A Palmprint Acquisition Device with Time-Sharing Light Source Used in Personal Verification

Weinan Zhao[1], Wenxin Li [1,2], Tao Wang[1], and Zhuoqun Xu[1]

[1]Department of Computer Science and Technology, Peking University
[2] Department of Computing, The HongKong Polytechnic University
wnzhao@water.pku.edu.cn
{lwx,zqxu}@pku.edu.cn
won_tar@ailab.pku.edu.cn

Abstract. This paper proposes a hardware-based line feature enhancement approach that uses a palmprint acquisition device fitted with a time-sharing light source. When capturing images, two lamps of the light source can be lit in turn, producing two, differently lit images. As the two lamps light the inner surface of the palm from different directions, they capture images with different lines enhanced. By fusing the two images with a nonlinear method, we can produce a palmprint with much clearer line features. Our research will focus on improving this device and integrating it into a functional palmprint verification system.

1 Introduction

Palmprint image acquisition is the first issue in a palmprint verification system. Previous acquisition methods are based on the requirement of "to make the captured image as clear as possible"[1]. This requirement calls for a uniform light source, since it doesn't emphasize specific palmprint features.

However, Palmprint verification systems commonly make use of the principal lines of the palm. In 1999, Wei Shu and David Zhang introduced a recognition algorithm based on palmprint line extraction and matching [2]. In 2002, Nicolae Duta and Anil K. Jain proposed an algorithm based on extraction and matching of the point on the major lines on the palm surface [3]; in 1998, J. You and W. Li presented a Hierarchical method based on feature points in principal lines and line patterns [4]; in 1998, Jun-ichi Funada proposed an algorithm to extract ridge structure features by removing the principal lines [5].

What all these methods have in common is a software approach to line feature extraction. In this paper, our proposed approach in contrast seeks to enhance line features with a new palmprint acquisition device. The rest of this paper is organized as follows. Section 2 explores the principal line imaging mechanism and describes the principal line imaging model. Section 3 presents the design of the palmprint acquisition device. Section 4 introduces our image fusion algorithm. Section 5

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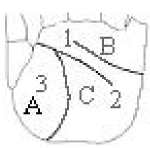
provides the experimental results. Section 6 concludes the proposed method and gives the future research directions.

2 The Principal Line Imaging Model

Principal lines on the palm surface are shown in Fig. 1. We name 1, 2 and 3 as Line 1, Line 2 and Line 3 respectively. To model them in an optical imaging system, we need the knowledge of their exact geometry properties. The anatomical structure of a principal line is shown in Fig. 2; besides, according to our observations, the most depressed part of the palm surface is generally located between Line 2 and Line 3 (area C in Fig. 1). That means for Line 3, the side near area A is higher than the other; while for Line 1 and Line 2, the side near area B is higher. These properties can be integrated into the principal line imaging models shown in Fig. 3 and Fig. 4.

To increase the contrast between the groove and its two sides, we need to illuminate the latter while at the same time reduce the amount of light that enters the former as much as possible. In the models shown in Fig. 3. and Fig. 4, this means the incoming ray should go along the direction from the higher side to the other side (direction 2 in Fig. 3 and Fig. 4), and the angle between the incoming ray and the palm surface (θ in Fig. 3 and Fig. 4) should as small as possible as long as it is bigger than some threshold that ensure the two sides sufficient illumination. Obviously, the three lines cannot be enhanced simultaneously using a single lamp. We use two lamps in the device. One lamp L_1 is used to enhance Line 3 and another lamp L_2 suffices to enhance Lines 1 and Line 2, since their directions are similar.

The effect of the enhancement relies on the relative location between the lamp and the principal lines. Thus two factors are important: palm positioning and individuality in the geometry of the palm surface. Our positioning method is shown in Fig. 5. a support saddle is installed to position the wrist and a support pole to position the fingers. When capturing, the subject is required to put his wrist on the support saddle, fingers on the support pole with the positioning wheel between middle finger and ring finger. In order to dealing with the individuality in the geometry of the palm surface, we experiment on a sample set of 30 samples (each sample includes two images) from 10 persons. Finally the location of the light source is fixed, as can be seen in Fig. 5.



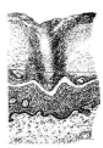
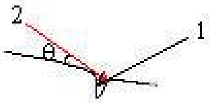


Fig. 1. Principal lines on the palm surface **Fig. 2.** Anatomical structure of a principal line



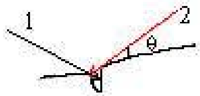


Fig. 3. Imaging model of Line 3 **Fig. 4.** Imaging model of Line 1 and Line 2

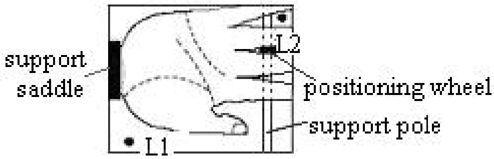


Fig. 5. Palm positioning and the location of the time-sharing light source

3 The Palmprint Acquisition Device with Time-Sharing Light Source (TSLS)

In this section we will present the design of our device. Its appearance is shown in Fig. 6.

When L_1 and L_2 are lit at the same time, they will interfere with each other. As a result, the enhancement effect will be weakened: for Line 3, the incoming rays from L_2 will increase the amount of the rays entering the groove so that the enhancement effect achieved by L_1 will be weakened. Similarly, the rays from L_1 will also weaken the enhancement effect achieved by L_2. To address this problem, we introduce a time-sharing light source that employs a time-sharing light source controller (TSLSC) to control the two lamps: light up L_1 when capturing image with Line 3 enhanced, while light up L_2 when capturing image with Line 1 and Line 2 enhanced. To avoid hand moving in the interval between two capture, we desire the interval to be as small as possible. Our palmprint acquisition system is shown in Fig. 7. In this system, TSLSC, controlling the quartz lamps, is connected to PC through the parallel port, and a camera is connected to PC through the usb port. We use software approach to synchronize lamp lighting with image capture. The minimum interval between two capture achieved by this system is 1s. It is possible for subjects to keep their hand still in such a small interval.

Fig. 6. Outlook of the palmprint acquisition device

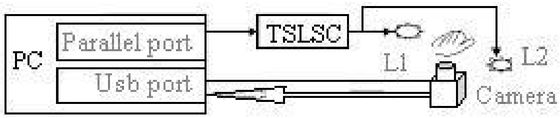


Fig. 7. Palmprint acquisition system with time-sharing light source

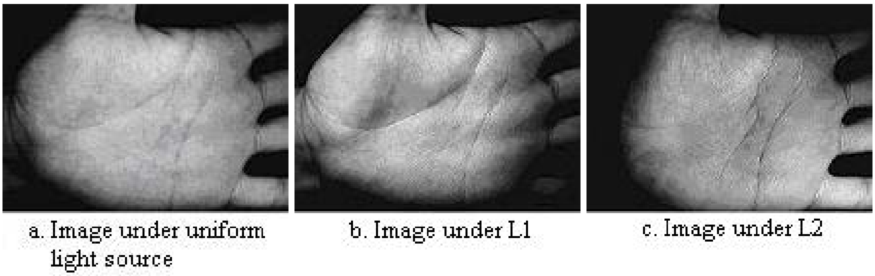


Fig. 8. Image under uniform light source and under the time-sharing light source

4 Image Fusion Algorithm

4.1 Objective

An example of captured images using our approach is shown in Fig. 8. (For contrast, we also give the image captured under a uniform light source). Examine the three images, we can find that Line 2 is blurry under the uniform light source but is successfully enhanced under L2. At the same time, we can find obvious enhancement to Line 1 (when contrast a and c) and Line 3 (when contrast a and b). For convenience of discussion, we refer to the image captured under uniform light source as I0, the image captured under L1 as I1, and the image captured under L2 as I2. Our objective is to fuse I1 and I2 into one image named I, in which all enhanced lines will be reserved as possible with least other information lost. Since the subjects are required to keep their hands still during capturing process, image registration is unnecessary. Then we can focus on the fusion method. Image fusion methods have been discussed extensively in the literature, but few of them apply to this special case. An example of these methods [6] is shown in Fig. 10 (a).

4.2 Nonlinear Fusion

Our nonlinear fusion method is based on the following observations (we refer to the pixels in the image that correspond to the vertical projection point of L_1 and L_2 on the image plane as LP_1 and LP_2 respectively): in I_1, the information closer to LP_1 than to

LP_2 is more desired to be reserved in I; in I_2, the information closer to LP_2 than to LP_1 is more desired to be reserved in I. It can be formulated as follows:

For each pixel P in I, its value,

$$p = p_1 \times w(d_1, d_2) + p_2 \times (1 - w(d_1, d_2)) \tag{1}$$

where, p_1 and p_2 are pixel values in I_1 and I_2 respectively; d_1 and d_2 are the distances from P to LP_1 and to LP_2; $w(d_1, d_2)$ is the weight function with the form:

$$w(d_1, d_2) = u(N(d_1, d_2)) \tag{2}$$

$$N(d_1, d_2) = \frac{wod \times d_1}{wod \times d_1 + (2 - wod) \times d_2}\ ,\ 0 < wod < 2 \tag{3}$$

$$u(x) = \begin{cases} -\left(\frac{1}{2}\right)^{1-pow}\left(x - \frac{1}{2}\right)^{pow} + \frac{1}{2}\ , & x > \frac{1}{2} \\ \frac{1}{2}\ , & x = \frac{1}{2} \\ \left(\frac{1}{2}\right)^{1-pow}\left(\frac{1}{2} - x\right)^{pow} + \frac{1}{2}\ , & x < \frac{1}{2} \end{cases} \tag{4}$$

where, $N(d_1, d_2)$ together with $u(x)$ decide weights for p_1 and p_2 that measure their importance in I according to their location. $N(d_1, d_2)$ calculates the initial weight according to d_1 and d_2. It indicates the relative location of P between LP_1 and LP_2 in sense of weighted distance: the more is the weighted distance of d_1 greater than that of d_2, the greater $N(d_1, d_2)$ will be. When $N(d_1, d_2)=1/2$, the corresponding locations form a line (named balance line) on which p_1 and p_2 are of equal importance. *wod* controls the location of the balance line. If $wod<1$, the balance line will bias to LP_2 and I_1 will hold more portion in I. And vice versa.

$u(x)$ enlarges the difference between the initial weights for p_1 and p_2 using a nonlinear transform. It is a descending function since we consider p_1 more important when its initial weight $N(d_1, d_2)$ is smaller. Fig. 9 shows the curve of $u(x)$. It has two desired properties: 1) the point $x=0.5$ corresponds to the balance line. When $x=0.5$, $u(x)>0.5$, that means in the area between LP_1 and the balance line, I_1 will be treated more important than I_2, and vice versa; 2) in the area around the balance line, it provides a smooth transition. *pow* value controls the convex degree of the $u(x)$ curve (see Fig. 9) and thus affects the two properties: as *pow* value decreases, the difference between I_1 and I_2 in their importance will be more enlarged; however, the transition will be less smooth.

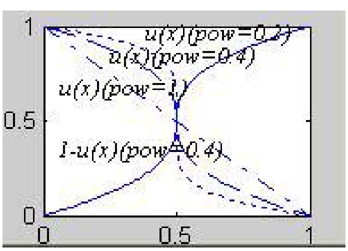


Fig. 9. Curve of *u(x)*

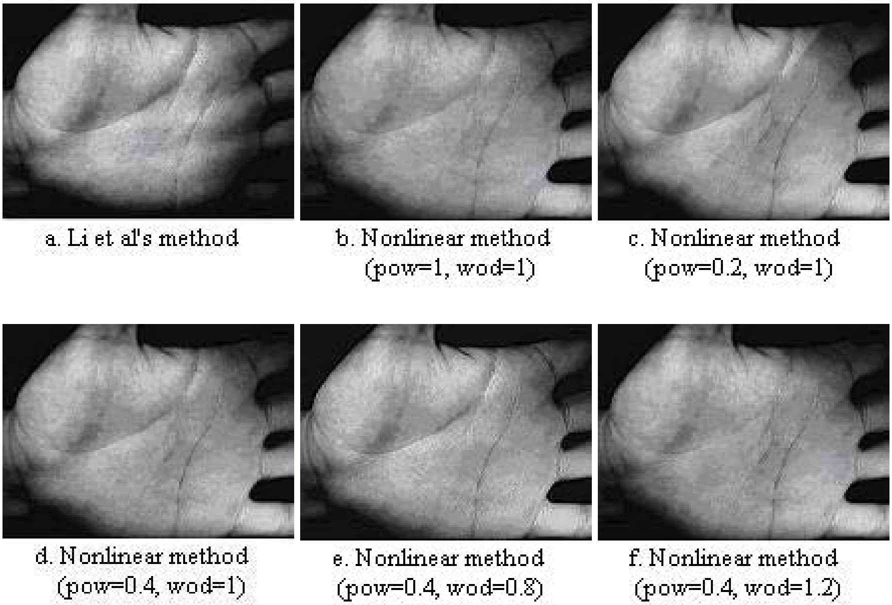


Fig. 10. Image fusion result

5 Experimental Results and Discussion

5.1 Results of Different *pow* Value

As *pow* value decrease, the fused image becomes sharper, but the balance line becomes obvious. Since the former is desired for line feature extraction and the latter is not, we have to made tradeoff between them. Experiments show the optimal value is 0.4. Typical results are shown in Fig. 1.0 (b, c, d).

5.2 Results of Different *wod* Value

wod value controls the location of the balance line. Since in the area around the balance line, the image will become less sharp, we need to find the optimal *wod* value. Through experiments we found the optimal value to get quite sharpness in most cases is 1. Typical results are shown in Fig. 1.0 (d, e, f).

5.3 Discussion

Using the nonlinear fusion method, we experiment on a sample set of 80 samples (each sample includes two images those are captured under L_1 and L_2 respectively) from 10 persons. Principal lines in 77 groups are enhanced in different degrees. This result is encouraging. However, the 3 exceptions show we need more precise positioning method; besides, in our fusion algorithm, due to the variation in the relative locations between the principal lines and LP_1 and LP_2, the sharpness of the principal lines near the balance line will vary a little. To improve that requires an adaptive mechanism.

6 Conclusion and Future Work

The palmprint acquisition device with time-sharing light source demonstrates a good ability to enhance the principal lines in palmprint in contrast with software enhancement method. When adopting more precise positioning method, we can use this device in large-scale sampling. Our future work will focus on two issues: 1) to further reduce the interval between two capture in order to provide more user-friendly interface; 2) to make the nonlinear image fusion method more adaptive.

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