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Fingerprint minutiae extraction using topographic distances

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1. Introduction

The most widely used method for fingerprint recognition is based on minutiae matching. This is due to the analogy with the way the forensic experts compare fingerprints and its acceptance as a proof of identity in the courts of law in almost all countries. Prior to the matching stage, minutia must be extracted, and each minutia is described by a set of attributes. The existing methods for minutia detection are normally based on a sequence of algorithms that extract ridge endpoints. Existing methods are not robust since the minutiae detected are strongly dependent on image acquisition and image processing. Figure 1(b) shows an example of two close minutiae detected in the image shown in Figure 1(a). They correspond to two ridge endpoints. As it can be seen they can easily become connected when other images are captured in different conditions. Even a simple rotation of the captured image could lead to a different connectivity due to pixelation effects. Even though the minutiae shown in Figure 1(a) are not connected in the processed image, their connectivity is very high.

(a) (b)

Figure 1. Weak minutiae detection (a) Weak minutia in valley. (b) Valley endpoints.

The objective of this paper is to make the minutiae detection robust to the mentioned variations in the input image, by means of a measure of the distance between minutiae. The topographic distance between minutiae must be taken into account when modeling the minutiae. High connected minutiae should not have a big weight in a further matching process, while low connected minutiae should have a highest importance since they correspond to isolated ridge endings. In Section 2 we briefly describe the process of minutiae extraction using morphological techniques. In Section 3, the distance between minutia is presented. The results are shown and referenced within the body of the corresponding sections.

2. Minutiae extraction process

The stages of the algorithm for minutiae detection are briefly described in this section. The width of ridges and valleys of the fingerprint is a parameter needed for the rest of processing techniques. This width is determined by a granulometry test [1], and will be named RW in the rest of the paper. The orientation of the ridges has been obtained by the principal component analysis described in [2].

The fingerprint image is then filtered in the directions of the ridges. The objective is to enhance the ridges that are oriented in the local direction, and to smooth the shapes oriented differently. The input image is filtered using an open-close filter with line shaped structuring elements oriented in the local ridge direction [3].

Fingerprint images are usually unevenly illuminated. There is a need of correcting this effect. As the illumination gradient lies within the low frequencies of the image, it is removed by a top-hat transform using a structuring element bigger than RW . Contrast can be adjusted by dividing the result obtained by its closing [4], that is, $(WTH(I)/\phi(WTH(I)))$. Figure 2(b) shows the result of equalizing the filtered image using an isotropic structuring element sized RW.

The equalized image is binarized using the moving averages algorithm [5]. This technique has been widely used in OCR systems because it takes advantage of the presence of alternating white and black sets of pixels. We can use this technique with fingerprint images due to their nature of alternating ridges and valleys.

The next step is to thin the ridges to a set of lines, condensing the information of the binary fingerprint while preserving its homotopy. Figure 2(c) shows the skeleton of the black set of the binary image(valleys).

Finally, skeleton endpoints are selected. Figure 2(d) shows the endpoints of the skeleton.

3. Distance between minutiae pairs

The detection of the minutiae obtained from the skeleton endpoints is not robust. Ridges easily be-

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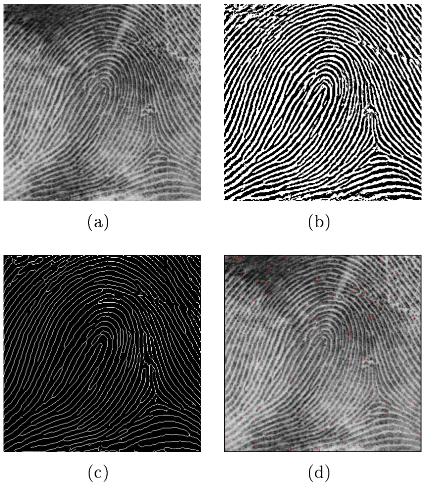

Figure 2. Minutia Extraction. (a) Original image. (b) Equalized image. (c) Black set skeleton (d) Valleys endpoints.

come connected depending on image conditions, and a lot of endpoints are lost (see Figure 1). The distance between minutiae is a feature that must be taken into account in order to determine the 'strength' of each detected minutia. Close minutiae facing each other are the ones that will probably be lost in different captures of the same fingerprint. These minutiae should be considered as weak minutiae.

Our definition of distance is based on the topographical distance framework proposed by [6]. The topographical distance along a path $\pi = (p_0, p_1, ..., p_n)$ is defined as:

$$T_f^\pi = \sum_{i=0}^{i=n-1} Cost(p_i, p_{i+1})$$

And the topographical distance between p and q is the minimum of the topographical distances along all paths between p and q:

$$T_f(p,q) = \min_{\pi \in [p \to q]} T_f^\pi$$

In our application $Cost(p,q)$ has been defined as the 'walking' cost (using the terminology of [7]) between p and q, that is: $Cost(p,q) = |f(p) - f(q)|$. The algorithm has been implemented using dynamic programming techniques.

Note that our cost definition does not make any difference between walking up and walking down. The distance used does not define a metric since two different points may be separated by a null topographic distance. This is not a problem in our applications since if two different minutiae are at distance zero, it means that there is no change in the grey level of the path joining them, and they should be considered the same minutia. Finally, minutiae located further than RW from other minutiae are considered to have an infinite distance. Figure 3 shows all the detected minutiae after the whole process is completed. Minutia marked in green are those not having any other affine minutia in a finite distance (strong minutia). Minutiae marked in red are those having another minutia in their neighbourhood, that is, $M_j/Dist(M_i, M_j)$ is finite for some M_i.

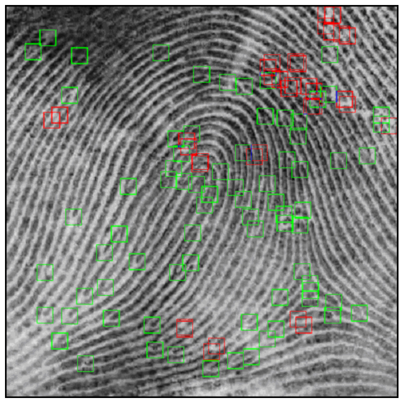

Figure 3. Detected minutia.

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