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Letters

Online personal verification by palmvein image through palmprint-like and palmvein information

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ABSTRACT

Recently, palmvein recognition has been attracting much research interest. The joint use of palmprint and palmvein features can effectively increase the accuracy, robustness of palm based biometric techniques. And, as it is an inner vessel structure feature, palmveins can increase the anti-spoof and liveness detection capability of a palm based biometric system. However, lack of techniques to separate palmveins from palmprints in one image weakens the anti-spoof and liveness detection capability. This paper presents a novel online personal verification system by fusing palmprint and palmvein information. The proposed system includes: (1) A single camera and single light source to simplify the imaging system and save data collection time; (2) A morphological palmprint erasing technique to increase the accuracy of palmvein segmentation; (3) The fusion of palmprint and palmvein information to further improve the system accuracy. The experimental results demonstrated that since palmprints and palmveins contain complementary information, much higher accuracy could be achieved by fusing them than using only one of them. In addition, the whole verification procedure can be completed within 1 s, which implies that the system can work in real time.

1. Introduction

Biometric characteristics are now widely used in security applications. Among various biometric techniques, palmprint recognition is getting popular in personal authentication because it provides robust features from a large palm area and the palmprint image can be captured with a cost-effective device. Although palmprint recognition has achieved great success, it has some intrinsic weaknesses. For example, some people may have similar palm lines, especially principal lines [1]; also it is not so difficult to forge a fake palmprint [2]. One way to improve the discriminativeness and anti-spoofing capability of palmprint systems is to use more features from the palm, such as the veins of the palm. The veins of the palm generally refer to the inner vessel structures beneath the skin and the palmvein images can be collected using both far infrared (FIR) and near-infrared (NIR) light [3]. Obviously, the palmvein is much harder to fake than the palmprint. And, since both palmprint and palmvein are from the palm, it is possible to establish a convenient multi-biometric system to acquire and use the two traits jointly.

A number of studies have been conducted to fuse palmprint and palmvein information for personal recognition. Hao et al. [4] evaluated various image level fusion schemes of palmprint and palmvein images. Wang et al. [5] developed such a system and obtained good results, but their system uses two separate cameras and requires a time-consuming registration procedure, which makes it difficult to use in real-time application. Moreover, they evaluated the method using a very small database (only 84 images), making it hard to draw strong conclusions. Zhang et al. [6] developed a personal verification system fusing palmprint and palmvein information and obtained relatively good results on a large database (6000 images), but their system needs two separate light sources and the switching between different light sources cost extra time. Lee [7] developed a personal verification system using only a single camera and a single light source. He only used palmvein features and designed a “VeinCode” to represent palmvein features. This system obtained relatively good results on a large database (4140 images). However, in all above works, the palmvein is generally referred to the palm feature under near

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infrared (NIR) spectrum. There are both palmprint and palmvein information in the NIR images. And the palmprint or palmprint-like feature is not as stable as the palmvein feature in the NIR images captured by our system (we will discuss it in detail later), which will affect the palmvein feature extraction. A precise palmvein segmentation method is required to separate palmveins from palmprints and to generate stable palmvein segmentation so that verification accuracy could be improved. In addition, the pure palmvein feature is helpful to improve current liveness detection system. A liveness detection system will be more robust, if the palmvein feature is extracted accurately without the affection of palmprint or palmprint-like feature.

In this paper, we propose a new personal verification system by fusing palmprint and palmvein information on the same NIR image, where the palmvein is separated from the palmprint using a morphological reconstruction based technique. We design and construct a device that can acquire NIR images which contain both palmprint and palmvein information. The device involves one CCD camera and one NIR light source. With the captured NIR images, the personal verification framework has four main parts. (1) First, it separates palmveins from palmprints using a morphological reconstruction based technique. (2) Second, it uses matched filters to extract the palmvein features. (3) Third, it performs texture coding to extract palmprint-like features. (4) At last, a fusion matching score is computed through weight sum.

The rest of the paper is organized as follows. Section 2 briefly describes the image acquisition and Region of Interest (ROI) extraction. Section 3 introduces the extraction and matching of palmvein features. Section 4 introduces the extraction and matching of palmprint features, and the fusion of palmprint and palmvein information. Section 5 reports the experimental results on the established database. Section 6 makes the conclusion and suggests some future work directions.

2. Image acquisition and ROI extraction

The developed image acquisition device is made up of a light source, a gray level CCD camera, lens, and an A/D (analog-to-digital) converter connecting the CCD and the computer. The uniformly distributed 880 nm LEDs (light emitting diode) are used for the NIR illumination as it has been shown that 880–930 nm provides a good contrast of subcutaneous veins [15]. Fig. 1 shows the structure and a photo of the acquisition device.

We extract the palmvein and palmprint information under the same light source so that the switching time between different light sources can be saved and system cost is lower. In order to acquire high quality palmvein feature, a near-infrared sensitive camera, is used in our system. As we do not deploy any light filter in front of the camera, the NIR images captured by our device contain palmprint and palmvein feature. And, as we will see in this paper, the fusion of palmvein and palmprint could improve the performance of personal verification significantly. Fig. 2(a) shows the captured NIR image.

Before feature extraction, it is necessary to extract Region of Interest (ROI) to remove the translation and rotation in the data collection process and to extract the most informative area in the images. In this study, we set up ROI coordinates on palmprint image using the algorithm proposed in [1] and then use the coordinates to crop the ROI from the images. Fig. 2(b) shows the extracted ROI.

3. Palmvein feature extraction and matching

It is observed that the cross-sections of palmveins are similar to Gaussian functions. Based on this observation, the matched filter [8], which is widely used in retinal vessel extraction, can be a good technique to extract these palmveins. We define matched filter using the second derivative of Gaussian similar to [8]. Eq. (1) defines the 1-D matched filter and Eqs. (2)–(3) defines the 2-D matched filter.

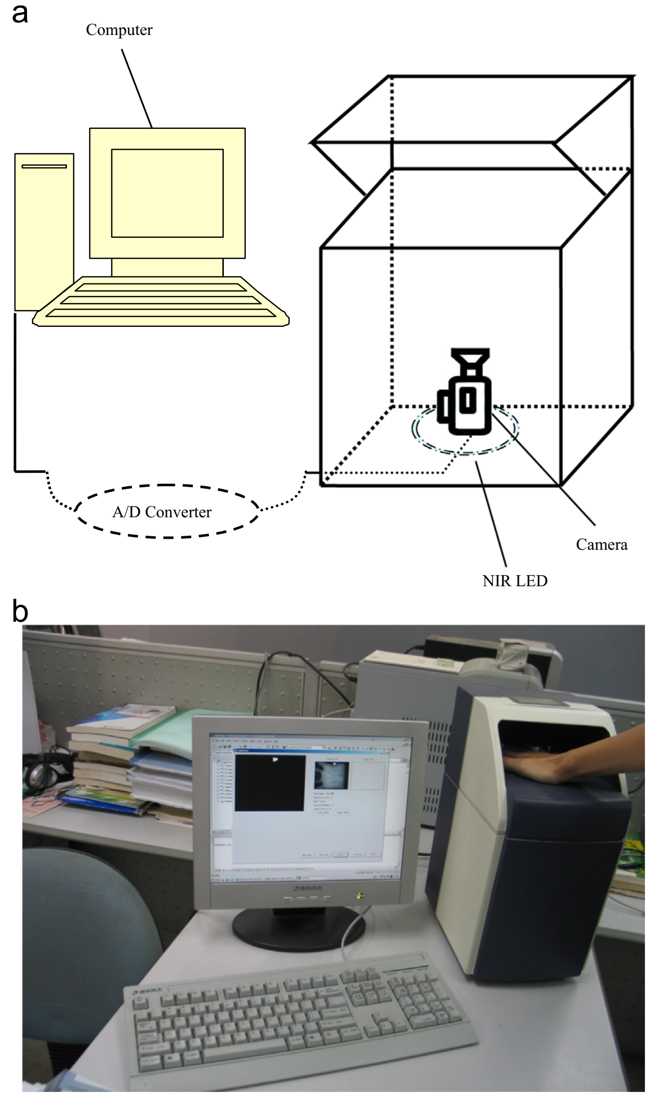

Fig. 1. (a) Structure of the acquisition device; and (b) photo of the device.

$$g''_{\sigma} = \frac{x^2-\sigma^2}{\sqrt{2\pi}\sigma^5} e^{-\frac{x^2}{2\sigma^2}} \tag{1}$$

$$m_{\sigma}(x,y) = \frac{x^2-\sigma^2}{\sqrt{2\pi}\sigma^5} e^{-\frac{x^2}{2\sigma^2}} \quad \text{for } |x| \le 3\sigma, \quad |y| \le L/2 \tag{2}$$

where σ represents the scale of the filter; L is the length of the neighborhood along y-axis to smooth noise. In practice, we will fix L to get square filters and we will rotate $g(x,y)$ to detect the vessels of different orientations, and the maximum filter response of all orientations is retained as the final response at that scale. The rotation of $m(x,y)$ with angle ϕ is

$$\begin{cases} m^{\phi}(x',y') = m(x,y) \\ x' = x\cos\phi + y\sin\phi \\ y' = y\cos\phi - x\sin\phi \end{cases} \tag{3}$$

However, similar to any other "band-pass" filters, the matched filter also responses to strong edge, which mixes the palmprint