Non-contact finger vein acquisition system using NIR laser

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ABSTRACT

Authentication using finger vein pattern has substantial advantage than other biometrics. Because human vein patterns are hidden inside the skin and tissue, it is hard to forge vein structure. But conventional system using NIR LED array has two drawbacks. First, direct contact with LED array raise sanitary problem. Second, because of discreteness of LEDs, non-uniform illumination exists. We propose non-contact finger vein acquisition system using NIR laser and Laser line generator lens. Laser line generator lens makes evenly distributed line laser from focused laser light. Line laser is aimed on the finger longitudinally. NIR camera was used for image acquisition. 200 index finger vein images from 20 candidates are collected. Same finger vein pattern extraction algorithm was used to evaluate two sets of images. Acquired images from proposed non-contact system do not show any non-uniform illumination in contrary with conventional system. Also results of matching are comparable to conventional system. We developed Non-contact finger vein acquisition system. It can prevent potential cross contamination of skin diseases. Also the system can produce uniformly illuminated images unlike conventional system. With the benefit of non-contact, proposed system shows almost equivalent performance compared with conventional system.

Keywords: Finger vein, biometrics, Non-contact

1. INTRODUCTION

1.1 Finger vein as a biometrics

Finger vein pattern is originated from lower light absorbance characteristic of hemoglobin in red blood cell[1]. In the near infrared region, hemoglobin have lower absorbance than around tissue [2]. In result blood vessels in plenty of hemoglobin show darker contrast than other tissue. A typical finger vein pattern image is shown in Figure1.

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Fig. 1. A typical finger vein image using infrared LED array and CCD camera

Finger vein pattern is the distinct personal characteristic which is distinguished from each person. It can be utilized for personal authentication like other unique human body patterns (e.g. fingerprint and iris) [3]. Commercialized models are also available, mainly in Japan.

1.2 Drawbacks in conventional light source

In various conventional finger vein authentication systems, LED array was used as light source[4-6], because it can be easily designed and integrated into the system. But there are two drawbacks in LED array light source. Firstly because of its discrete characteristic, acquired images are not uniform. Also the fixed LED location can make slightly different images, when the user insert a finger with different depth, because the relative position between user's finger and LED array is changed. It can be one of the factors which lower false rejection rate (FRR).

The other problem is direct contact between finger and LED array. Emitted light from the LED array is not collimated well. It spreads out with broad angle. So without close contact, partial light do not pass through the finger. Moreover unabsorbed light is not attenuated, and it blurs the entire image so that the overall quality of image decreases. With these reasons, direct touch is essential for conventional finger vein acquisition system. But direct contact can cause cross-contamination between users since authentication system is naturally used by a number of people. Several studies showed risk of cross-contamination by direct skin touch in various circumstances [7-9].

2. MATHERIALS AND METHODS

2.1 The comparison between conventional and proposed system

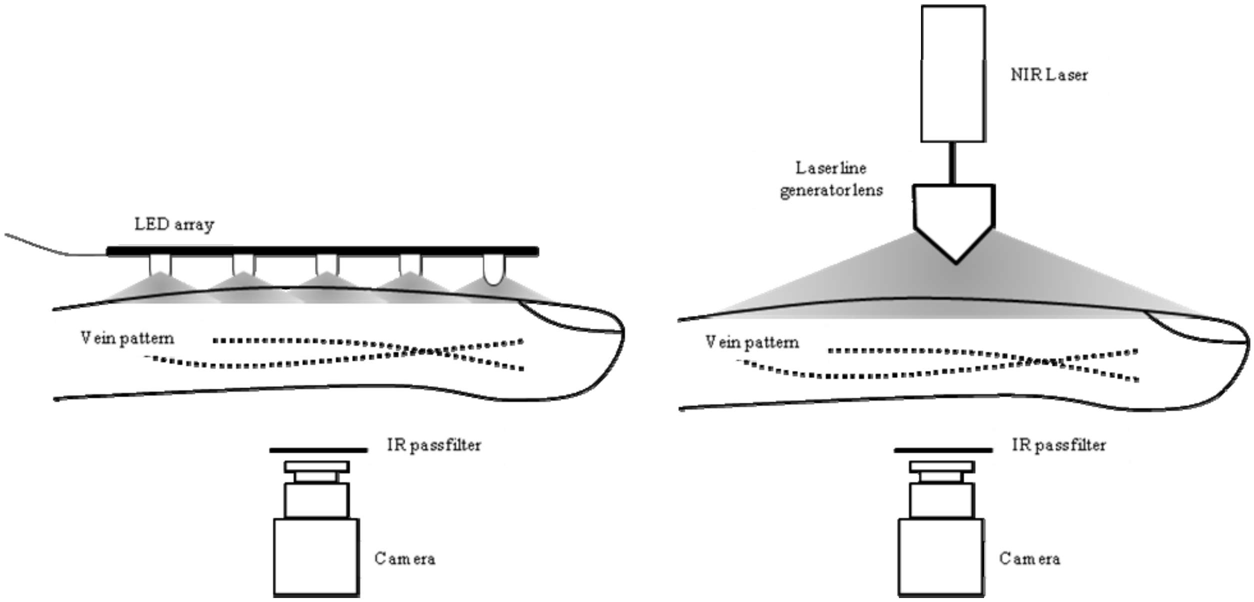

Fig. 2. Schematics of conventional LED light source finger vein acquisition system (left) and proposed line laser source system (right).

To evaluate proposed system we built two finger vein image acquisition systems.

The proposed finger vein acquisition system uses near infrared (λ=830nm) laser (Lasiris Laser, StokerYale, Canada) as a light source and laser line generator lens (E43-475, Edmund optics, Singapore) to make line laser from spot laser. Laser line generator lens has fixed pan angle, and makes evenly distributed power profile along the laser line. The transmitted light through the finger is filtered by IR pass filter which prevent the interference from other light sources. Finally the CCD camera (GF 038B NIR, ALLIED Vision Technologies, Germany) captures the finger vein image. In proposed system, the incident line laser barely diffract within small distance, 5~10 cm, so it enables high quality vein image without direct contact between finger and sensor.

In the conventional setting, 850nm LED array was used to minimize the effect of wavelength difference. And same IR filter and CCD camera were used.

2.2 Acquired images

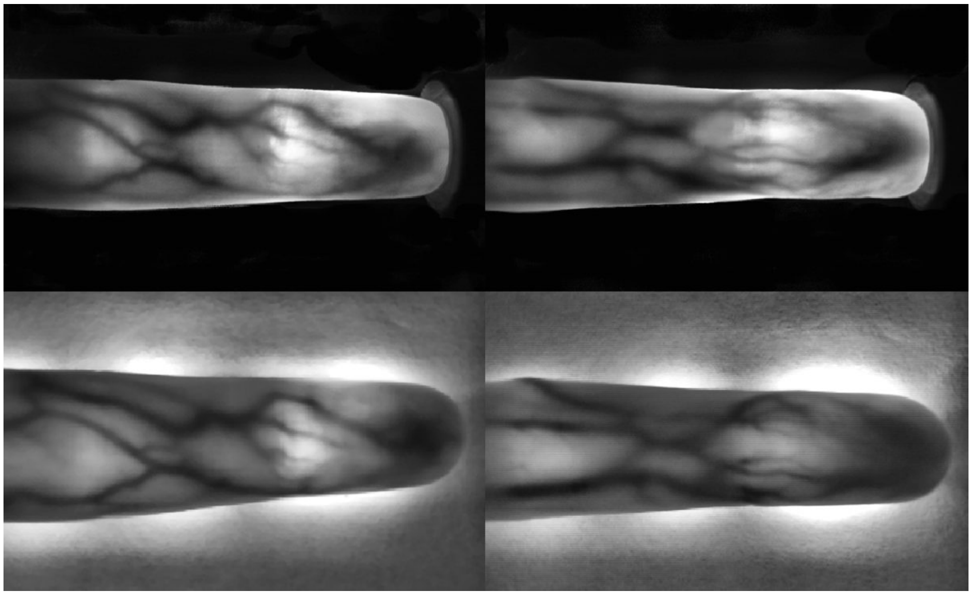

Fig. 3. Acquired images from two systems: Two image of upper side were taken by proposed line laser source system, the others by conventional LED array system

For each finger vein acquisition system, 100 finger vein images were taken from 10 volunteers. 10 vein images were acquired from same finger of volunteers. Raw data images have 768x492 pixels, and 8 bit gray level and BMP format. For image acquisition LABVIEW 8.2 (National Instrument, Austin, Texas, USA) was used. Using real-time camera control program which was made for this study, several camera properties, including brightness, gamma, exposure time were adjusted for better image qualities. Figure3 shows vein images of two index fingers. Two vein images of the upper part were acquired by newly proposed line laser source system, and images of the lower part were acquired by conventional LED array system. Images at the each column were from same index finger.

Because of well collimated property of laser light, images of upper side shows little back ground noise. On the other hand, images of the lower side show bright background saturation by scattered and diffracted LED lights. Also discrete characteristics of LED arrays are appeared in the images. Because of short penetration length of the distal knuckle, there are bright saturated region.

Images from two systems show different characteristic especially in background, but overall quality of finger vein in clearness looks similar with the bear eyes. It is necessary to adopt quantitative vein image evaluation method to compare two image groups.

2.3 Image quality evaluation method

For image quality evaluation, Maximum curvature points method was applied as a line feature extraction method which was proposed by Miura and others[10]. The center lines of the vein are extracted by calculating curvature of the cross-sectional image profile of the image.

For a continuous plane curve

$$y = f(x) \tag{1}$$

The curvature k is defined as

$$k = \frac{y''}{(1 + y'^2)^{3/2}} \tag{2}$$

But in practice, the curvature of the digital discrete line can be approximated as follows

$$D_{+} = \frac{1}{w}\sum_{i=0}^{w-1}\frac{y_i - y_{i+1}}{x_i - x_{i+1}} \tag{3}$$

$$D_{-} = \frac{1}{w}\sum_{i=-w+1}^{0}\frac{y_{i-1} - y_i}{x_{i-1} - x_i} \tag{4}$$

$$D_{\pm} = \frac{1}{w}\sum_{i=-w/2}^{w/2}\frac{y_i - y_{i+1}}{x_i - x_{i+1}} \tag{5}$$

$$k = \frac{D_{+} - D_{-}}{\{1+(D_{\pm})^2\}^{3/2}} \tag{6}$$

Because orientation of the vein patterns is various, it is needed to use various profile direction. In this study, vein patterns are extracted along with four profile direction (x, y, and two oblique directions). Fig.4. represent definition of directions. Main direction is the profile scanning direction. Once the process for single profile information is done, next profile is selected along with main direction.

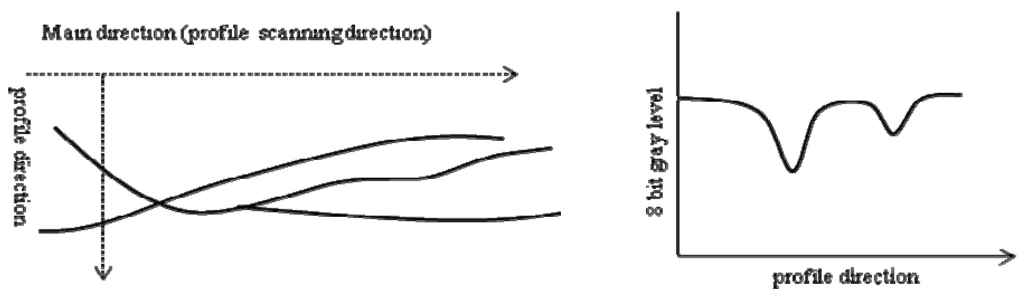

Fig. 4. Definition of profile direction and main direction: Right graph represent gray level profile

To extract vein patterns by maximum curvature points method, following steps are performed;

[Step1] Profile selection

Select a profile of which direction is normal to main direction

[Setp2] Curvature calculation

Using equation (6), curvature of the selected profile is calculated

[Step3] Find center of vein detection

At center of vein, curvature value becomes positive maximum. For localization of center of vein, find local positive maximum points of the curvature.

[Step4] Assign probability scores at the position of each center

At each center of vein, probability score is defined as

$$p = \max(k) \times W \tag{7}$$

It is multiple of local maximum curvature value and width of the concave curvature W.

[Step5] repeat [Step1] ~ [Step4] for each profile along with main direction

[Step6] repeat [Step1] ~ [Step5] for each main direction

Before extracting vein patterns, raw images were filtered by median filter to eliminate salt and pepper noise. And only pre-determined ROI region of the image was selected for vein extraction. Selected ROI region was 470x180 pixel size.

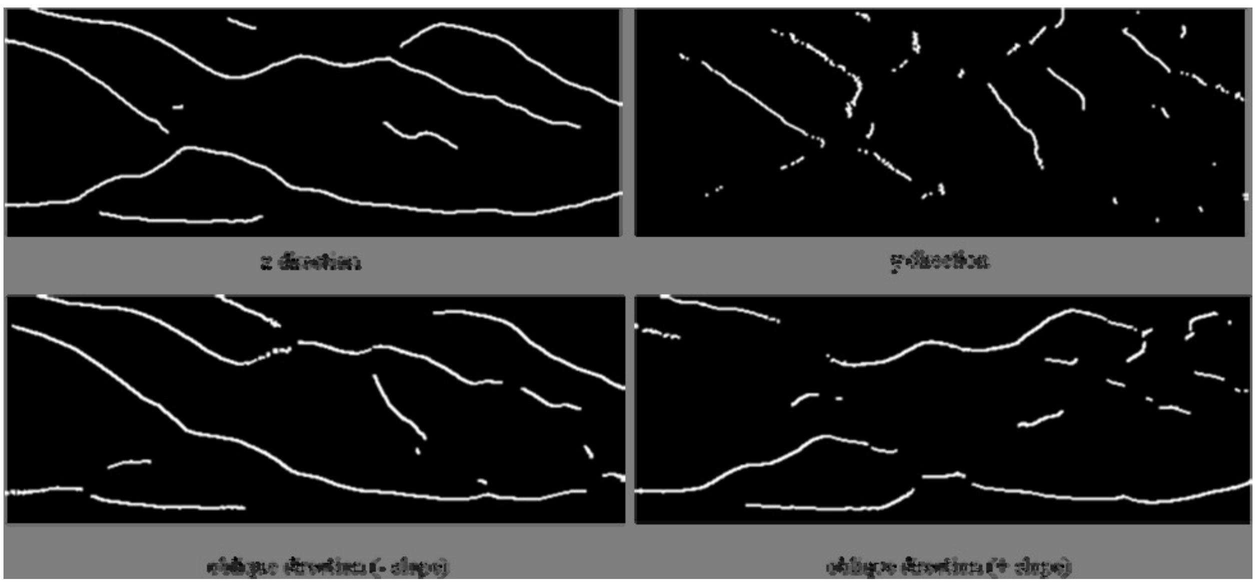

Fig. 5. Binarized probability score image: Each image is generated by vein extraction of noted direction.

Figure5 shows calculated probability score image of one index finger. Each image was binarized according to the threshold which was determined as 0.05 of maximum value. Figure6 is extracted vein image which union of each binarized probability image.

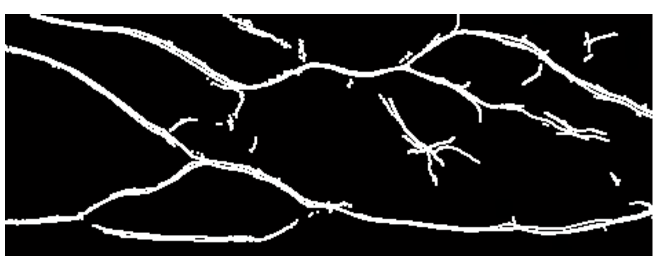

Fig. 6. Extracted vein patterns by combing probability score images

3. RESULTS

2D correlation values among extracted vein pattern images were calculated for each system. Figure7 is correlation distributions for suggested laser line light source system. And Figure8 is correlation distribution of conventional LED array system.

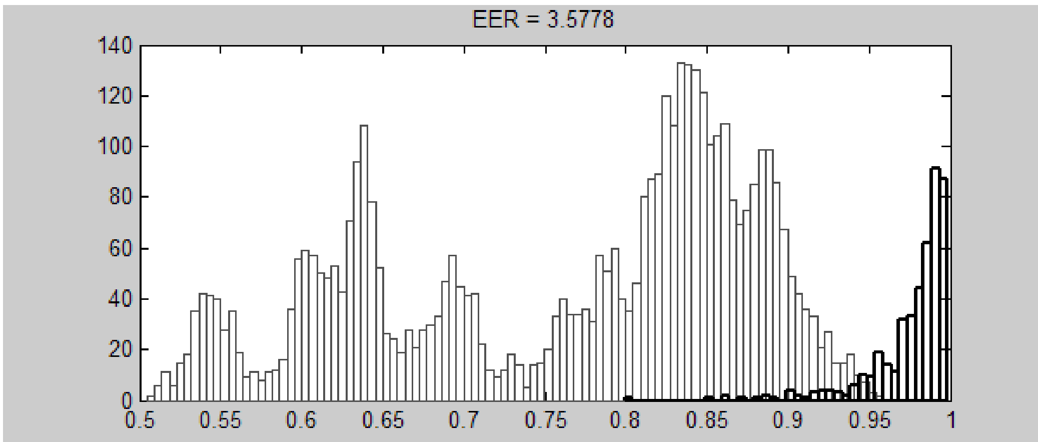

Fig. 7. Correlation distribution of suggested system

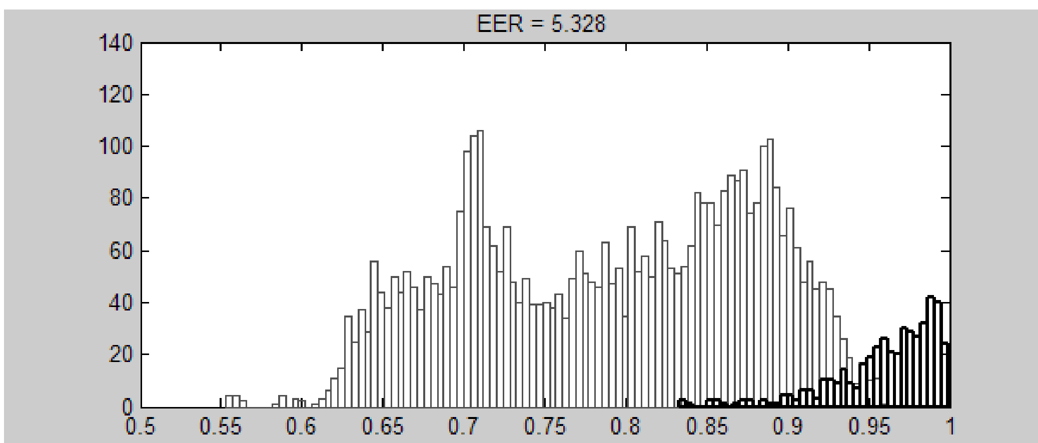

Fig. 8. Correlation distribution of conventional system

In both cases, equal error rate (EER) was calculated to evaluate matching power. Thick line bars in Figure7 and Figure8 are distribution of correlation between same finger images, and faint line bars are distribution of correlation between different finger images

EER value of proposed system was 3.6% and it was 5.3 % for conventional system. Although EER value of proposed system is lower than conventional system, it is hard to assert superiority of proposed system. Regarding overall shape of distributions, the performances of the systems are similar.

4. CONCLUSION

We proposed non-contact finger vein acquisition system. Unlike the conventional one, NIR laser and line generator lens was used in this system instead of LED array. Because the line laser source is continuous and equally distributed, almost uniform image of the vein is obtainable. Moreover, the proposed system doesn't need direct contact of skin with sensor. It is important merit when the system is used for multitude of users on a daily basis.

Overall performance of proposed Non-contact finger vein acquisition system was comparable to conventional one. EER of proposed system was slightly higher than conventional system.

Proposed system is more costly than LED array based conventional system due to expensive laser device. But by using low cost diode laser it is practicable to adopt proposed system, especially when it is in the need of sanitary biometric security system.

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