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Automatic Feature Extraction from non-uniform Finger Vein Image and its Application to Personal Identification

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Abstract

A new method to extract vein patterns from an unclear finger image is proposed. Finger vein pattern can be used for personal identification technology. The finger vein image that is captured with infrared light contains not only the vein patterns but also irregular shades and noises. They result from the different thickness between finger bones and muscles and, light intensity fluctuations also produce them. Therefore, the robustness and the tolerance to the uneven luminance and noises in pattern extraction algorithm are required.

In this paper, we propose a method for extracting the finger vein patterns in the image that is unclear and/or affected by the fluctuations of LED intensity. The method is based on special line tracking that starts at various positions.

The robustness of the finger vein extraction method against LED intensity fluctuation is tested and the result shows the performance of the method is more robust than the conventional method. In the evaluation of the personal identification using the proposed extraction method, the finger vein patterns of 678 people are collected. The performance is 0.145% equal error rate in the evaluation.

1 Introduction

Personal identification technology is applied to a wide range of systems such as an area access control, a PC login, an E-commerce, etc. Biometrics, which is the personal identification technology based on human physiological or behavioral traits, has been paid attention recently because traditional personal identification using keys, passwords, and pins cannot cope with theft, obliviscence and loss. In biometrics, there are several methods based on fingerprints, irises, voice, veins on the back of a hand and so forth. However, these methods sometimes have low confidentiality because features in the methods are exposed outside of the human body. These methods could be therefore susceptible to forgery.

To solve this problem, we proposed a biometrics system using finger vein patterns that exist inside of the human body [1]. In the system, an infrared light is transmitted from the back-side of a hand. A finger is placed between the infrared light source and a camera (Fig.1). As hemoglobin in the blood absorbs the infrared light, the finger vein patterns spread in the palm-side of a hand are captured as shadows. Fig.2(a) shows the example of the finger vein input device, and Fig.2(b)(c) show the examples of the captured finger vein images. A long side of the finger is along the horizontal direction, and the fingertip is located in the right side in the image.

In order to use the finger vein patterns for personal identification, they should be separated from other unnecessary organizations in the captured image. However, the image contains not only the vein patterns but also irregular shades and noises. These shades and noises result from the different thickness between the finger bones and muscles. And the contrast of the image fluctuate due to light intensity fluctuations.

Because of the existence of these shades and noises, some finger vein pattern in the image are observed clearly but others are not. Moreover, there is an additional problem that the number of veins, their locations and lengths are unknown. Therefore when some finger vein pattern can be emphasized by a conventional method using some filters, for instance, based on matched filter[3] and morphology, other irregular shades which are obstacles for the extraction can be also emphasized. Moreover, the large-scale properties of finger vein must be ignored.

In this paper, we propose a method for solving above mentioned problems. The method is based on special line tracking that starts at various positions.

2 Algorithm

In this section, the finger vein extraction algorithm is described.

The cross sectional profile of the vein is observed as a valley microscopically, because the vein part in the captured image is darker than its surroundings. Fig.3 shows the model of the cross sectional profile of typical finger vein. The line tracking is realized by checking

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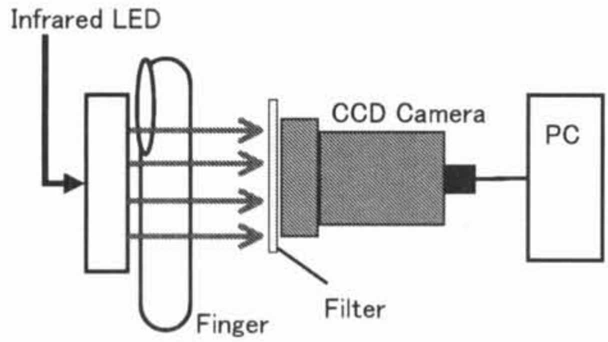


Figure 1: Principle of acquiring a finger vein image.

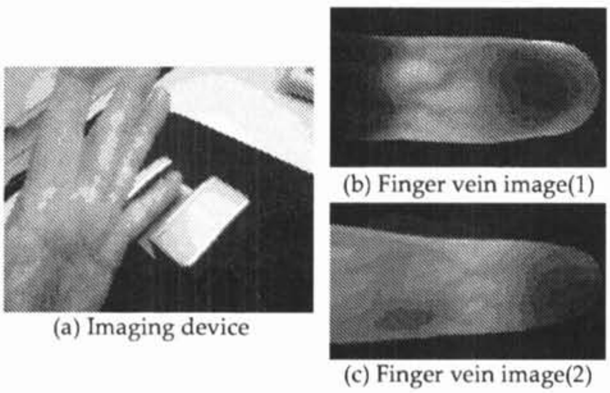


Figure 2: (a) Finger vein imaging device, and (b)(c) infrared images of the finger.

the depth of the valley in a local view and by moving the view toward a direction existing a deepest valley.

To solve the problem that the number of veins, their locations and lengths are unknown, the vein tracking starts at several random positions. Though this process have a side effect that the tracking might be done on the noise patterns, we can obtain the correct finger vein patterns as the ones having high frequency in the total number of pixels to be tracked.

This is based on the statistical principle that the pixels on the finger vein pattern are composed of the pixels having high frequency in the number of pixels tracked.

The algorithm of the method can be described as follows.

STEP 1 Initialize $L(x,y)=0$.

STEP 2 Carry out the dark line tracking.

STEP 3 Increment the $L(x,y)$ ($(x,y) \in$ the pixels which are tracked in STEP 2).

STEP 4 Repeat STEP 2 and STEP 3 N times.

STEP 5 Acquire the finger vein pattern from $L(x,y)$.

Where $L(x,y)$ is a position at which the number of line tracking is stored, N is the total number of trials of the line tracking. As finger veins are distributed everywhere in the image, the line tracking must be repeatedly carried out everywhere.

The total number of line trackings on dark parts is stored in $L(x,y)$. Because the finger vein pattern is composed of dark lines, it can be obtained as a chain of high value of $L(x,y)$.

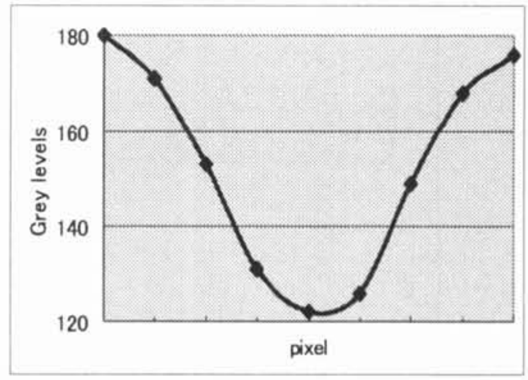


Figure 3: Cross sectional profile of typical finger vein.

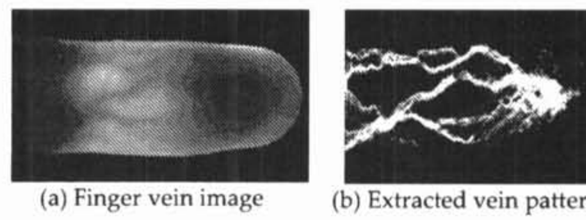


Figure 4: Result of extracted finger vein patterns;(a)Finger vein image. (b)Extracted vein pattern.

The feature extraction by using a conventional method such as convoluting the matched filter can emphasize the depth of the cross-section profile. However, the noises are also emphasized.

On the other hand, the proposed method emphasizes only the line patterns extracted b the number of tracking. Thus, if the cross sectional profile is observed the valley, irrespective of its depth or contrast, the feature can be emphasized evenly.

The dark line tracking of the above STEP2 can be executed as follows.

STEP2-1 Determine a initial location of the current tracking point (x_c, y_c) by using a random number.

STEP2-2 Evaluate the depth of the valley around the current tracking point by calculating the following equation named the line evaluation function:

$$\begin{aligned} V_l = \max_{(x_i,y_i)\in N_c} \{ & \\ & F(x_c+r\cos\theta_i-\frac{W}{2}\sin\theta_i,\ y_c+r\sin\theta_i+\frac{W}{2}\cos\theta_i) \\ & +F(x_c+r\cos\theta_i+\frac{W}{2}\sin\theta_i,\ y_c+r\sin\theta_i-\frac{W}{2}\cos\theta_i) \\ & -2F(x_c+r\cos\theta_i,\ y_c+r\sin\theta_i)\}. \quad (1) \end{aligned}$$

STEP2-3 If the maximum value of V_l is minus, then exit out of STEP2 as (x_c, y_c) is not on the dark line.

STEP2-4 Move the current tracking point (x_c, y_c) to (x_i, y_i) where V_l is maximum.

STEP2-5 Go to STEP 2-2.

F in the previous equation means the captured finger image, and $F(x,y)$ is the brightness of pixel (x,y). N_c is the set of pixels which the current tracking point (x_c, y_c) can move to. W is the width of investigating profile, r is the distance between (x_c, y_c) and the

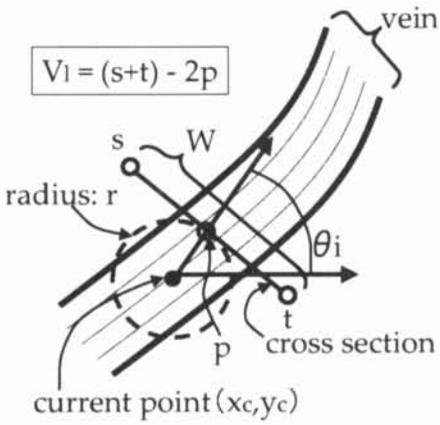


Figure 5: Line evaluation function

cross section. θ_i is the angles of line segment (x_c, y_c)-(x_c+1, y_c) and (x_c, y_c)-(x_i, y_i).

N_c expresses 8-neighbor area around a pixel (x_c, y_c). However, finger vein tend to be distributed to a long side of finger. Therefore, N_c is determined by considering the finger vein feature. That is, the upper and lower pixels of (x_c, y_c) in the 8-neighbor area around (x_c, y_c) is eliminated from N_c at random. Consequently, the current tracking point (x_c, y_c) is easy to move to the left or right direction. Moreover, the pixels already tracked by the current tracking point are eliminated from N_c.

Fig.5 shows an example of the positional relationship between the current tracking point (x_c, y_c) and the line evaluation function V_l. Since the pixel p is dark and the pixel s and t are bright on the vein, V_l has high value. This means that the dark line is distributed toward the direction θ_i.

3 Experiments

In this section, the finger vein extraction algorithm is tested by the two manners. Firstly, for investigating the robustness of the algorithm against the fluctuation of the LED light intensity, two algorithm, the proposed method and a conventional method are tested, and the results of the pattern extraction are compared. Secondly, for investigating the ability of identification by using finger vein patterns, using the finger vein images of 678 volunteers and the experiment is done.

In the following experiments, the captured finger images are 240×180 pixels in size, 8-bits per pixel. The algorithm's parameters are set at $N = 3000$, $W = 11$, $r = 1$.

3.1 Robustness against the light intensity fluctuation

In order to examine the robustness of proposed method against the LED light intensity fluctuation, we acquired the finger vein images with different LED light intensities and investigate the quality of the finger vein patterns extracted from these images.

For comparison, the conventional method which is based on the matched filter is also used for the finger vein extraction.

This experiment is carried out as follows.

1. Capture the finger vein images with varying the LED light intensity within the range that the finger vein can be visible.
2. Extract the finger vein patterns in those images using the proposed method.
3. Each pattern is compared to the pattern which is obtained in the brightest finger image and calculate the matching score(called mismatch ratio)[2].
4. Extract the finger vein patterns by using the conventional method and calculate the matching score in the same way procedure 2 and 3.

The conventional method is carried out convoluting two-dimensional filters. The filters are designed so that its profile can match the cross sectional profile of a typical vein. The filters consist of four different kernels, with each filter rotated to optimize for a different vein angular direction. All the filters are convoluted to the captured image independently, and all convolution values are added. Thus, the finger vein pattern is extracted by the matched filter.

The mismatch ratio is calculated as follows. Firstly, the extracted finger vein patterns are classified into three regions depending on the pixel value of the vein patterns; VEIN, AMBIGUOUS, and BACKGROUND. Secondly, the classified vein image are overlapped and compared pixel by pixel, and overlapped pixel values are compared each other. If a pixel classified into VEIN is overlapped a pixel classified into BACKGROUND, the pair of the pixels is said to be mismatched. The mismatched pixels are counted in the whole images. Finally, the mismatch ratio is acquired as (the number of mismatches) / (the total number of the pixels which are classified into VEIN in the two images). Since different finger vein patterns are compared, the mismatch ratio has high value.

Fig.6 shows the extraction results of the brightest image based on two methods, and Fig.7 shows the results of the darkest image.

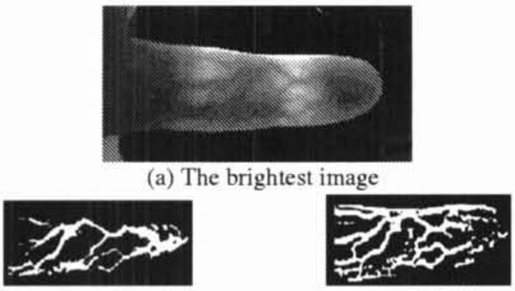
Especially, in Fig.7, the image(b) extracted by the proposal method is clearer than another(c) extracted by the conventional method.

Fig.8 shows the results of the robustness against the light power fluctuation. The horizontal axis is the darkness of image defined as $1 - \frac{(B_i - B_1)}{(B_{11} - B_1)}$, where B_i is the average intensity that is ith darkest in the captured images, thus $B_1 < B_2 < ... < B_{11}$. The vertical axis is the matching score by calculating the difference between the finger vein pattern extracted in each images and the finger vein pattern extracted in the brightest image.

As the captured image is getting darker, the mismatch ratio is increased in the both methods. The maximum value in the proposed method is 39%. In comparison with 52% obtained by the conventional method, the difference is 13%. This shows that our approach is more robust than the conventional method for LED light intensity fluctuation.

3.2 Personal identification using finger vein pattern

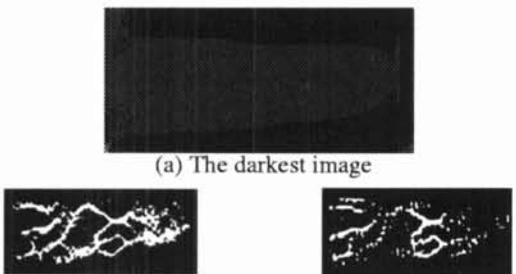
In order to examine the performance of the personal identification, we did an experiment for identifying all



(a) The brightest image

(b) proposed method (c) matched filter

Figure 6: Result of the extraction of the finger vein pattern in a brightest finger image.



(a) The darkest image

(b) proposed method (c) matched filter

Figure 7: Result of the extraction of the finger vein pattern in a darkest finger image.

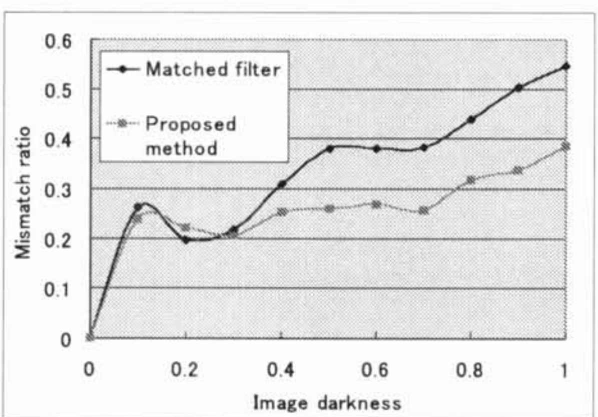


Figure 8: Robustness against the LED light intensity fluctuation.

these patterns by the method. The experiment is conducted using a database of finger vein images to evaluate false accept (FAR) and false reject (FRR) error rates. This database contains 678 different finger vein images, and there are two images per a finger. FAR and FRR are obtained as follows:

1. All finger vein patterns are obtained by the method described in section 2.

2. Two finger vein patterns of the same finger are compared and the matching scores are calculated.

3. Two finger vein patterns of the different finger are compared and the matching scores are calculated in all combinations.

4. FAR and FRR are calculated using those matching scores obtained at procedure 2 and 3.

The frequency of the mismatch ratios is shown in fig.9.

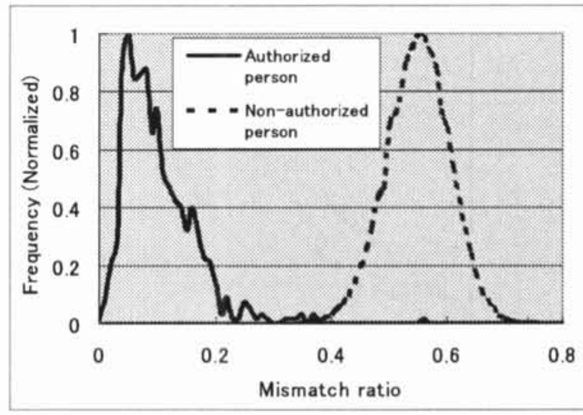


Figure 9: Mismatch ratio among same and different persons.

The result shows that the equal error rate (EER) is 0.145%, where EER is calculated by searching FAR so that |FAR−FRR| is minimum. On the other hand, EER in fingerprint systems has a range from 0.2% to 4% [4][5]. Thus, the result shows that the finger vein identification based on our approach is much effective.

4 Conclusion

We have proposed the personal identification system using finger vein patterns. To extract finger vein patterns from the unclear image, special line tracking is repeatedly carried out with changing its start point.

The evaluation of our approach against the LED light fluctuation shows that the our method is much more robust than the conventional method based on a matched filter.

Another experiment shows the EER is 0.145%, which means the personal identification by using finger vein patterns is very effective.

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