Pattern Recognition 45 (2012) 3360–3372

Contents lists available at SciVerse ScienceDirect

Pattern Recognition

journal homepage: www.elsevier.com/locate/pr

# Fingerprint reference point detection for image retrieval based on symmetry and variation

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ARTICLE INFO

*Article history:*
Received 31 August 2011
Received in revised form
29 December 2011
Accepted 21 February 2012
Available online 14 March 2012

*Keywords:*
Fingerprint recognition
Reference point
Orientation consistency
Rotational symmetry

ABSTRACT

Reference point plays an important role in fingerprint identification systems. The reference point is widely used for the fingerprint retrieval in large-scale databases. This paper proposes a novel algorithm for detecting a convex core point as a unique reference point consistently and accurately for all types of fingerprints. In order to detect robust core point candidates, a modified complex filter, called semi-radial symmetry filter, is proposed to detect correctly rotational symmetries of core points. Moreover, a vertical orientation variation feature, called VORIV feature, is proposed to remove spurious core points and concave core points. Therefore, the proposed technique computes the Variation and Symmetry Combined Energy (VSCOME). Then, the reference point is located by searching the global VSCOME maximum. The experimental results on the public database (FVC2004 DB1 set A) show that the proposed technique exhibits a very high robustness and gets the best performance in comparing with other approaches in literature.



## 1. Introduction

Fingerprint is increasingly being used for personal recognition in commercial, civilian and financial domains because of its uniqueness and immutability. Generally, there are two kinds of features for fingerprint recognition: global features like the special ridge flow pattern and local features like minutiae. At global level, there are unique landmarks of fingerprints, where the ridge curvature is higher than other areas and the orientation changes rapidly. They are commonly known as singular points. Typically, there are two types of singular points: core points (concave core points and convex core points) and delta points (see Fig. 1(a)). A core point locating on the convex curving ridge (see Fig. 1(c)) is called convex core point, or locates on the concave curving ridge (see Fig. 1(d)) is called concave core point. We can identify easily these points because of its special symmetry properties. They are used to align between the reference and the unknown fingerprint. In fingerprint identification systems, these points have played important roles in most fingerprint classification algorithms [1–5] and fingerprint matching algorithms [7–9,24,25]. In order to extract fingerprint features for fingerprint retrieval in large-scale databases, a reference point is widely used. The reference point is commonly located based on the singular points. The quality of the acquired fingerprint is poor. Moreover, the number of core and delta points differs in different types of fingerprints [1,10]. Therefore, how to efficiently detect a unique reference point consistently for all types of fingerprints is a great challenge. Many approaches of singular point extraction and reference point detection found in the literatures have been reviewed for optimization, such as Poincaré index based technique, Sine-map-based technique, Orientation-consistency-based technique, Complex filter technique and others. Most of them operate on the fingerprint block-orientation field.

The Poincaré Index (PI) based method is one of the conventional singular point detection methods [1,5,7,14,28]. This method calculates the total rotation of a vector along a closed curve in orientation field to judge whether it exists a singular point. This method is efficient, but it is sensitive to noise as the orientation deviation caused by noise will affect the computation of PI, especially when the direction change is near $\pi/2$ or $-\pi/2$ [10,14,17]. This method can locate core and delta points [28]; however, it cannot distinguish between convex core and concave core points. Jain et al. [7] proposed the Poincaré Index based method to locate the core point as reference point. This technique is still not overcome the limitation of the computation of PI.

Sine-map-based technique was proposed by Jain et al. [8] for detecting the reference point. This approach locates a convex core points as a reference point based on multiple resolution analysis of the differences of sine component integration between two defined regions of the orientation field. This method is robust to

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doi:10.1016/j.patcog.2012.02.017

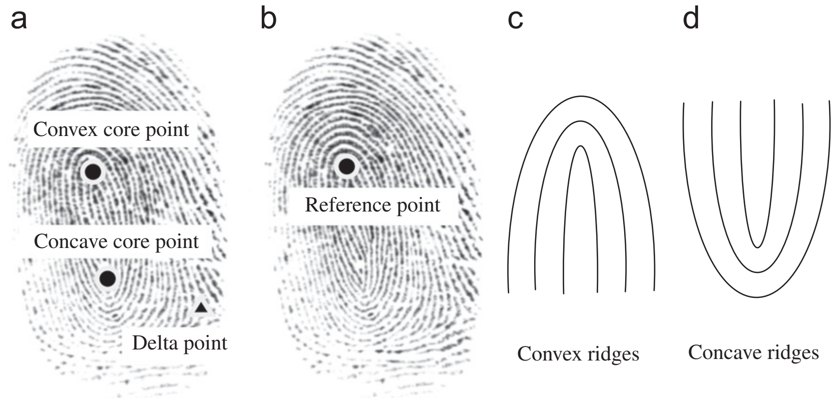


**Fig. 1.** (a) Core point and Delta point. (b) Reference point with maximum curvature on the convex ridge. (c) Convex ridges. (d) Concave ridges.

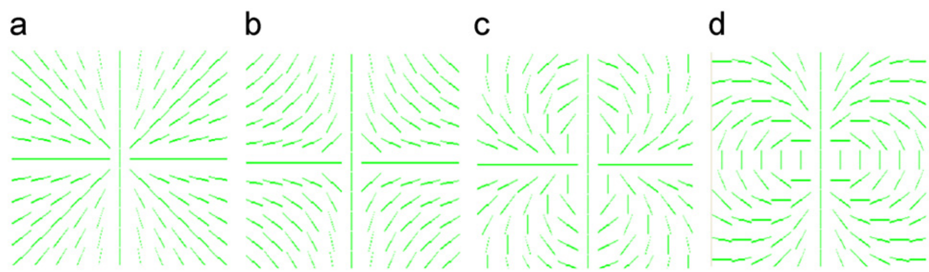


**Fig. 2.** The orientation field image of model: (a) $z(1)$, (b) $z(-1)$, (c) $z(-2)$, and (d) our model $z(m,k)=\exp\{im\phi^k\}$ with $z(-2,-1)$.

against noise; however the pre-defined semicircular mask makes it difficult to detect the reference points near the image border and accurately locate the reference points of the rotated fingerprint images.

Liu et al. [10] proposed an orientation consistency-based method, in which the reference point localization is based on multi-scale analysis of the orientation consistency to search the local minimum. This method is very efficient for delta point and core point detection by applying orientation consistency analysis. However, the performance of this method severely depends on the orientation field estimation. In addition, its limitation is the way to filter delta point based on analysis of curvature direction. Van and Le [18] proposed the improved version for detecting reference point based on computing the convex orientation consistency. All the methods [10,18] used the curvature based technique [13] to remove delta points and concave core points. However, the computed curvature can be unreliable measure in some cases.

In complex filter methods, symmetry properties have been used for singular point detection [13,15]. In this method, two complex filters are suggested that detect rotational symmetries for core points and delta points. The filtering was applied to complex images associated with the orientation tensor field [18] in different scales. This method has the advantage of being able to extract the position of core point and delta point. However, there are two disadvantages: (1) that the core-type filter cannot detect correctly the core point in plain arch fingerprints, and (2) that the singular points to be used as reference points cannot be located in fingerprint images without enough strong filter responses, especially the double-core fingerprint images.

Other approaches utilize various techniques such as orientation curvature [13,16,17], template model matching [29], and pixel-wised orientation field based-approaches [11,12]. The performance of these approaches degrades when the fingerprint quality worsens.

This paper proposes the novel algorithm to locate a unique reference point based on computing the Variation and Symmetry Combined Energy (VSCOME) which describes both the vertical orientation variation features and rotational symmetry features. The reference point is defined as the point with maximum VSCOME value, which is the convex core point located in the central area of fingerprint (see Fig. 1(b) and (c)). The main contributions of this paper consist of the following aspects: (1) A new complex filter is proposed for core point detection which tends to be more reliable than the parabolic symmetry filter; (2) A Vertical ORIentation Variation (VORIV) measure is proposed for detecting the convex core point and removing concave core points and spurious detections which can be robust to noise. The performance of our approach on the public database FVC2004 DB1 set A shows that our proposed method is accurate and robust for a wide variety of fingerprint types in comparing with other approaches in literature.

In the following sections, our proposed algorithms of reference point detection are presented in detail. In Section 2, the proposed semi-radial symmetry filter for core point detection is presented. Section 3 describes the VORIV feature for detecting the convex core points. Section 4 discusses how to select the unique core point as reference point. The experimental results are presented in Section 5. Finally, our conclusion work and future work are drawn in Section 6.

## 2. Semi-radial symmetry filter for core point detection

The complex filter [15] is very efficient in detecting singular points. Complex filters, of order $m$, for detection of patterns with radial symmetries are modeled by $z(m)=\exp\{im\phi\}$ [15,19]. A polynomial approximation of these fields in Gaussian windows yields $(x+iy)^m g(x,y)$ where $g$ is a Gaussian defined as the formula:

$$g(x,y,\sigma)=\exp\left\{-\frac{x^2+y^2}{2\sigma^2}\right\}, \tag{1}$$