Hand Vein Recognition Based on Improved Template Matching

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Abstract: *An improved template-construction method for hand vein recognition is presented. The accomplishment of the new algorithm involves several steps. First, we design the power-controlled multispectral vein acquisition handset to establish high-quality hand vein database. Second, we propose an improved valley-shaped enhancement operator with NiBlack algorithm to realize vein segmentation. Third, we get a basic-shaped template after dilation and erosion operation in the four neighborhoods firstly, and then we can get the final matching template combining all the shapes after the process of filling the connected region whose threshold is smaller than the one we set according to the experiment effect. Finally we design the hand vein recognition experiments using the designed template and traditional template respectively. The recognition rate of the improved template is 96.6% under the 1:1 mode and 95.75% under the 1:N mode while the recognition rate of the traditional template is 89.2% under the 1:1mode and 88.2% under the 1:N mode.*

Keywords: *Vein recognition, Template matching, Power-controlled, Multispectral, Vein segmentation, Enhancement operator.*

Introduction

In the present, hand vein recognition has become one of the focuses in the field of biometric identification with the character of noncontact inspection, uniqueness, universality, stability and scalability hand [5, 9, 11, 12]. The method used for vein feature description and recognition currently can be divided into four kinds generally: vein recognition based on morphological characteristics, vein recognition based on spatial and frequency feature, vein recognition based on subspace feature and vein recognition based on statistical features [3].

Many biometric approaches are based on templates matching [2]. The method of template matching mentioned in the paper is based on morphological characteristics which can be mainly divided into point features and line features: vein recognition based on the line features mentioned refers to ab series of pre-process including image segmentation, refinement and deburring to get the skeleton image; while the recognition based on the points features refers to the process to extraction of endpoint and intersection from vein image which is used as the vein feature for matching.

Concluding from the morphological characteristics based vein recognition, we find that the accuracy of recognition is mainly determined by the quality of vein image obtained and the accuracy of feature extraction. On the basis of studying the morphological characteristics shown in Fig. 1, the paper proposes design of multispectral LED (light-emitted diode) groups with power-controlled set to realize high-quality hand vein image acquisition, then develops a method to extract hand vein ROI (region of interest) inspired by the one used in palm contour extraction from Li et al. [8] and gets good extraction result. Then we come up with a new valley-shaped area enhancement operator combing with the method valley-shaped and NiBlack which get good segmentation effect, then get a high-quality and compressed vein spread image after operations including filtering, noise-removing, deburring and cutting. The test of the improved template matching method gets good result after adopting the method mentioned.

Establishment of experimental database

Vein recognition has broad application prospects because of its unduplicated and unchangeable features. It is also hard to be damaged than fingerprint recognition. But there is still not a complete and public database of hand vein image. Therefore, to obtain high-quality hand vein image is the most important prerequisite for the follow experiment design. The current vein image acquisition method concentrates on transmission imaging mode uses single spectrum of near infrared LED as light source which has some shortcomings:

1) unable to ensure the quality of vein image without taking the optical properties of hand tissue into full consideration;
2) unable to ensure the generality of vein image capturing device without taking the thickness of different samples into full consideration.

Based on the above disadvantages of the current devices, we design an acquisition device made up of multispectral LED groups with power-controlled set shown in Fig. 2 on the basis of taking the optical properties of hand vein biological tissues into account, the three main characters of the device are:

1) the LED groups are consisted of infrared LED at three different wavelength that are in cross order;
2) the controlling power signal is triangular signal shown in Fig. 3 whose output power for LED is controllable to meet with the different samples;
3) adopt MCU to achieve the synchronization on power of LED groups and CCD (charge coupled device) to realize high-quality vein image acquisition.

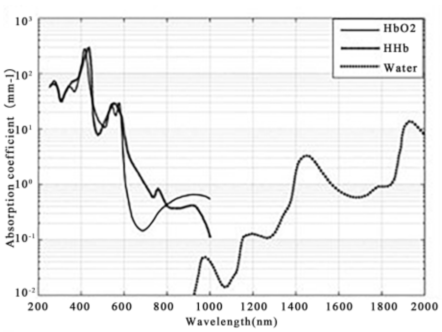

Fig. 1 Absorption coefficients of HbO2, HHb and water

Fig. 2 Vein capture device

As for the establishment of hand vein image database, we choose 50 volunteers taking the difference of hand thickness, ages and sex into consideration to establish a sample database shown in Fig. 4 including 500 images of high quality with the device.

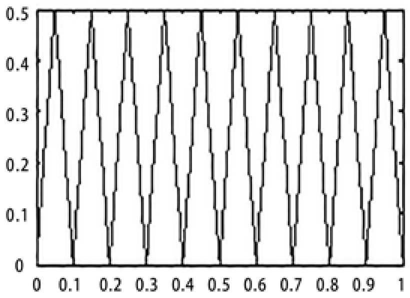

Fig. 3 The controlling signal on the LED groups

Fig. 4 Vein images of one volunteer

Experiments of pre-process and analysis

Before the feature extraction on the hand vein images, it is essential to go on some pre-process on the vein images to get the skeleton image of hand vein for later process. The pre-process refers to ROI location, size and grey scale normalization, image segmentation, removing noise, refinement and deburring.

ROI extraction

ROI extraction is a process of removing the background location and non-vein image information so that the vein image information for research can be retained to the most degree. After a deep study on the method by Kim et al. [6] we try to develop a method to extract hand vein ROI inspired by the one used in palm contour extraction from Li et al. [8] and get good extraction result.

Before getting the ROI location, we firstly decrease the noise influence by process of median filtering, and then adopt fixed threshold method (the thresh is set 0.5 which is determined by the experiment effect) to get binary image from the original grey image, then we extract the edge region by process of Sobel operator, then according to the step from Li et al. [8] we get the multiple tangent circumscribed circles along the edge line, then we set a rule related to the number of intersections between the circumscribed circle and edge line to determine the location of angle points, we should get the slope ratio of the middle vertical line after getting the middle vertical line between the found angle points to make rotation correction on the original vein image, then we could get the ROI location in the end (the size of the ROI we set is 180×180). Fig. 5 shows the procedure of ROI extraction.

After observing the experimental results, we conclude that the method we adopt overcome the shortage of uneven translucent and unexpected rotation when establishing database.

a) b) c) d) e)

Fig. 5 The process of ROI extraction

a) original hand vein image; b) vein image binarization; c) the edge figure; d) the angular point positioning image; e) the ROI region

Vein image normalization

After getting the ROI location, we find that the size of ROI is still bigger than analysis demand which may increase the time-consuming degree of the later analysis. We adopt normalization method both in size and in grey value after analysis on the histogram distribution of the ROI image. We adopt bilinear [1] interpolationin the process of size normalization to avoid the missing of useful information of vein image and self-defined linear grey transform algorithm to increase the image contrast and achieve uniformity of grey value.

Vein segmentation

After process of ROI extraction and vein image normalization, process of vein segmentation is necessary so that we can extract the skeleton feature of vein image. The commonly used methods cover mean threshold segmentation, OTSU and NiBlack [4] whose effect is not entirely satisfactory for the reason of importing fake vein information. Inspired by the method of enhancement algorithm based on the valley-shaped area with Canny gradient operator [7] we come up with a new valley-shaped area enhancement operator as shown in Fig. 6 combing with the method above which gets good segmentation effect. And according to the ROI extraction result and taking decrease on the time-consumption and complexity of algorithm into consideration, the window size of the operators we set is 11×11 and there are altogether 4 operators in four different directions.

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 3 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -4 & -5 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -4 & -5 & -4 & 3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -5 & -4 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 2 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

a)

$$\begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 2 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -5 & -4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -4 & -5 & -4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -4 & -5 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 3 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

b)

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & -3 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 2 & 3 & -5 & -5 & -5 & 3 & 2 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & -3 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

c)

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 2 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 3 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & -5 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -3 & -6 & -3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & -5 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 3 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 2 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

d)

Fig. 6 Valley-shaped area enhancement operator
(a) 45° operator; (b) 135° operator; (c) horizontal operator; (d) vertical operator

Striking the convolution of the self-defined operator and each pixel's neighbor 11×11 area in the image we can find from the convolution result that the convolution in the ridge location is negative because the grey value is larger than other area. On the contrast the convolution of valley-shaped area is positive, and the convolution of flat area is nearly equal to zero. In summary, the process of valley-shaped operator can retain the effective vein and pseudo-vein information area while excluding obvious non-vein area, then we will get the enhanced vein area by the process of mean threshold segmentation method and try NiBlack to get more detailed segmentation by cutting the pseudo-vein information, the final hand vein image after segmentation process is the one for later analysis.

The specific procedure of segmentation is:

1. Striking the convolution of the self-defined operator and each pixel's neighbor 11×11 area in the image to get the value in each convolution getting step $F_i(x, y)\,(i = 1, 2, 3, 4)$, record the maximum one of $F_i(x, y)\,(i = 1, 2, 3, 4)$:

$$G(x, y) = Max\{F_1(x, y),\ F_2(x, y),\ F_3(x, y),\ F_4(x, y)\} \tag{1}$$

2. Removing the obvious non-vein area to get a new vein image:

$$G'(x,y)=\begin{cases}G(x,y) & G(x,y)>0\\ 0 & else\end{cases} \tag{2}$$

3. Adopting mean threshold segmentation method to get the non-zero points number *Num* and average grey value *Tavg* of non-zero points:

$$Tavg = sum(G'(x,y))/Num\,. \tag{3}$$

Set the grey value that is larger than *Tavg* of $G'(x, y)$ zero to get $G''(x, y)$ including some pseudo-vein information, and then set a two-dimensional matrix $G_{BW1}(x, y)$ whose size is the same as original vein image to store the value as follows:

$$G_{BW1}(x,y)=\begin{cases}1 & G'(x,y)>=Tavg\\ 0 & else\end{cases} \tag{4}$$

4. Moving the template matrix sized 11×11 in image $G''(x, y)$ and calculating the mean value and standard deviation and then get the corresponding threshold value of every point according NiBlack in the image, then set another two-dimensional matrix $G_{BW2}(x, y)$ whose size is the same as $G_{BW1}(x, y)$ to save the current image:

$$Avg(x,y)=\frac{1}{11\times 11}\sum_{i=x-5}^{x+5}\sum_{j=y-5}^{y+5}G''(i,j) \tag{5}$$

$$\sigma(x,y)=\frac{1}{11}\sqrt{\sum_{i=x-5}^{x+5}\sum_{j=y-5}^{y+5}[G''(i,j)-Avg(x,y)]^2} \tag{6}$$

$$T(x,y)=Avg(x,y)+\alpha\times\sigma(x,y) \tag{7}$$

$$G_{BW2}(x,y)=\begin{cases}1 & G''(x,y)>T(x,y)\\ 0 & else\end{cases} \tag{8}$$

5. Adding the matrix of $G_{BW1}(x, y)$ and $G_{BW2}(x, y)$ to get the vein image covers the obvious vein information without the non-vein and pseudo-vein information.

$$G_{BW}(x,y)=G_{BW1}(x,y)+G_{BW2}(x,y) \tag{9}$$

6. After analysis on $G_{BW}(x, y)$ we find that there still is some false-detection parts with small area of connectivity and they are independent of each other. We set the thresh from experiment data to cut the region whose square is smaller than the thresh to get the final high-quality segmentation vein image.

We can conclude from the experimental result that the method we define get better segmentation result than the classical method including mean threshold segmentation, OTSU and NiBlack. Fig. 7 shows the segmentation effect of different method.

a) b) c) d) e)

Fig. 7 Vein segmentation algorithm comparison
a) ROI of vein image; b) process of mean method; c) process of NiBlack;
d) process of OTSU; e) process of the proposed method

Vein refinement and deburring

Observing the vein image after segmentation, we can find that the spreading vein is thick resulting easily influenced by capture lighting situation, so we adopt refinement method to delete the edge pixels of the vein to get the vein morphological information as wide as one pixel, then we can remain the original topology structure, length, orientation, the end points and crosspoints basically unchanged as well as compress the vein information to reduce the time-consumption of recognition.

There is still some burr in the vein image after refinement which will reduce the accuracy of the feature extraction, so we set method to smooth the vein distribution by deburring. Fig. 8 shows the procedure of refinement and deburring. The specific procedure is searching the endpoints of the vein skeleton image and mark the points searched, then go on searching for the next points and record the distance of the current point and the former point, then analyze the distance change regulation to get a threshold (we set the threshold as 15 in our experiment according to the later recognition rate after the "threshold" process), then cut the vein whose threshold is smaller than the set threshold and we will get the vein image for feature extraction.

a) b) c)

Fig. 8 Vein refinement and deburring
a) vein after segmentation; b) vein after refinement; c) vein after deburring

Establishment of template database

The matching method we choose is vein matching based on geometric feature which includes point feature and line feature of the vein. The typical procedure of point feature-based matching refers to getting the key points of vein information including endpoints and crosspoints mainly, then get the feature description about the spread of the key points in the processed vein image, so the shortcomings of point feature-based method is any little but unnoticed change in every processing step results in the different feature description which means an extremely low recognition rate. While the line feature-based matching refers to a series of pre-process to extract the skeleton information of the sample and to establish the template for matching in the end, and the matching procedure is about scanning every test sample with the template to get the matching similarity value, the sample with the largest value is the matching result, so the anti-interference ability of line feature-based matching is far better than that of point-feature based matching because of the focus on the overall morphology feature of vein but not the specific points. So we do some research on the line feature-based matching method.

After some comparison and observation experiments, we find that there still exist little spin and offset for the vein image of the same person although with the pre-process of offset correction in the procedure of ROI location, so it may lead low recognition rate on the condition of using single skeleton image for template building. The traditional template-building method is making use of the single skeleton image mixed with other four images after rotation of -2, -1, 0, 1, 2 degree about the mentioned single one, then add the five vein images to get the final matching template [15]. The obvious shortcoming of the traditional method is without taking the difference of capture time and the lighting condition in different time into consideration so that unable to get high-quality templates which lead to low recognition rate.

The concrete steps to build the improved template are shown in Fig. 9: select randomly five vein images captured at different moment of the same sample, get the skeleton images of the selected ones after a series of pre-process mentioned above and add the skeleton ones to get the initial template, a basic-shaped template can be got after dilation and erosion operation inner the four neighborhoods, the final matching template combining all the shapes can be got after the process of filling the connected region whose threshold is smaller than the set one.

Matching experiment and result analysis

Theory of template matching

The main idea of template matching is getting the skeleton image of hand vein after a series of pre-process refers to ROI location, size and grayscale normalization, image segmentation, removing noise, refinement and deburring.

We define the skeleton image as $input(x, y)$ and the size of it as $M \times N$. The matching template whose size is the same as the input image is defined as $Model_i(x, y)$ and $\{i = 1, 2, 3, ..., n\}$, the number of pixels in an input skeleton image is:

$$len = sum(input(x, y) = 1) \tag{10}$$

The matching process of the input image $input(x, y)$ and the matching template $Model_i(x, y)$ is:

$$match_i(x, y) = input(x, y) + Model_i(x, y) - input(x, y) \oplus Model_i(x, y) \tag{11}$$

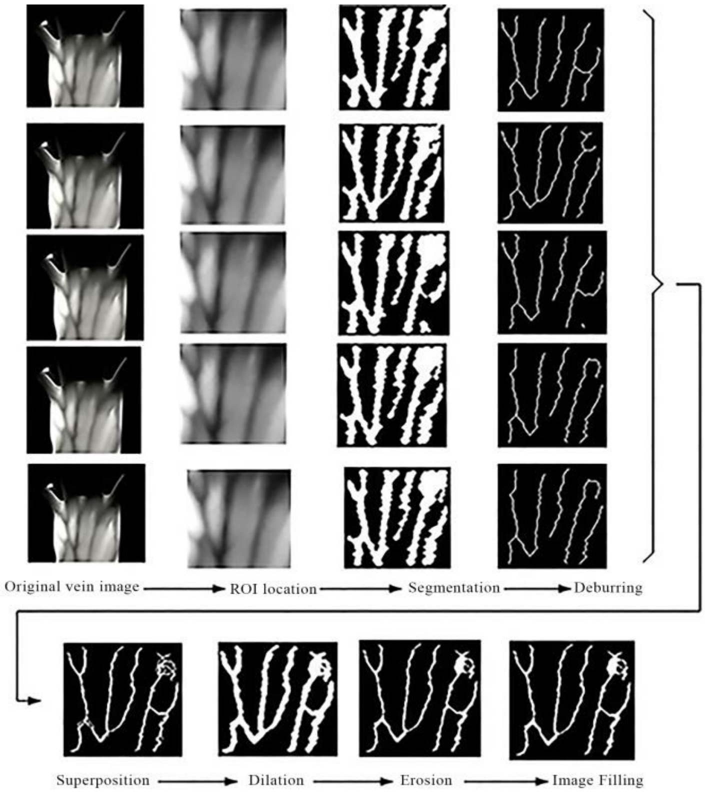

Fig. 9 Template forming model

The mark + stands for the OR operation of the corresponding points and the mark $\oplus$ stands for the XOR operation of the corresponding points, so we define the number of the matching ones of the corresponding points as:

$$len_{match}(i) = sum(match_i(x, y) = 1) \tag{12}$$

And we can get the definition of the matching rate between $input(x, y)$ and $Model_i(x, y)$ from the above formulas:

$$rate_{match}(i) = \frac{len_{match}(i)}{len} \tag{13}$$

Calculating the matching rate between $input(x, y)$ and every template in the database to get the set of the recognition rates, and the principle is that the biggest one of the set is the best matching ones, and the main matching steps are shown in the Fig. 10.

$$result = \max(rate_{match}(i)), \quad i = 1, 2, 3, ..., n \tag{14}$$

Experiment and results

For the purpose of comparing the recognition rate of adopting the traditional template and the improved template, we set two experiments of which the condition is 1:1 (One-to-One matching involves a process of verification) and 1:N (One-to-Few matching involves a process of identification) mode, the procedure is shown in Fig. 10 and the concrete results are shown in Table 1 and Table 2.

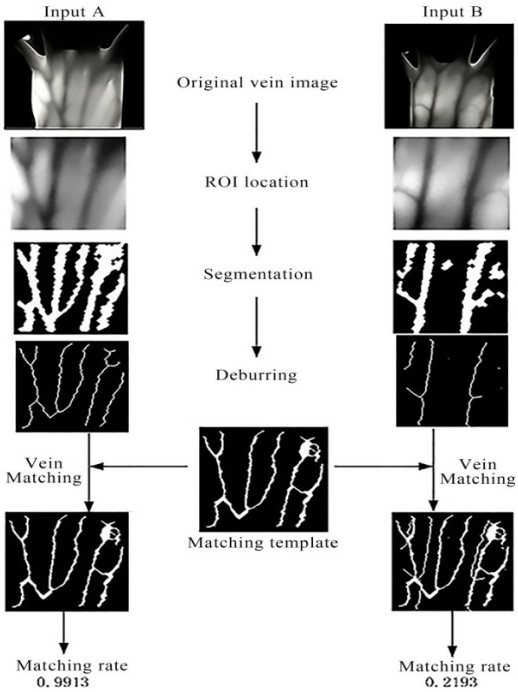

Fig. 10 Vein matching process

Table 1. Experimental results in 1:1 matching mode

Template selected	Success counts	False counts	Recognition rate
Traditional	178	22	89.2%
Improved	192	8	96.6%

Table 2. Experimental results in 1:N matching mode

Template selected	Success counts	False counts	Recognition rate
Traditional	353	47	88.2%
Improved	383	17	95.75%

Comparing the condition the charts show, we can conclude that the recognition rate of adopting the improved template is much better than that of the traditional template, the concrete change is that the recognition rate improves from 89.2% to 96.6% in the mode of 1:1 and improves from 88.2% to 95.75% in the mode of 1:N, and it is fully proved that the improved template has good effect. On the other hand, We can find that the recognition rate with the improved template still can't meet with the demand of application, the reason we analyze is that the time-consumption of matching is too long, we have come up with a new method combining 2DPCA and 2DFLD [10, 14] to solve the problems, and the detailed information of the method, please view the paper [13] we have published.

Conclusion

In order to solve the problems of low recognition rate with the traditional template, we introduce an improved template-construction method for hand vein recognition, the accomplishment of the new algorithm involves several steps. First, we design the power-controlled multispectral vein acquisition handset to establish high-quality hand vein database. Second, we propose an improved valley-shaped enhancement operator with NiBlack algorithm to realize vein segmentation. Third, we get a basic-shaped template after dilation and erosion operation in the four neighborhoods firstly, and then we can get the final matching template combining all the shapes after the process of filling the connected region whose threshold is smaller than the one we set according to the experiment effect. Finally we design the hand vein recognition experiment using the designed template and traditional template respectively. The recognition rate of the improved template is 96.6% under the 1:1 mode and 95.75% under the 1:N mode while the recognition rate of the traditional template is 89.2% under the 1:1mode and 88.2% under the 1:N mode. We expect that the method proposed in the paper could be beneficial in a variety of other applied optical problems and pattern recognition problems related to template matching.

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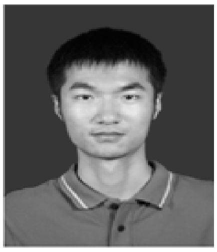

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