Fingerprint Binarization Using Convex Threshold

Doo-Hyun Kim and Rae-Hong Park
Dept. of EE, Sogang Univ., C.P.O. Box 1142, Seoul 100-611, Korea
dhkim@eevision1.sogang.ac.kr

ABSTRACT

A fingerprint identification system is popular and important in biometric identification applications. Its process is composed of two stages: feature extraction and matching. Most fingerprint features include ending points and bifurcation called minutiaes. In this paper, we propose a new fingerprint binarization method based on convex threshold for effective minutiaes extraction. The proposed method is efficient, fast, and simple compared with conventional filtering techniques. Main processes include noise reduction, directional vector estimation, and ridge detection. For noise reduction and directional vector estimation, we use the conventional method. For ridge detection we propose a convex threshold technique using fingerprint structures.

KEY WORDS: Fingerprint identification, fingerprint binarization, feature extraction, minutiaes, convex threshold

1. INTRODUCTION

In the electronically interconnected information society, a large amount of information is easily exchanged through computer networks. As today's society becomes more complex, the security of information becomes more important [1, 2].

Obtaining positive identification of parties to an exchange of information is a vital element of data security. Thus, various methods for automatic personal identification have been proposed. Biometrics is the science of analyzing biological observations, and is the basis of automated methods for recognizing a person based upon physical or behavioral characteristics [3].

Biometric approaches use fingerprints, speech patterns, facial features, retinal scanning, hand-writing, hand veins, and hand geometry as recognizable and identifiable human traits [4]. For personal identification, fingerprint identification has been much more widely used than other biometric identification methods. The major reason for the wide usage and popularity of fingerprints as a means of personal identification is that fingerprints are unique and do not change as a person ages [5].

A large number of methods for feature detection from fingerprint images have been proposed. Most of them transform gray level fingerprint images into binary ones. Next, a thinning process is applied to the binary images. The features are then extracted from the thinned fingerprint images.

For the fingerprint binarization, many conventional methods use adaptive filters that depend on ridge width, thus requiring estimation of ridge width. This process is difficult and requires a high computational load.

In this paper, we propose a fingerprint binarization method called the convex threshold that does not need to estimate ridge width.

2. PROPOSED FINGERPRINT BINARIZATION ALGORITHM

2.1 Feature Information in Fingerprint Images

In a fingerprint, the main features are ridges and valleys that alternate. Within ridge lines there are some anomalies such as ridge bifurcations and ridge endings. We can define the anomalies as features. Fingerprint identification is based on the analysis of features in a fingerprint. Thus, the performance of the fingerprint identification system depends on the accuracy of the extracted features [6].

Various representations of features can be defined. Generally the feature information is represented by three fields: the location of the feature, the angle of the ridge line tangential to the feature with respect to the horizontal direction, and the feature type (ending or bifurcation). Figure 1 shows the feature representation depending on the type, where (x_0, y_0) and μ denote the location of the feature and the angle of the ridge line, respectively.

2.2 Fingerprint Binarization Using Convex Threshold

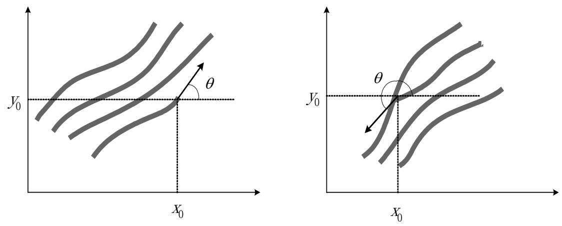


Fig. 1. Feature representation

The proposed algorithm is composed of four processes: estimation of the local ridge orientation, the local ridge orientation quantization, fingerprint regularization filtering, and convex threshold. Figure 2 shows the flowchart of the proposed algorithm.

The local ridge orientation is a local direction in a fingerprint image. The fingerprint ridge flows with uniform direction in local area and it can be used for next processes of filtering and convex threshold. To estimate the local ridge orientation, we use the modified least mean square orientation estimation algorithm [7], which is suitable for a flow image:

$$\nu_x(i_b, j_b) = \sum_{u=w\times i_b}^{w\times i_b+w-1} \sum_{v=w\times j_b}^{w\times j_b+w-1} 2\partial_x(u,v)\partial_y(u,v) \quad (1)$$

$$\nu_y(i_b, j_b) = \sum_{u=w\times i_b}^{w\times i_b+w-1} \sum_{v=w\times j_b}^{w\times j_b+w-1} (\partial_x^{\,2}(u,v) - \partial_y^{\,2}(u,v)) \quad (2)$$

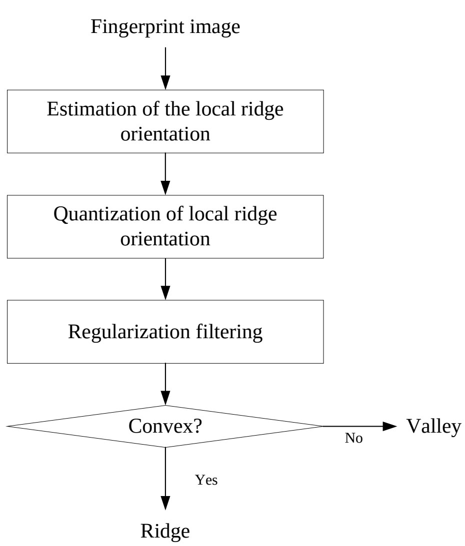


Fig. 2. Flowchart of the fingerprint binarization

$$\theta(i_b, j_b) = \frac{1}{2}\tan^{-1}\left(\frac{\nu_x(i_b, j_b)}{\nu_y(i_b, j_b)}\right) \quad (3)$$

where $\partial_x(u,v)$ and $\partial_y(u,v)$ represent the gradients at pixel (u,v). $\theta(i_b, j_b)$ denotes the local orientation at block index (i_b, j_b) of a $w \times w$ window.

The local ridge quantization divides $\theta(i_b, j_b)$ into one of four quantized directions bands:

$$\theta_q(i_b, j_b) = \begin{cases} 0, & \text{if } -\pi/8 < \theta(i_b,j_b) \le \pi/8 \\ \pi/4, & \text{if } \pi/8 < \theta(i_b,j_b) \le 3\pi/8 \\ -\pi/4, & \text{if } -3\pi/8 < \theta(i_b,j_b) \le -\pi/8 \\ \pi/2, & \text{if } \theta(i_b,j_b) > 3\pi/8 \text{ or } \theta(i_b,j_b) \le -3\pi/8 \end{cases} \quad (4)$$

Because convex threshold uses only three pixels, four-direction quantization is sufficient.

The fingerprint ridge structure is irregular because of noise, pressure of finger touching in image acquisition, and so on. Thus the fingerprint ridge structure regularization is necessary and important. Basic process and the filter used for this goal are similar to those in [8]. We use a two-dimensional (2-D) filter, which is defined by

$$f(i,j) = \frac{1}{K}\sum_{n=-N/2}^{N/2}\sum_{m=-M/2}^{M/2} W(m,n) I(m-i', n-j') \quad (5)$$

$$i' = i\sin\theta(i_b, j_b) + j\cos\theta(i_b, j_b) \quad (6)$$

$$j' = i\cos\theta(i_b, j_b) - j\sin\theta(i_b, j_b) \quad (7)$$

where (i', j') represents a rotation coordinate of (i, j). Figure 3 shows a filter mask $W(m,n)$. The filter mask coefficients are Gaussian-like ones for the ridge direction and mean filter ones for the ridge normal direction.

1	2	5	2	1
1	2	5	2	1
1	2	5	2	1

Fig. 3. Fingerprint regularization filter mask

The convex threshold detects the ridge. If we regard the fingerprint of the ridge normal direction as a one-dimensional (1-D) signal, as shown in Figure 4, where the ridge is convex and the valley is concave. Figure 4 shows the process for ridge detection. If the mean value of right and left pixels of the current center pixel is smaller than the current pixel, it is regarded as a ridge. This process is described as

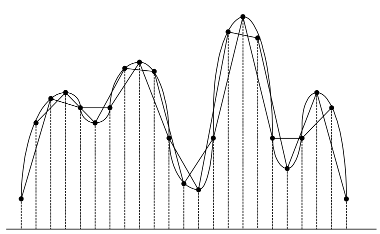
$$\begin{aligned} &(i''_k, j''_k) = \text{Ridge} \\ &\text{if} \quad I(i''_k, j''_k) \geq \frac{I(i''_{k-1}, j''_{k-1}) + I(i''_{k+1}, j''_{k+1})}{2} \end{aligned} \tag{8}$$

where (i''_{k+p}, j''_{k+p}), $p \in \{-1,0,1\}$, signifies a rotation position along the ridge normal direction.

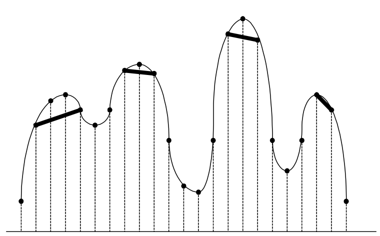
Figure 5 shows each location of the three pixels along quantized direction vector $\theta_q(i_b, j_b)$.

3. EXPERIMENTAL RESULTS & DISCUSSIONS

We show the effectiveness of the proposed algorithm through experiments. In experiments, National Institute of Standards and Technology (NIST) fingerprint images are used as test images. They are 8 bit gray scale images with 512×512 pixels.



(a) Convex detection process



(b) Result of convex detection

Fig. 4. Convex threshold

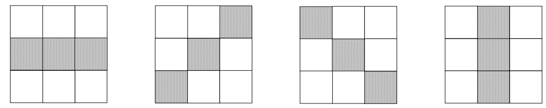


Fig. 5. Pixel position with different $\theta_q(i_b, j_b)$

For performance comparison, we simulate Gabor filtering [9], in which a Gabor filter defined by

$$G(x, y; f, \theta) = \exp\left\{-\frac{1}{2}\left[\frac{x'^2}{\delta_{x'}^2} + \frac{y'^2}{\delta_{y'}^2}\right]\right\}\cos(2\pi f x') \tag{9}$$

$$x' = x\sin\theta + y\cos\theta \tag{10}$$

$$y' = x\cos\theta - y\sin\theta \tag{11}$$

is used, where f represents the frequency of the fingerprint sinusoidal signal along direction θ. Note that f is a reciprocal of the ridge width. In experiments, f is set to 0.1. For spatial domain filtering, we use a 21×21 Gabor filter mask.

Figure 6 shows the original fingerprint image. Figures 7 and 8 are processed images by Gabor filtering and the proposed method, respectively. In Gabor filtering of the binary image, ridge width is smaller than original width because ridge width is incorrectly estimated, resulting in false feature extraction. But with the large filter mask, a Gabor filtered image becomes smoother than the proposed method.

In the proposed method, the ridge width of a binary image is similar to original ridge width. On the other hand it is sensitive to noise, however the noise can be eliminated through a thinning process.

4. CONCLUSIONS

This paper proposes a simple and efficient fingerprint binarization algorithm. The binarization process is important in feature extraction, thus the number of parameters depending on image characteristics should be small. But most of conventional fingerprint algorithms have many parameters. If parameter extraction is incorrect, the performance will be degraded.

In this paper we propose a fingerprint binarization method that does not require a parameter, thus it can be used successfully in

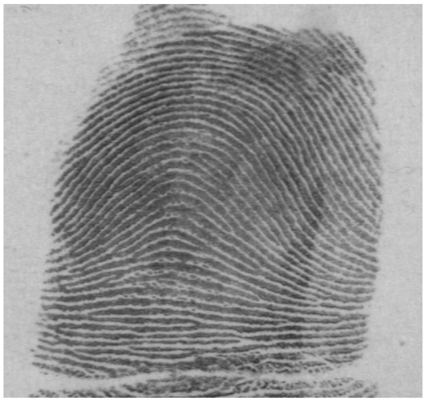


Fig. 6. Original fingerprint image

Fig. 7. Binary fingerprint image using the Gabor filter

Fig. 8. Binary fingerprint image using the proposed algorithm

various fingerprint identification systems. It is simple and fast with a low computational load, in which the most complex operation is regularization filtering using a 5×3 mask.

Future work will focus on development and analysis of the effective algorithm robust to noise.

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