristics although it used the histogram to attenuate noise effect. Fourier transform method is not efficient enough to allocate the singular points because of working in the frequency domain. But, some researchers have claimed to obtain good results. In general, method that applied on fingerprint structures have been tested on large databases and was successfully implemented [8][24][25]. Table 1 below shows the comparison techniques for singularity detection that have been proposed among all researchers.

Table 1. Comparisons of Previous Techniques
### 3.1 Core Point Detection Technique

A major common step in core point detection is used the orientation estimation of fingerprint images [26] [12]. Simply refers the orientation as the direction of the ridges in the images, which we can use different techniques namely Poincare Index method, Detection of Curvature, and Geometry of Region Technique. Following are the elaboration for three techniques that implemented by researchers to detect the core point location.

#### 3.11 Poincare Index (PI)

Following are the overall steps for the PC technique as described by [1] [27]:

1. Let \( \theta(i, j) \) be the orientation field and estimate the orientation by using the least square estimation algorithm as mentioned in [2] [26].
2. Initialize a label image \( A \) which is used to indicate the core point. For each pixel in \( \theta(i, j) \) compute Poincare index, \( PI(x, y) \) as defined in the [26] [27].
\[
Poincare(x, y) = \frac{1}{2\pi} \sum_{k=0}^{n-1} \Delta(k)
\]

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

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

3. As mentioned in [9] the core point object should yield the Poincare Index between 0.40-0.51. If it comes then we label the corresponding A (i, j) with 1 else we label it with 2. If the Poincare index is -0.5 then such a block is the delta block.

4. Then, we calculated the center of that object. The largest regions and the center of the block with the value of one are considered to be a core point. However, it is enabling to make average calculation if there is more than one block with those values.

5. The center location will gives us the core point location as shown in Figure 3. But, first found core point may be slightly errored. To overcome this problem, core point tuning is being performed on that false regions area as described in [28].

![Figure 3. Core point detection; a) Detected core point; b) Tuned core point.](image)

3.12 Detection of Curvature

According to [26] [27], DC technique can be summarizes as follows:

1. By using the equation in [2], compute the local orientation \( \theta(i, j) \). The input block size will be as small as defined \( w = 3 \), such an example take \( k \times l = 3 \times 3 \) pixels.

2. Smoothing process of orientation field is required in order to get the better result by using equation in [2].

3. For every block that has been defined before, compute the difference of direction components via the following equations:

\[
\text{Diff}Y = \sum_{k=1}^{3} \sin 2\theta(k, 3) - \sum_{k=1}^{3} \sin 2\theta(k, 1)
\]

\[
\text{Diff}X = \sum_{l=1}^{3} \cos 2\theta(3, l) - \sum_{l=1}^{3} \cos 2\theta(l, 1)
\]

The core point location will be located at the corresponding pixel \((i, j)\) where \(\text{Diff}X\) and \(\text{Diff}Y\) are both negative.

3.13 Geometry of Region Technique (Gr)

The geometry region of fingerprint images play an important role to detect the core point since the line curvature varies sharply near the core region [12]. The GR technique can be explained as follows.

1. Compute the smoothed orientation field \( \theta(i, j) \) by using the equation below [2]:

\[
\theta(i, j) = \frac{1}{2} \tan^{-1}\left(\frac{\Phi_y(i, j)}{\Phi_x(i, j)}\right)
\]

2. By using the equation below,[2], we need to compute \( \varepsilon(i, j) \) which is the sine component of \( \theta(i, j) \):

\[
\varepsilon(i, j) = \sin(\theta(i, j))
\]

3. Initialize a label image A which is used to indicate the core point.

4. To compute equation below, we need to assign the corresponding pixel in the value of the difference in integrated pixel intensity of each region of an image.

\[
A(i, j) = \sum_{R1} \varepsilon(i, j) - \sum_{R2} \varepsilon(i, j)
\]

To get the maximum curvature in concave ridges of fingerprint images and at least get one ridge, the region R1 and R2 are determined empirically.

5. Find pixel \((i, j)\) which have the maximum value in A and we assign it as the core point.
To overcome the problem if the core point still can not be locate successfully, the construction procedure for steps (1-5) will be iterated for a number of times while it decreasing the window size that used in step 1.

4. CONCLUSION AND DISCUSSION

Determination of core point localization may be highly accurate by using fine orientation estimation. Extracting fine and reliable orientation estimation is the challenging task especially for the poor quality fingerprint images. Solving this problem as well, an enhancement process need to be done first to increase the accuracy of orientation estimation and get the better results for detecting core point locations.

Singular points, including cores and deltas are very important features. The number and the position of cores and deltas are concerned to classify the types of fingerprints. Most of the fingerprint classifications are based on these singularities because of their high stability, rotation and scale-invariant. The process of singular points detection must be accurate due to their influences on the performance of the fingerprint classification system. According to Neil and Adnan [28], the best features for classifying fingerprint images are fingerprint singularities. However, due to the presence of noisy images, core points and delta points can be difficult to detect.

In this chapter, we presented a various method for detecting the core point location. Poincare index is much faster than DC technique as compared by [29]. DC approaches working in the small window, therefore the detection of core point location is quite slowly. Through several experiments, the GR technique showed fairly good results in detecting the core point. However in some cases, it can not allocate the singular points as accurate as well. Currently, the modifications of several methods in singular points detection are required to improve the accuracy of fingerprint classification system.

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6. REFERENCES


