Palm-Line Detection

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***Abstract*—Palm lines, which consist of principal lines and wrinkles, are stable and essential traits for palmprint-based individual identification and can be extracted in low-resolution images. However, the research on palm-line detection has done little. Due to special properties of palmprint, in addition to the structure feature, width of the palm-line, which generally reflects strength information, is important to identify palms especially when various palmprints have similar structures. In this paper, a palm-line detection approach is proposed to simultaneously extract structure and strength features of palm lines by minimizing a local image area which is of similar brightness to each individual pixel. The presented method has been tested on the PolyU Palmprint Database and compared with the Canny edge detector and SUSAN edge finder. Experimental results illustrate the effectiveness of this approach.**

Keywords-line detection; palm line; palmprint; Biometrics

I. INTRODUCTION

Palmprint is a new emerging biometric characteristic for personal recognition. Observing palmprint, we can find some principal lines, wrinkles and ridges on a palm. Usually, there are three principal lines in a palm which are most notable and vary little over time. Wrinkles are generally much thinner than principal lines and much more irregular. Ridges exist all over the palm just like the ridges do in a fingerprint and cannot be observed in low-resolution images. Palm lines, *which refer to principal lines and wrinkles*, are stable and reliable for individual identification and can be obtained from a low-resolution palmprint image. Principal lines and some thick wrinkles are very strong and look *wider* than other light palm lines. That is, palm lines have different width which generally reflects strength information. Therefore, the palm-line strength feature is important to describe a palmprint clearly, especially when different palmprints have similar line structures. Hence, not only structure features but also strength characters of palm lines are necessary and important for palmprint recognition.

Palm line based palmprint identification schemes, such as interesting points [2, 3, 5], line segments [1] and line features [4, 6], have been presented. However, none of these methods directly extracted palm lines which are fundamental and most important to characterize a palm. In this paper, a palm-line detection approach is proposed to simultaneously extract palm-line structure and strength features by minimizing a local image area which is of similar brightness to each individual pixel. To give a smooth and isotropic response, a Gaussian weighting mask is defined as the local area. A stable and sensible similarity function for brightness comparison is used to obtain the area within the mask. The line response is determined by the inverted area. An analysis of the relationship between the size of Gaussian weighting mask and the width of detected lines is also given.

II. THE MAIN IDEA OF THE APPROACH

The principle of the proposed palm-line detector is illustrated in Fig. 1 showing a dark line on a white background. A circular mask, having a center pixel called "nucleus", is shown at six image positions. The detector firstly examines the intensity of the nucleus of the mask and counts pixels that have similar brightness to the nucleus into a 'univalue segment assimilating nucleus' (USAN) [8]. The USAN is at a maximum when the nucleus lies in a flat region of the image, decreases to about half of this maximum very near a straight edge, and decreases even further when inside a corner. That is, the smaller the USAN area is, the larger edge or corner response is given, as mentioned in [8]. Thereby, in order to detect a line, the USAN area of any pixel on the line should be less than those of background pixels. In other words, when the maximum of USAN areas of line pixels is less than those of background pixels, the line will be detected completely.

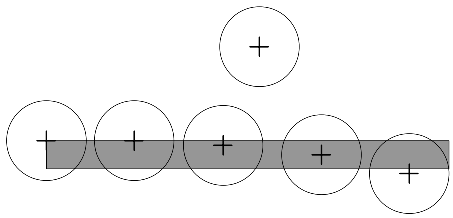

Fig. 1. Six circular masks at different positions of a dark line

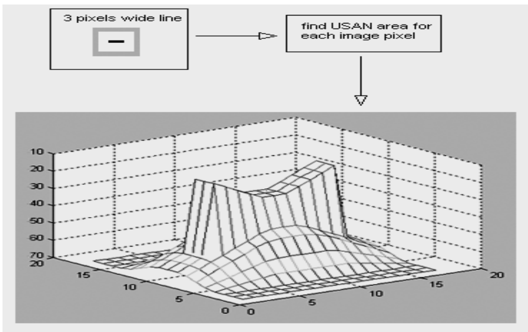

Fig. 2. A three dimensional plot of USAN area given a test image with a 3 pixels wide line.

In Fig. 2, a test image with a 3 pixels wide line has been processed to give USAN area as output. All of USAN areas can be divided into two groups: one is obtained from pixels on the line and the other is from background. From the three dimensional plot, we can see that the USAN of a pixel on the line reaches a local maximum when the line passes through the center of the circular mask, just like the mask *d* shown in Fig. 1, while the USAN of background is at a local minimum when the nucleus of the circular mask is very near the edge of the line. Obviously, in order to completely extract the line, the local maximum

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of USAN areas given by pixels on the line should be less than the local minimum obtained from background. This can be realized by using a circular mask with a proper radius.

III. THE PALM-LINE DETECTION APPROACH

A. Palm-Line Detector

Denote the palmprint image as *I*. The palm-line detector is defined as follows:

$$L(x_0,y_0)=\begin{cases} g-u(x_0,y_0) & \text{if } u(x_0,y_0)<g \\ 0 & \text{otherwise} \end{cases}, \quad g=u_{\max}/2 \tag{1}$$

$$u(x_0,y_0)=\sum_{\substack{x_0-r\le x\le x_0+r,\\ y_0-r\le y\le y_0+r}} n(x,y,x_0,y_0) \tag{2}$$

$$n(x,y,x_0,y_0,t)=\begin{cases} e^{-\frac{(x-x_0)^2+(y-y_0)^2}{r^2}}\times e^{-(\frac{I(x,y)-I(x_0,y_0)}{t})^6} & \text{if } I(x,y)\ge I(x_0,y_0) \\ e^{-\frac{(x-x_0)^2+(y-y_0)^2}{r^2}} & \text{otherwise} \end{cases} \tag{3}$$

where (x_0,y_0) is the coordinate of the nucleus, (x,y) is the coordinate of any other pixel within the mask, $u(x_0,y_0)$ is the USAN area and $u_{\max}$ is the maximum value which u can take, t is the brightness difference threshold, r is the radius of the Gaussian weighting mask, $n(x,y,x_0,y_0)$ is the output of brightness comparison weighted by a Gaussian function, and $L(x_0,y_0)$ is the line response.

This is a formulation of the principle for the palm-line detector. According to Eq. (3), if surrounding pixels' brightness is less than the nucleus, i.e., the nucleus is brighter than its neighbors, these pixels will be directly counted into USAN to decrease the line response of the nucleus, which can eliminate the affection of local exposure in palmprint images. In Eq. (3), a stable and sensible function $e^{-(\frac{I(x,y)-I(x_0,y_0)}{t})^6}$ is used to count USAN which allows a pixel's brightness not to have too large an effect on n even if it is near the threshold t. The use of the sixth power has been proved to be the theoretical optimum in [8]. In order to give smooth and isotropic responses, a 2-D Gaussian mask is used as the weight function of brightness comparison.

Fig. 3 shows palm-line detection results of a segmented palmprint image by using Gaussian weighting masks with different radius. It can be seen that with the increase of the mask radius, more and more palm-line strength features (or width information) can be extracted. In other words, the higher degree of completeness of detected palm lines can be achieved as the radius of Gaussian weighting mask increases. When using a Gaussian mask with a small size such as 3-pixel radius, only structure features of palm lines can be detected as shown in Fig. 3 (b). As the radius of Gaussian mask increases, the detected palm lines, especially thick lines in original palmprint images, become thicker and close to the real width of palm lines. Therefore, palm-line structure and strength features can be extracted simultaneously by using the proposed palm-line detector and, further, the detected strength features are determined by the size of Gaussian weighting mask.

B. Parameter Selection

The Gaussian weighting mask determines the strength features, i.e., the width of palm lines, detected by using the proposed approach. Therefore, the radius of the Gaussian weighting mask is an important parameter to this line detection approach. In this section, a brief analysis of the parameter selection is given to show the relationship between the width of detected palm lines and the size of Gaussian weighting mask.

As mentioned in section 2, the USAN area on a palm line reaches a local maximum when the line passes through the center of the circular mask. Assume that a circle C with a radius r has a Gaussian density $e^{-\frac{x^2+y^2}{r^2}}$ and a line of width $2\times w$ traverses the center of the circle as shown in Fig. 4. Let L denote the part of the line within the circle. According to the definition of the palm-line detector, if a line of width $2\times w$ is fully detected by using a Gaussian mask with radius r, it requires

$$\iint_L e^{-\frac{x^2+y^2}{r^2}}dxdy<\frac{1}{2}\iint_C e^{-\frac{x^2+y^2}{r^2}}dxdy\ , \tag{4}$$

which is equivalent to

$$\int_0^w\int_0^{\sqrt{r^2-x^2}} e^{-\frac{x^2+y^2}{r^2}}dxdy<\frac{1}{2}\int_0^r\int_0^{\sqrt{r^2-x^2}} e^{-\frac{x^2+y^2}{r^2}}dxdy\ . \tag{5}$$

The right hand side can be simplified as

$$\int_0^r\int_0^{\sqrt{r^2-x^2}} e^{-\frac{x^2+y^2}{r^2}}dxdy=\int_0^{\frac{\pi}{2}}d\theta\int_0^r e^{-\frac{\rho^2}{r^2}}\rho d\rho=\frac{\pi}{4}r^2(1-e^{-1})\ . \tag{6}$$

Therefore,

$$\int_0^w\int_0^{\sqrt{r^2-x^2}} e^{-\frac{x^2+y^2}{r^2}}dxdy<\frac{\pi}{8}r^2(1-e^{-1})\ . \tag{7}$$

TABLE I. The relation between the radius of Gaussian mask and the critical width of detected line.

Radius of Gaussian mask	6	7	8	9	10	11	12	13
Approximate critical width of line	4.2	4.9	5.6	6.3	6.9	7.7	8.4	9.1
Digital approximation to width of line	4	4	5	6	6	7	8	9

The relationship between the width of detected line and the radius of Gaussian mask can be determined based on Eq. (7). Given the mask with radius r, the critical value of detected line of width $2\times w$ is obtained when the left and right arguments of Eq. (7) are equal. As the analytic form of the left function is not available, we only give the approximate critical value of detected line of width, as shown in Table I.

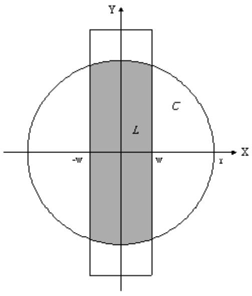

Fig. 4. A $2 \times w$ wide line passing through the centre of a circle with radius r

Therefore, given the mask with radius *r*, a palm line can be definitely detected if the width is not larger than the corresponding critical value of detected line of width.

IV. Experimental Results

The proposed palm-line detection approach as well as Canny edge detector [10] and SUSAN edge finder [8] have been tested on the public palmprint database [9] built by the Biometric Research Center at the Hong Kong Polytechnic University. This database contains 600 palmprint images from 100 different palms. Each of palmprint images was matched with all of the other palmprint images in the public database. We first introduce the matching method of palm-line images followed by the palm-line verification.

A. Palm-Line Matching

Let P and Q be two palm-line images which are logical matrices. The matching score between P and Q is defined as below:

$$S(P,Q) = \frac{2}{M_P + M_Q} \times \sum_{i=1}^{M_Q} P(x_i, y_i) \tag{8}$$

where M_P and M_Q is the number of line points in P and Q, respectively; (x_i, y_i) $(i = 1,\ldots,M_Q)$ are coordinates of line points in palm-line image Q. Palm lines detected by using Canny edge detector and SUSAN edge finder are single-pixel wide lines which are easily affected by noise. To overcome this problem, we can first dilate P before using Eq. (8) to obtain the corresponding matching score.

Obviously, $S(P,Q)$ is between 0 and 1 and the larger the matching score, the greater the similarity between P and Q. Due to imperfect preprocessing, we need to vertically and horizontally translate Q by some points and then match again. Finally, the maximum score obtained in these matching is regarded as the final matching score.

B. Palm-Line Verification

Before matching, a post processing for the palm-line detector has been done to discard weak line responses and to smooth detected palm-line images. A Gaussian filter is used to smooth the palm-line image. Table II gives the equal error rates (EER) by using palm-line detector based on Gaussian weighting masks with different radii and Gaussian smooth filters with different standard deviations. It can be seen that the EER reaches at the minimum 1.00% by using a weighting mask with radius 12 and a Gaussian smooth filter with standard deviation 1.0. Considering Table I, we can conclude that based on the palm-line detector, a Gaussian weighting mask with radius 12 is proper for palmprint authentication.

TABLE II. Equal error rates (%) based on Gaussian weighting mask with radius r and Gaussian smooth filter with standard deviation σ.

σ \ r	6	7	8	9	10	11	12	13
0	1.67	1.68	1.60	1.60	1.54	1.34	1.26	1.25
0.5	1.74	1.72	1.55	1.29	1.21	1.30	1.26	1.18
0.75	1.47	1.44	1.26	1.31	1.36	1.25	1.27	1.29
1.0	**1.30**	1.38	**1.22**	1.24	1.23	**1.10**	**1.00**	**1.11**
1.25	1.32	**1.25**	1.22	**1.22**	**1.19**	1.11	1.10	1.11

The Canny edge detector uses two thresholds to detect strong and weak edges, which are very important to palm-line detection results. However, the thresholds vary with different images. So we manually determined the two thresholds for each palmprint image in the database. Fig. 5 shows several segmented palmprint images and the corresponding palm-line detection results by using Canny edge detector, SUSAN edge finder and the palm-line detector, respectively. Fig. 6 shows the receiver operating characteristic (ROC) curves of the Canny edge detector, SUSAN edge finder and the proposed palm-line detector. The EER of the palm-line detector is 1.0% which is the lowest one compared with the SUSAN edge finder (2.3%) and the Canny edge detector (5.4%).

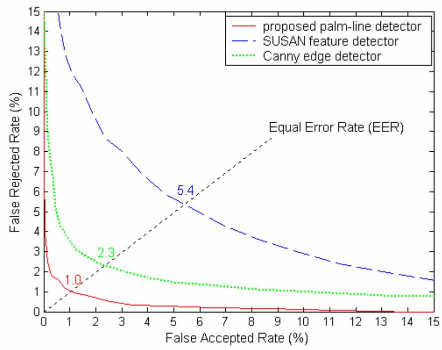

Fig. 6. Receiver operating charachteristic curves of the Canny edge detector, SUSAN edge finder and the proposed palm-line detector, respectively.

V. Conclusions

We have presented a palm-line detector to simultaneously extract structure and strength features of palm lines. This line detector is based on the brightness comparison in a local area. A stable and sensible function is introduced to obtain line response. In order to give a smooth and isotropic response, a Gaussian weighting mask is used as the local area for brightness comparison. An analysis of the algorithm shows the size of the Gaussian weighting mask determines the degree of completeness of extracted palm lines. Experimental results show that a Gaussian weighting mask with radius 12 is proper for palm-line based palmprint recognition. The lowest EER (1.0%) compared with the Canny edge detector and SUSAN edge finder represents the effectiveness of the proposed palm-line detection approach.

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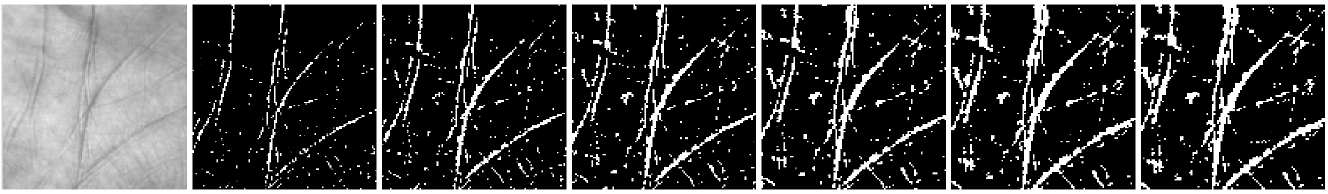

(a) (b) (c) (d) (e) (f) (g)

Fig. 3. Palm-line detection results by using the palm-line detector; (a) segmented palmprint image, palm-line extracted images by using Gaussian weighting mask with radius of 3 in (b), 5 in (c), 7 in (d), 9 in (e), 11 in (f), 12 in (g).

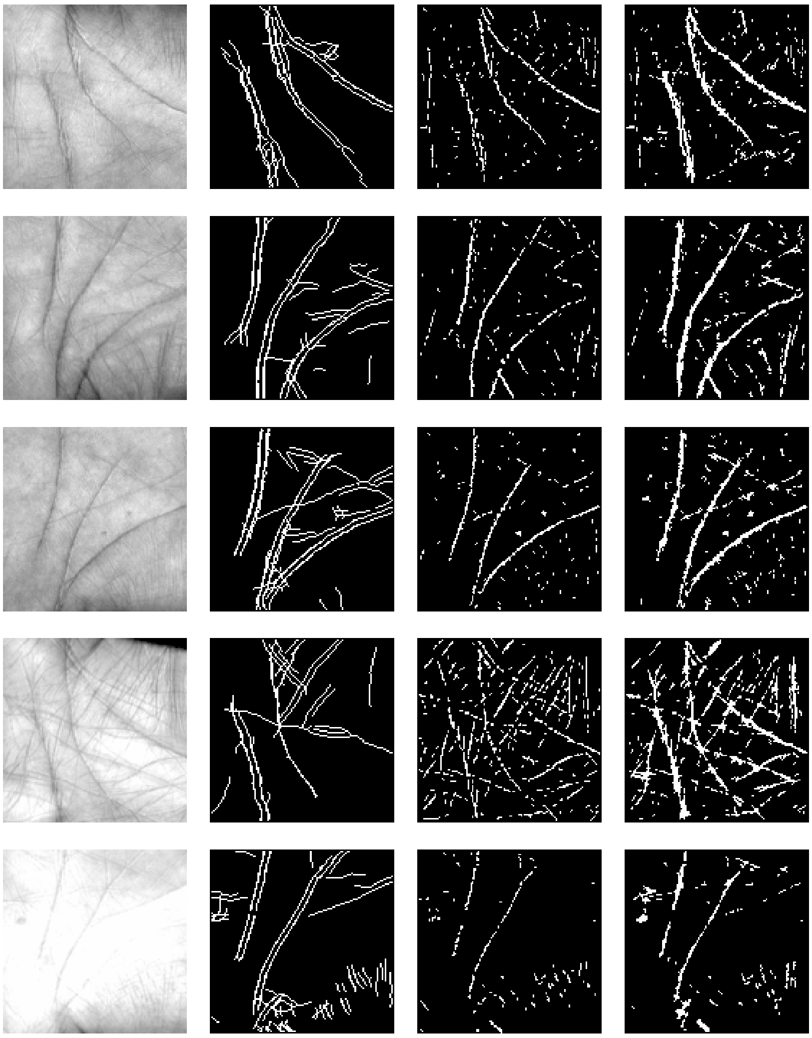

Fig. 5. The segmented palmprint images (the first column) and the palm-line detection results by using the Canny edge detector (the second column), the SUSAN edge finder (the third column) and the proposed palm-line detector (the last column), respectively.