A Novel Approach of Palm-line Extraction

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Abstract

Palm-lines, including the principal lines and wrinkles, can describe a palmprint clearly. This paper presents a novel approach of palm-line extraction for the online palmprints. This approach is composed of two stages: coarse-level extraction stage and fine-level extraction stage. In the first stage, morphological operations are used to extract palm-lines in different directions. In the second stage, for each extracted line, a recursive process is devised to further extract and trace the palm-line using the local information of the extracted part. Experimental results show that the proposed approach is suitable for palm-line extraction.

1. Introduction

Computer-aided personal recognition is becoming increasingly important in our information society. Biometrics is one of the most important and reliable methods in this field [1]. The most widely used biometric feature is the fingerprint and the most reliable feature is the iris. However, it is very difficult to extract small unique features (known as minutiae) from unclear fingerprints and the iris input devices are very expensive [1]. Other biometric features, such as the face and voice, are less accurate and they can be mimicked easily. The palmprint, as a relatively new biometric feature, has several advantages compared with other currently available features [2]: palmprints contain more information than fingerprint, so they are more distinctive; palmprint capture devices are much cheaper than iris devices; palmprints also contain additional distinctive features such as principal lines and wrinkles, which can be extracted from low-resolution images; a highly accurate biometrics system can be built by combining all features of palms, such as palm geometry, ridge and valley features, and principal lines and wrinkles, etc. It is for these reasons that palmprint recognition has recently attracted an increasing amount of attention from researchers [3, 4, 5, 6, 7].

There are many features in a palmprint such as geometrical features, principal lines, wrinkles, delta points, minutiae, etc. [1]. However, geometrical features, such as the width of the palm, can be faked easily by making a model of a hand. Delta points and minutiae only can be extracted from the fine-resolution images. Principal lines and wrinkles, called palm-lines [3], are very important to discriminate between different palmprints and they can be extracted from low-resolution images. Therefore, palm-lines are one of the most important features in automated palmprint recognition. The palm-lines in a palm are very irregular and even in the same palm they have quite different directions, shapes and contrast, thus it is a very difficult task to extract these lines. Zhang et al. [3] extracted palm-lines by using twelve templates. Duta et al. [4] binarized the offline palmprint images directly to get the lines by applying an interactively chosen threshold, but they fail to explicitly extract these lines. Both methods were devised for the off-line palmprints, which were created by inked palms. Because of the noise and unexpected disturbance such as the movement of hand, lighting, settings, etc., the online palmprints, which are captured online from palms using some digital devices, have much worse quality than offline images. Thus it is much more difficult to extract lines from online images. This paper proposed a novel approach of palm-line extraction for on-line palmprint images based on their characteristic and morphological operations.

All palmprints used in this paper were captured by a CCD-based device and pre-processed by using the technique described in [5]. After the pre-processing, the central 128×128 rectangle part was cropped to represent the

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whole image.

The rest of this paper is organized as follows. Section 2 describes the proposed approach. Section 3 gives some experimental results. Section 4 provides some conclusions.

2. The Proposed Approach

There are two stages in our approach: coarse-level extraction and fine-level extraction.

2.1. The First Stage: Coarse-Level Extraction

Morphology theory [8] has been successfully used in image processing and feature extraction. Han [6] used this theory to extract line-like features from palmprints. However, instead of extracting palm-lines, they used morphological operations to enhance the palm-lines and employed the magnitude of the enhanced image to compute the line-like features. In our approach, morphological operations are used to extract the palm-lines explicitly.

In the gray-scale morphology theory, two basic operations, namely *dilation* and *erosion* for image f are defined as follows:

Dilation:

$$(f \oplus b)(s,t) = \max\{f(s-x,t-y)+b(x,y)| \\ (s-x,t-y) \in D_f \text{ and } (x,y) \in D_b\} \quad (1)$$

Erosion:

$$(f \ominus b)(s,t) = \min\{f(s-x,t-y)-b(x,y)| \\ (s-x,t-y) \in D_f \text{ and } (x,y) \in D_b\} \quad (2)$$

where D_f and D_b represent the domains of image f and structuring element b . Furthermore, two additional operations *opening* and *closing* are defined by combining the dilation and erosion operations:

opening:

$$f \circ b = (f \ominus b) \oplus b \quad (3)$$

closing:

$$f \bullet b = (f \oplus b) \ominus b \quad (4)$$

And using the closing operation, *bothat* operation is defined as below:

bothat:

$$h = (f \bullet b) - f \quad (5)$$

The bothat operation can be used to detect the valley in an image. Because all palm-lines are valley in a palmprint, the bothat operation is suitable for palm-line extraction. The shape of the structuring element heavily affects the result of line extraction. Since the directions of the palm-lines are very irregular, we should extract these lines in different directions. The directional structuring element b_{0° used to extract the palm-lines in 0° direction is shown in Figure 1(a) and the directional structuring element b_θ used to extract the palm-lines in direction θ can be obtained by rotating b_{0° with degree θ. b_{45°, b_{90° and b_{135° are also shown in Figure 1.

$$\begin{matrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{matrix} \qquad \begin{matrix} 1 & 1 & 1 & 1 & 1 \end{matrix} \qquad \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix} \qquad \begin{matrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{matrix}$$

(a) b_{0° (b) b_{90° (c) b_{45° (d) b_{135°

Figure 1. The directional structuring elements used in coarse-level extraction

The palm-lines in θ direction can be extracted by the following process:

1. Smoothing the original image I by convolving the original image with $b_{\theta+90^\circ}$;
2. Processing the smoothed image by using bothat operation with structuring element b_θ and get the θ-directional magnitude M_θ;
3. Looking for the local maximum points along direction $\theta + 90^\circ$ in M_θ;
4. Thresholding the maximum magnitude image.

In the coarse-level stage, palm-lines are extracted in several directions. Figure 2 shows an example of coarse-level palm-line extraction.

2.2. The Second Stage: Fine-Level Extraction

Most of the palm-lines can be extracted in the coarse-level extraction stage, but some weak parts of the lines have been missed. For example, in Figure 2(a), a long part of Line **A** fails to be extracted. A careful examination of a palmprint reveals that the palm-lines do not curve greatly, thus we can use the current extracted part of the line to predict the position and direction of the next short part and then choose a suitable structuring element to extract the this next part.

Let **ab** be the extracted part of Line **A** (Figure 3(a)). To extract the next part connected with **b**, we trace back the extracted line **ab** from Point **b** and get the Kth point **c** (here $K = 20$). Since the line does not curve greatly, the region of interest (ROI), in which the next segment of the line would be located, can be defined as a $L \times W$ rectangular region whose center point is Point **b**. Point **c** is the midpoint of one

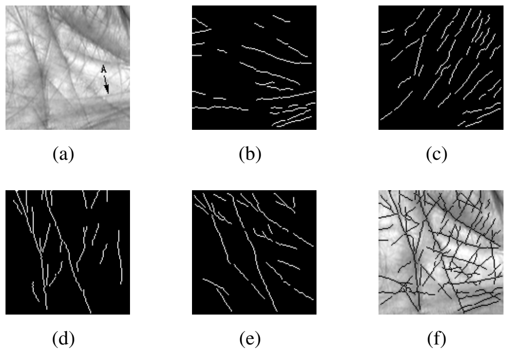

Figure 2. An example of the coarse-level palm-line extraction: (a) is the original palmprint; (b)-(e) are the palm-lines in $0°$, $45°$, $90°$ and $135°$ directions, respectively; (f) is the palmprint overlapped with all extracted lines.

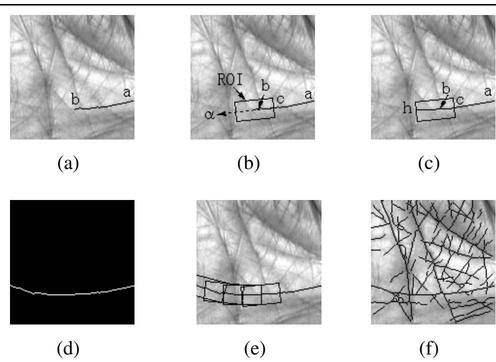

Figure 3. The process of the fine-level palm-line extraction: (a) is an extracted line; (b) is the predicted ROI and direction; (c) is the extracted next line segment; (d) is entire extracted line; (e) is all ROIs involved in this line extraction; (f) is the palmprint overlapped with all extracted lines.

border whose length is W. W is a predefined value (here $W = 20$), and L equal to twice the distance between Points **b** and **c** (Figure 3(b)).

Joining Points **b** and **c** gives us Straight-line **cb**. Let the slope angle of Straight-line **cb** be α. Because palm-lines curve so little, the direction of the next line segment should not vary much. Therefore, in this ROI, we employ the process described in Section 2.1 to extract the line segments in direction α and then keep all of the branches connecting with **cb** (Figure 3(c)). If only one branch connected with **cb**, this branch is regarded as the next line segment. Otherwise, we choose the branch that is the smoothest at Point **b** as the next line segment. Denote the extracted next line segment as **bh**.

After obtaining the next line segment, we should determine whether the line reaches its endpoint. We regard the line as having reached its endpoint if Line **ch** in the ROI satisfies one of the following conditions:

1. If **ch** has reached the border of the image, then Point **h** is the endpoint;
2. If the minimum distance from the endpoint **h** to three sides of the ROI (not including the side passing through Point **c**) exceeds a threshold T_d (here $T_d = 5$), then Point **h** is the endpoint;
3. If Angle **cmh** is less than a threshold T_α (here $T_\alpha = 135°$), having joined Points **c** and **h**, having supposed that Point **m** is the farthest point to Straight-line **ch** on Curve **ch**, and having joined **cm** and **hm**, then Point **m** is the endpoint.

If Curve **ch** satisfies none of these conditions, we take the longer curve **ah** as the current extracted line and repeat this process recursively until the extracted curve reaches its endpoint. Figure 3(d) shows the entire extracted line and Figure 3(e) shows all of the ROIs involved in this line extraction. Figure 3(f) is the palmprint overlapped with the resulting lines of the proposed approach.

3. Experimental Results

In our experiments, we have applied the proposed approach to several thousand palmprint images. The hysteresis thresholding technique [9] is used, in which the high threshold is automatically obtained using Otsu's method [10] and the low threshold takes the minimum non-zero value in the maximum magnitude image. In other words, no parameter is needed to tune for our approach in the experiments. We employ several samples to compare our approach with another well-known edge detection method, Canny algorithm [9]. In order to obtain the best results, we manually tune the parameters, the variance of the smoothing Gaussian function, high threshold and low threshold, in Canny algorithm for each palmprint image.

Figure 4 shows some results obtained by our approach and Canny algorithm. In this figure, the left, middle and right columns are the original palmprint images, the results of the proposed approach and the results of Canny algorithm, respectively.

From Figure 4, each palm-line corresponds two parallel edges in Canny algorithm. This is because that Canny algorithm is based on magnitude maximums of the gradient image. The proposed approach has no this problem because

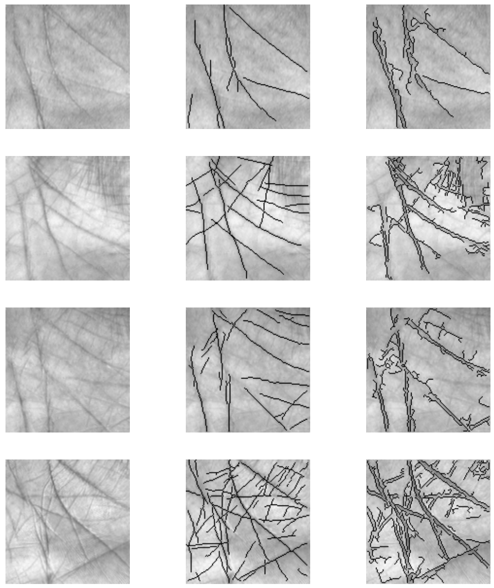

Figure 4. Some experimental results and comparisons. Left column: the original palmprints; Middle column: the palm-lines extracted using our approach; Right column: the palm-lines extracted using Canny algorithm.

it is based on bothap operation. Before extracting a palm-line, the proposed approach smoothes the image along this line's direction, which improve the smoothness and connection of this palm-line. Canny algorithm tries to extract all palm-lines at the same time, thus, before thresholding, many edges intersect each other including some false edges created by noises. It is difficult for the hysteresis thresholding technique to remove the false edges connecting with palm-lines. However, the proposed approach extracts palm-lines in different directions at the first stage, thus in each directional line image, the slopes of the lines are similar and the lines seldom intersect each other. Therefore, we can easily remove the false edges from a directional line image and at the same time keep the week parts of the palm-lines using the hysteresis thresholding technique. Another characteristic of the proposed approach is its fine-level extraction stage. At this stage, the missing parts of palm-lines can be further extracted and some broken palm-lines can be linked. Hence the proposed approach outperforms Canny algorithm in palm-line extraction. According to Figure 4, though the palm-lines in some palmprints are very complex: their shapes, directions and contrasts are quite different to each other, the proposed approach still can extract them effectively. This figure also shows that the proposed approach can extract some very weak palm-lines.

4. Conclusion

Palm-lines form one of the most important features for palmprint recognition. In this paper, a novel approach is devised to extract palm-lines from online palmprint images. This approach includes two stages: coarse-level extraction and fine-level extraction. At the coarse-level extraction stage, most of the palm-lines are extracted using the morphological operations with different directional structuring element. At the fine-level extraction stage, based on the extracted lines at the first stage, the missing parts of palm-lines are extracted using a recursive process, in which the local information about the extracted part of the palm-line is used to decide a ROI and then a suitable directional structuring element is chosen to extract the next part of the line in this ROI. This approach can effectively extract the palm-lines from palmprints including those containing unclear palm-lines and very complex line structures.

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