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Fingerprint Refinement Model Based on Improved OPTA

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Abstract. Image thinning is an important part of fingerprint preprocessing technology. OPTA method is a classic fingerprint image thinning method [1-2]. However, the thinning algorithm and improved algorithm of OPTA have some problems such as unsmooth fingerprint image, more burr and low thinning quality. In order to solve this problem, this paper reconstructs the thinning module and proposes a new thinning algorithm. The simulation results show that the algorithm can better meet the thinning requirements, ensure that the fingerprint skeleton is in the ridge center line position, reduce the occurrence of burr, make the thinning lines more uniform and clear, and greatly improve the thinning speed, shorten the processing time, thus saving the required memory space.

Keywords: algorithm, binarization, OPTA, refinement

1 Introduction

In domestic at present, the fingerprint recognition because of its long development time, and the development speed is faster, and after years of market promotion and application, in the aspects such as access control, attendance, in-room safe, identity authentication has more mature products [3-4], at the same time because of its low cost compared with other identification technology, more and accepted by the user, so the current domestic application of fingerprint identification of the biometric applications about 90% of the market [5]. As people pay more and more attention to the security and privacy of personal life and property, fingerprint identification has been widely used.

Therefore, the market for fingerprint application is more extensive, so the problem of fingerprint storage will gradually emerge. A complete fingerprint identification system should include image acquisition -- image processing -- functional extraction -- functional coding -- pattern matching and other processing [6]. Fingerprints can be stored in an image format via a fingerprint acquisition device. Typically, fingerprint images take up more space and the pixel information in the image is not suitable for computer analysis or matching. According to this problem, this paper introduces a fingerprint refinement scheme, which can greatly reduce the memory of fingerprint, and optimize the original classical algorithm, so that the operation speed is faster and the effect is more perfect.

Section 2 introduces the classical OPTA thinning algorithm and the improved algorithm, and describes their characteristics. Section 3 introduces the establishment of fingerprint thinning model and analyzes

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the improved thinning algorithm. In Section 4, simulation images and data tables are used to verify the effectiveness of the algorithm. Section 5 introduces the development prospect of fingerprint thinning algorithm. Section 6 summarizes the whole paper and draws a conclusion.

2 Related Work

The classic OPTA refinement algorithm binarizes a graph [7], and then scans the image from left to right from top to bottom starting from the value in the upper left corner of the fingerprint image digitization matrix. If the scanned pixels are not background points, then 10 adjacent pixel points are selected from this point as the center.

Then extracted pixels and set a good eight elimination of 3 * 3 matrix to compare, if any of these and a matching, is the second step, and two reserved matrix (a reservation is 3 * 4 matrix, a matrix are reserved 4 * 3), compared with one of the match is successful, the keep the pixels, or delete the pixels, in accordance with this method for thinning binary graphics [8], until not pixels can be refined.

Although the classic OPTA algorithm can meet four basic requirements (1. Image refinement should retain the connectivity of the original graphics. 2. The fining graph should be the center line of the original image as far as possible [9]. 3. The fining result should be as wide as possible as a line image of pixel. 4. Details should be retained [10-11]). But the algorithm in the three prong thinning is not entirely as desired, its ridge line is not very smooth, a little burr, the refinement don't assembly to the back of the fingerprint feature extraction and fingerprint matching brings great difficulties, moreover, for the first of two template operation, its running speed can also be affected, and the additional terms of template some loose, is likely to slash refinements generate pairs of pixels to refine the results. In literature [1] USES a thinning algorithm based on the eight neighborhood look-up table, the algorithm without burr phenomenon after refining, but complex lookup table structure, refined speed slow, literature [2-3] for the OPTA optimization algorithm, the algorithm adopts the method of template matching, according to the pixel neighborhood of image processing, realize the basic skeleton processing meets the demand of refinement, though the speed faster, but refinement is not complete, and is not smooth, have a burr phenomenon.

3 System Model

Fingerprint image can only be recognized by the system after image preprocessing. The main content of image preprocessing includes fingerprint segmentation, binarization, filter enhancement and thinning.

3.1 Model Assumptions

Assume that the image quality is the same and standard. Assume that the picture information is intact and little is missing. Assume that all fingerprint types are within the normal range.

3.2 Normalization and Cutting

By reducing the image standardization, the byte size of the image can be effectively reduced and the noise reduction function can be achieved [12]. You need to standardize the image and then divide it up. The collected fingerprint images are normalized to prevent unwanted noise by adjusting the gray mean and variance of the fingerprint gray images once, so that the collected fingerprint images have the expected variance and mean values. Fingerprint normalization does not change the quality of fingerprints, so it is helpful for subsequent fingerprint processing. Normalization can adjust the mean and variance of fingerprint grayscale to the standard state and prevent unnecessary noise.

The fingerprint is divided into small pieces of W*H. Let the gray value of pixel points in the image be denoted by I(i, j) and the normalized image is denoted by G(i, j), the gray mean value and variance are respectively M_i and V_i, then the normalization algorithm is as follows:

First, calculate the mean value and variance of image gray scale:

$$M_i = \frac{1}{WH}\sum_{i=0}^{H}\sum_{j=0}^{W} I(i,j). \tag{1}$$

$$V_i = \frac{1}{WH}\sum_{i=0}^{H}\sum_{j=0}^{W} \left(I(i,j) - M_i\right)^2. \tag{2}$$

After specifying the expected image variance and mean value, the normalized image can be calculated as follows:

$$G(i,j) = \begin{cases} M_0 + \sqrt{\dfrac{V_0\left(I(i,j)-M_i\right)^2}{V_i}} & I(i,j) > M_i \\ M_0 - \sqrt{\dfrac{V_0\left(I(i,j)-M_i\right)^2}{V_i}} & I(i,j) \le M_i \end{cases}. \tag{3}$$

Where, M_0 and V_0 are the expected mean value and variance (M_0=150, V_0=2000).

After the image is standardized, it is cut out to distinguish the foreground color from the background color. The segmentation method used is based on the local gray variance of the image segmented according to the multi region threshold. The effect of multi region segmentation depends on the size of the region, and the fingerprint region is best divided into ridge and valley. Please select an area size of 3 * 3. According to the mean and variance of the region, the segmentation will be carried out several times. The image is divided into 3 * 3 squares, and the average and variance of each block are calculated. The result of image standardized clipping is shown in Fig. 1, which is a comparison between the original image and the first two fingerprint images.

Fig. 1. Original fingerprint image (left) and normalized cut image (right)

3.3 Binarization

The direction of figure. The fingerprint image has unique characteristics, in which the direction and texture of the fingerprint are very strong, so it can be regarded as a kind of fluid model, which can be specially expressed as the direction map. The directional pattern represents the tangent direction of the pixels in the fingerprint image, ridges or valleys with small fingerprints, because the fingerprint orientation of the fingerprint image is almost the same in a small area. Therefore, in calculations, the orientation of a pixel is usually replaced by the orientation of a small piece with a dot.

For a more intuitive representation, use the fingerprint image as a template and draw a circular area that represents the fingerprint. Here, the patch in the sector area represents the patch after the fingerprint is divided into blocks. The breakdown is shown in Fig. 2.

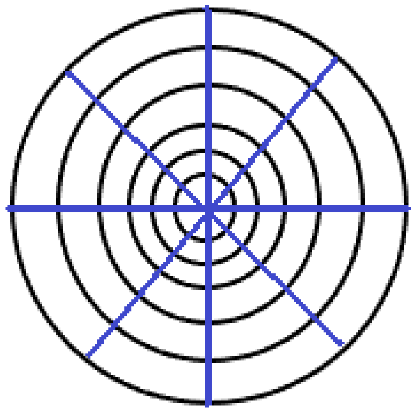

Fig. 2. Fingerprint patch model

The statistics of each patch are calculated based on the original grayscale fingerprint image, and the difference in the direction of each patch determines the direction of the patch.

Binarization based on direction field. In order to estimate the direction field, the direction of fingerprint ridge is divided into the following eight directions (Fig. 3):

3		4		5		6		7
2		3	4	5	6	7		8
		2				8		
1		1		x		1		1
		8				2		
8		7	6	5	4	3		2
7		6		5		4		3

Fig. 3. Eight directions at one pixel

The average filtering is first performed on the image, and then the eight passes of each pixel in the image are calculated to determine the direction of the ridge line of the pixels in the pixel-centered 9 * 9 window. The processed grayscale values, that is, the grayscale values of 1 to 8 pixels in the photo, are deleted. This is the maximum (summax) and minimum (summin), the sum of the maximum, minimum and 4I(x, y) is greater than (3*sum/8), the elevation direction of the pixel is equal to summin, otherwise is equal to summax. After determining the direction of the ridge, the image is binarized by the direction field.

3.4 Remove Burrs and Cavities

For various collection reasons (oil, moisture, etc.), fingerprints are attached and damaged, affecting subsequent feature extraction and recognition, reducing noise in the original image, and improving the contrast between ridges and valleys to repair the fingerprint image bulge. The broken part removes the intersecting part of ridge or valley from the fingerprint image, and ensures as much clear fingerprint texture structure as possible from the original fingerprint image to ensure the reliability of fingerprint extraction. If the value of the current position point is 0 (background), then the sum of the four adjacent points of the point (top, bottom, left, right) is greater than 3. This is a minor problem. The hole is judged by the fact that the point is white (background) and surrounded by black (foreground). If the sum of the two is 0, it is empty. The first two effects are shown in Fig. 4. On the left is deburring, and on the right is deburring.

Fig. 4. Remove burrs and cavities

3.5 Refinement Based on the Improved OPTA Algorithm

In the improved OPTA algorithm, the difference between the two templates is eliminated. Use the integrated 4 * 4 templates, 8 eliminate templates, 6 retain templates, and the template structure is shown in Fig. 5, Fig. 6, and Fig. 7.

P_1	P_2	P_3	P_{13}
P_4	P_5	P_6	P_{14}
P_7	P_8	P_9	P_{15}
P_{10}	P_{11}	P_{12}	X

Fig. 5. Template 4*4

0	0	0
X	1	X
1	1	1

0	X	1
0	1	1
0	X	1

1	1	1
X	1	X
0	0	0

1	X	0
1	1	0
1	X	0

X	0	0
1	1	0
X	1	X

0	0	X
0	1	1
X	1	X

X	1	X
0	1	1
0	0	X

X	1	X
1	1	0
X	0	0

Fig. 6. Eliminates the template

X	1	X	0
0	1	1	0
X	1	X	0
X	X	X	X

X	X	0	0
0	1	1	0
X	X	1	X
X	X	X	X

X	X	1	X
0	1	1	0
X	X	0	0
X	X	X	X

X	0	X	X
1	1	1	X
X	1	X	X
0	0	0	X

X	0	X	X
X	1	X	X
1	1	0	X
X	0	0	X

X	0	X	X
X	1	X	X
0	1	1	X
0	0	X	X

Fig. 7. Preserves the template

First, compare the images of the eight erasure templates shown in Fig. 5. If it doesn't match, keep point P. If there is a match, enter the next match link and compare the point to be tested with the item in Fig. 6. It compares the six reserved templates, retaining points if they match and deleting points in the test if they don't. When the point P to be measured is detected, it enters the next point P cycle. The improvement process is shown in Fig. 8, The effect of fingerprint refinement is shown in Fig. 9.

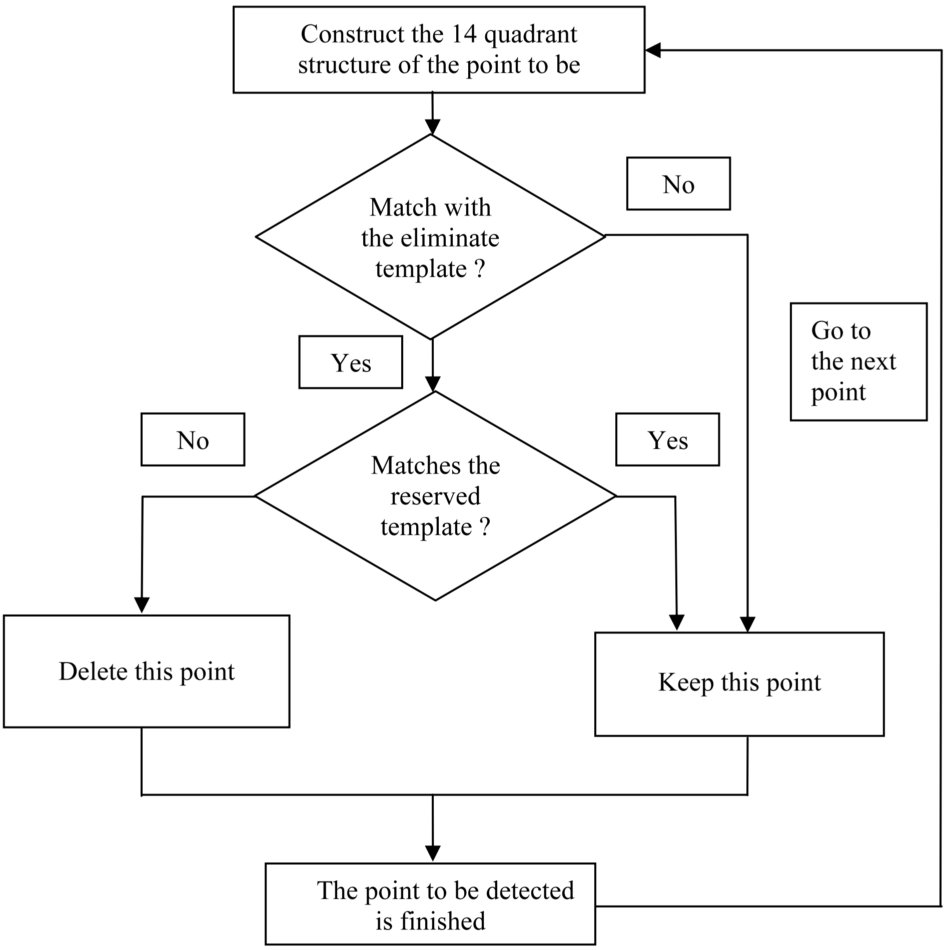

Fig. 8. Illustrates the refinement process

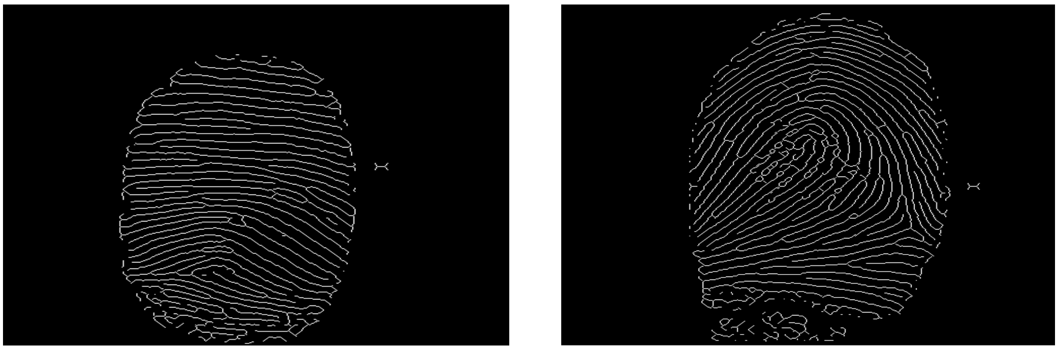

Fig. 9. Effect of refining

The fine tuning of fingerprint image greatly reduces the storage space of fingerprint image, eliminates a lot of redundant information, and improves the efficiency of fingerprint recognition.

4 Result Analysis

The experiment is carried out in MATLAB. First of all, a small oblique line (Fig. 10) is used to show the superiority of the improved OPTA thinning method.

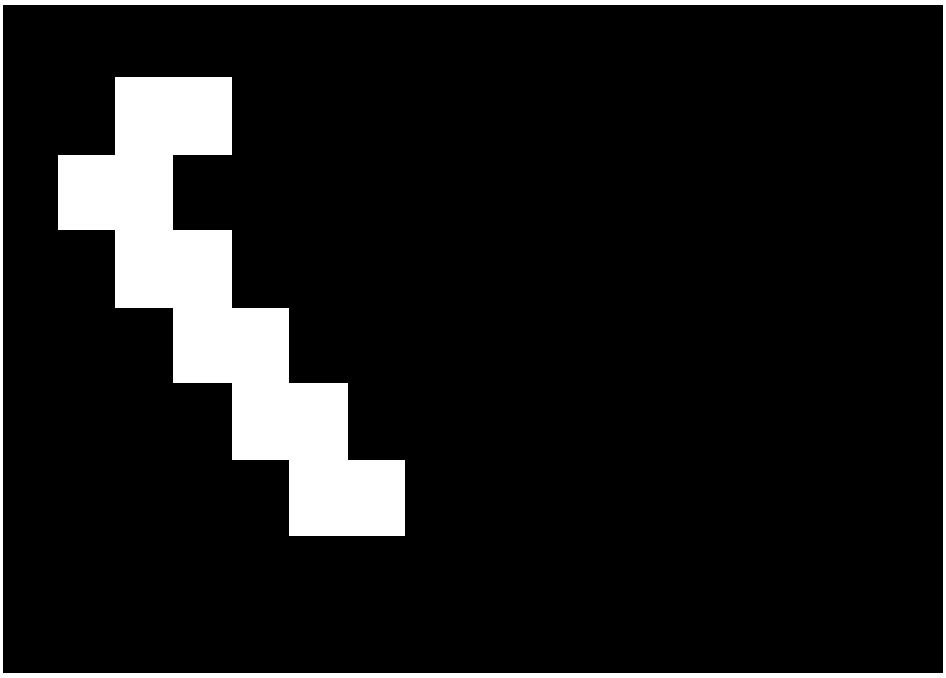

Fig. 10. Slash template

If the classic OPTA algorithm is used to scan The Fig. 10, it can be seen that no pixel points can be refined, but we can see that this is a diagonal line with double pixel width, so it can be seen that the classic OPTA algorithm cannot completely refine the diagonal line in the figure. By using the OPTA thinning method in literature [2] and [3], the results in Fig. 11 are obtained. It can be seen from the results that the slash has been refined, but it seems not perfect, with a small amount of burrs.

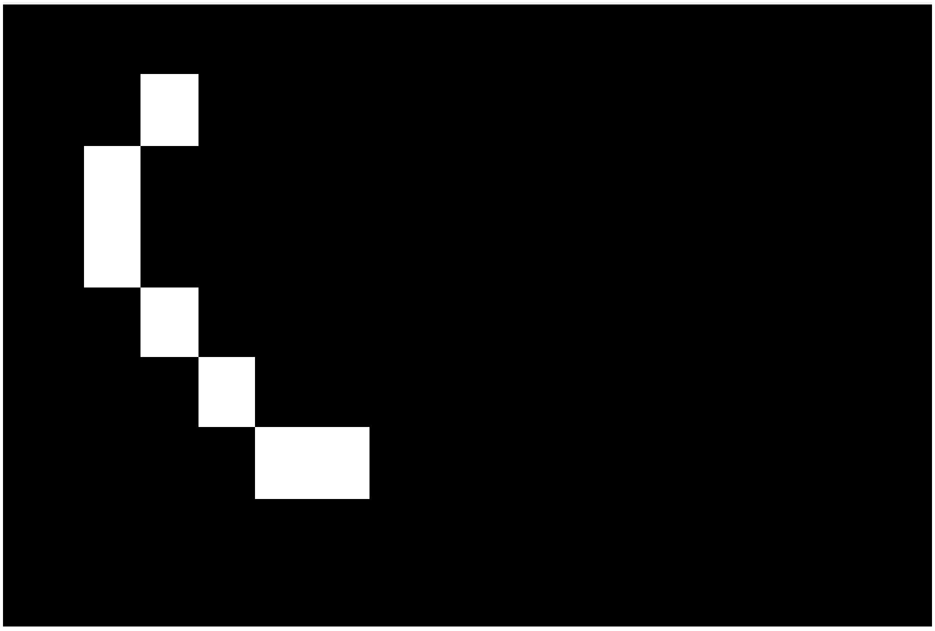

Fig. 11. A detailed diagram of OPTA in literature [2] and literature [3]

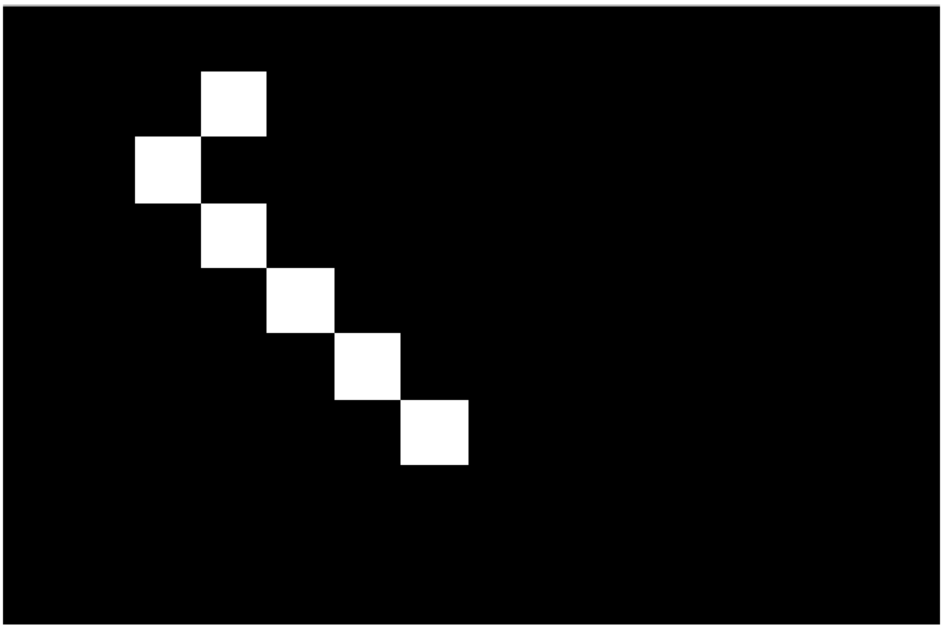

Fig. 12. Refinement model of improved OPTA algorithm

It can be seen from the Fig. 12 that compared with the OPTA method in literature [2] and [3], this refinement has a better effect without burr, so it is more perfect than the classic OPTA method in terms of refinement. The experimental data of the classical algorithm and the improved algorithm running time are shown in Table 1.

Table 1. Comparison table of thinning processing time under different algorithms

Image number	Operation time of algorithm in reference [1]/ms	Operation time of new algorithm /ms
1	13.38	11.90
2	8.22	7.86
3	10.88	9.69
4	12.12	10.25

It can be seen from the experimental data in Table 1 that, due to the influence of multiple factors such as the number of matrix operations, the improved algorithm saves time to a great extent compared with the classical algorithm, and the improved algorithm does not have the problems of dual pixel width and burrs.

Fig. 13. OPTA fingerprint refinement diagrams in references [2] and [3]

Fig. 14. This article improves the OPTA refinement diagram

Fig. 13 and Fig. 14 respectively show the refinement comparison of fingerprint when using classic OPTA and improved OPTA algorithm. Although both can be refined, the burr in Fig. 14 is less than that in Fig. 13, and the refinement speed is greatly improved.

5 Future Work

The process of fingerprint image processing can also be transferred to other types of image processing. In terms of feature extraction and matching, it can be combined with the actual research image, and the corresponding improved algorithm, such as facial information recognition, on the basis of fingerprint feature extraction and so on, is added to the feature extraction of facial features and face shape, and the corresponding improved version of matching is added Process, can effectively realize the recognition of facial features.

6 Conclusion

In this paper, aiming at the defects of the existing OPTA thinning algorithm and its improved algorithm, a new thinning algorithm is proposed on the basis of the original thinning algorithm. By modifying and eliminating the template, improving the reserved template and improving the thinning process, the thinning time and memory space are effectively saved, and the thinning burr is reduced. Experimental results show that the algorithm can significantly reduce the occurrence of burr in the thinning process, so as to improve the accuracy of features. It is a practical thinning algorithm.

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References

[1] W. Yang, K. Guo, Y. Wei, An efficient index thinning algorithm of fingerprint image based on eight neighborhood point, Journal of Sichuan University of Science & Engineering (Natural Science Edition) 21(2)(2008) 61-63.

[2] L. Zhao, Q. Chen, Z. Chen, A new Improved OPTA Refinement Algorithm, Computer Applications 10(28)(2008) 2639-2642.

[3] J. Zang, J. Yuan, S. Du, Research on Fingerprint Matching Algorithm based on Fourier-Mellin Transform, Computer Simulation 3(2)(2009) 25-28.

[4] W. Zhao, Study on fingerprint image preprocessing and refinement algorithm, Chongqing: Chongqing University, 2007.

[5] Runjunhong, Study on fingerprint image preprocessing, Hohhot: Inner Mongolia University of Technology, 2006.

[6] Z. Guo, R.W. Hall, Parallel thinning with two - subiteration algorithms, Communications of the ACM 32(3)(1989) 359-373.

[7] M. Wang, D. Tang, Region of interest extraction for finger vein images with less information losses, Multimedia Tools andApplications 76(2017) 14937-14949.

[8] J. Yang, J. Chen, Y. Su, Q. Jing, Z. Li, F. Yi, X. Wen, Z. Wang, Z.L. Wang, Eardrum-Inspired Active Sensors for Self-Powered depreciation System and Throat-Attached Anti-Interference Voice Recognition, Advanced Material 27(8)(2015) 1316-1326.

[9] J. Yang, Y. Shi, Finger-Vein ROI localization and Vein Ridge Enhancement, Pattern Recognition Letters, 2012.

[10] B. Bataineh, S.N.H.S. Abdullah, K. Omar, An adaptive local binarization method for document images based on a novel thresholding method and dynamic windows, Pattern Recognition Letters 32(14)(2011) 1805-1813.

[11] Y. Wang, Y. Wu, Face recognition using intrinsicfaces, Pattern Recognition 43(10)(2010) 3580-3590.

[12] S. Jirachaweng, Z.Hou, W.-Y. Yau, V. Areekul, Residual orientation modeling for fingerprint enhancement and singular point detection, Pattern Recognition 44(2)(2011) 431-442.

[13] N. Miura, A. Nagasaka, T. Miyatake, Feature extraction of finger-vein patterns based on repeated line tracking and its application to personal identification, Machine Vision and repeated line patterns Applications 15(2004) 194-203.