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A Study on the Extraction of the Minutiae and Singular Point for Fingerprint Matching

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ABSTRACT

The personal identification procedure through the fingerprints is divided as the classification process by the type of the fingerprints and the matching process to confirm oneself. Many existing researches for the classification and the matching of the fingerprint depend on the number of the minutiae of the fingerprints and the flow patterns by their direction information. In this paper, we focus on extracting the singular points by using the flow patterns of the direction information from identification. The extracted singular points are utilized as a standard point for the matching process by connecting with the extracted information from the singular point embodied. The orthogonal coordinates which is generated by the axises of the standard point can increase the accuracy of the fingerprints matching because of minimizing the effects on the location changes of the fingerprint images.

Keywords: minutiae, singular point, orthogonal coordinate

1. INTRODUCTION

In recent years, as the use of computer has increase, and the use of information technology for changing original data is also generalized, it is necessary to limit and to secure the access of the social and personal data. For this, biometrics is the one of the most efficient technologies that verify automatically the identification on a basis of physiological or behavioral features.

The biometrics technology is more competitive than other personal access technology in aspect of stability because of the capacity improvement of processor.

Particularly, the personal identification procedure through the fingerprints is divided as the classification process by the type of the finger print and the matching process to confirm oneself.

The classification process of fingerprints is to extract the same characteristics in the different fingerprints, to divide them into some categories as the characteristics, and to decide which categories fingerprints are inputted in. The matching process is to decide whether an inputted fingerprint matches with the registered fingerprint after registering personal fingerprints identified.

The extent of the classification and the matching of the fingerprints depends on the number of minutiae in the finger images and the information of the singular point through the flow pattern by the direction. The minutiae point means bifurcation and ridge ending. The characteristics of the fingerprint images is decided by the number of the points, and these points are used as registered point to match. The singular point means core and delta, and it is also used as important information for testing fingerprints[1,2].

In this paper, we classify the fingerprint images in the fingerprint cognition and extract the

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singular points to select standard points. After creating the orthogonal coordinates on the basis of the singular points, we compare the minutiae distribution for each part.

The general singular point extraction algorithm contains the methods of the Poincare numerical index[3,4], the singular point extraction reference table[5], and the singular point extraction. We choose the method of the singular point extraction by the direction information. We set up the diverse direction values considered as the singular point about designated direction values in the above process. We applied the direction values to Arch, Tented Arch, Left Loop, Right Loop, Whorl matching, created orthogonal coordinates to normalize the singular points extracted by moving the fingerprint images which are having problems to up, down, left and right, and compared minutiae in divided parts.

This paper is organized in the following manner. In section 2, we find representative direction information and detect the minutiae points. We extract singular points by the direction information in section 3. We create the orthogonal coordinates with the extracted singular points in section 4. In section5, we describe results of our experiment and end with a concluding statement in section 6.

2. DECIDING DIRECTION AND DETECTING MINUTIAE OF THE FINGERPRINT RIDGE

The direction information on the fingerprint images is the technology converting all sectional light and shade values into the characteristics of the direction. The direction extraction can be calculated by a block unit, and we use 8*8 shapes of the block. We used Sobel mask of equation(1) to find representative direction each block[6,8]. We can find the representative direction by calculating the deviation of the light values of the axis X and Y from equation(2) and equation(3) for each point in the block.

$$sobel_x = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix}, \quad sobel_y = \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix} \tag{1}$$

$$V_y(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} (\partial_x^2(u,v) - \partial_y^2(u,v)) \tag{2}$$

$$V_x(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} 2\partial_x(u,v)\partial_y(u,v) \tag{3}$$

$$\theta(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{V_y(i,j)}{V_x(i,j)}\right) \tag{4}$$

The representative direction by the calculation indicates 4 values from 0 to 3 as shown in Fig. 1, and the values are divided into each of 45 degree to the opposite direction of the clock between degree 0 and degree 180.

An image extracted from the 4 directions is shown in Fig. 2, and we know that the size of a block is 8*8 pixels in 256*256 pixels size of an input image.

We used the well-known algorithm[6,7,9-11] as shown in Fig. 3. to extract our minutiae points.

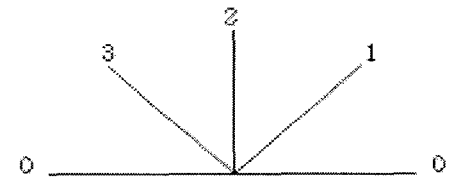

Fig. 1. direction component of four.

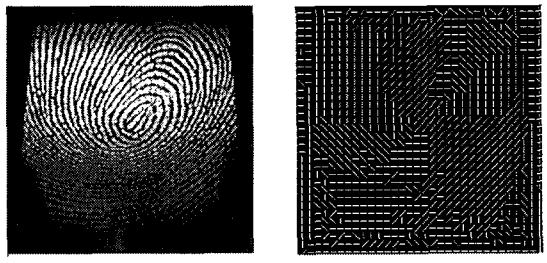

Fig. 2. The direction extraction image using the Sobel mask.

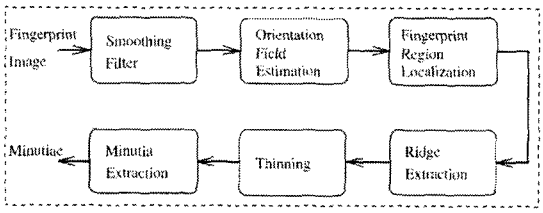

Fig. 3. Flowchart of minutiae extraction algorithm.

3. THE SINGULAR POINTS EXTRACTED BY THE DIRECTION INFORMATION

In general, the singular points have the patterns of the rapid direction change and the fixed direction. In the paper, the singular point is extracted from comparing the patterns of Fig. 4 with the direction image extracted from the Soble mask method[9].

In Fig. 4, when the extracted direction image is matched with pattern 8, 10, 11, 13, 14, 16 except the marked block succeeds and with the other patterns, the matched blocks in the extracted direction image are decided as the singular points. The patterns are ordered as shown in Fig. 4.

The singular point patterns are in the most of the singular points existing in the direction of the regular shape. The core extraction process using the singular point pattern is composed of 4 steps as the below. Fig. 5 indicates the image of the singular point extracted from the pattern 2.

The process to extract singular points using the singular point patterns is as followings :

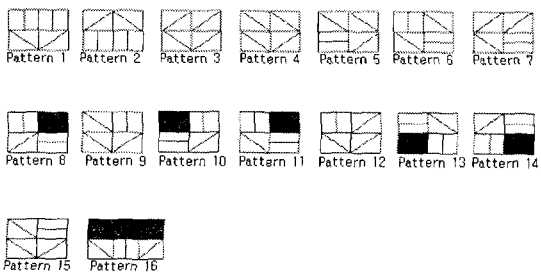

Fig. 4. The priority order of the singular point pattern.

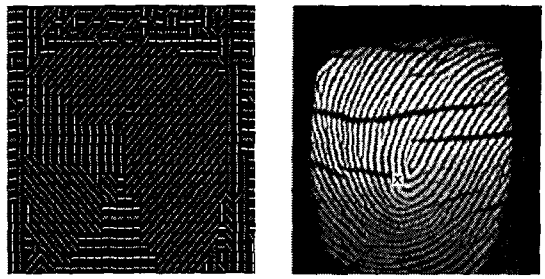

Fig. 5. The image extracted from the singular point.

(1) setting up representative direction for each block after dividing the fingerprint image into 8*8 pixels size of block.

(2) Comparing the direction image with the duplicated 2*2 size of block, 2*3 in case of pattern 16.

(3) If a block has the same direction component with pattern 1, choose the block which is in the same position with the singular point coordinates (x+1, y+1) as the singular point domain and exit the search.

(4) Otherwise, if a block having the same pattern shape with pattern 1 is not searched, repeat the second step from pattern 2 to pattern 16 in order, and choose the singular domain.

4. THE CREATION OF ORTHOGONAL COORDINATES USING THE SINGULAR POINTS

In above process, the coordinate values of the extracted singular point are used as the standard coordinates of the fingerprint image, and the standard coordinates are utilized with the bifurcation point coordinate in the nearest distance with the singular point. By the orthogonal coordinate, the fingerprint image is divided into 4 parts, and we compare the singular point distribution of each part and match the fingerprints. The process to match the fingerprint from the singular points is composed of 4 steps as the below. Fig. 6 indicates the singular point extraction image and the orthogonal coordinate creation of the fingerprint image.

Fig. 6. The image of the orthogonal coordinate extraction and the minutiae.

The process to match the fingerprint images is as followings :

(1) Putting the singular point coordinates (Xcore1, Ycore1) and the bifurcation point coordinates (Xbif i, Ybif i) into the formula (5), and calculating the nearest bifurcation point.

$$Dist = \sqrt{(Xcore1 - Xbifi)^2 + (Ycore1 - Ybifi)^2} \quad (5)$$

(2) Finding the straight line from two points, the singular point coordinates (Xcore1, Ycore1) and the nearest bifurcation coordinates (Xbif, Ybif)

$$a = \frac{Ycore\ 1 - Ybif}{Xcore\ 1 - Xbif}$$
$$k = Ycore\ 1 - (a \times Xcore\ 1) \quad (6)$$

(3) Finding the perpendicular line of the singular point and the nearest bifurcation.

$$Equation\ of\ the\ straight\ line : Y = a \times x + k$$
$$Orthogonal\ Equation : Y' = -\frac{1}{a} \times x + k'$$
$$k' = Ycore1 + \left(\frac{1}{a}\right) \times Xcore1 \quad (7)$$

(4) Dividing the image into 4 parts by using the equation of the straight line and the perpendicular line, and storing the minutiae information of the fingerprint image of each part.

5. EXPERIMENTAL RESULTS

The singular point listed in the Fig. 7 (a) and (b) are not significantly affected by the movement

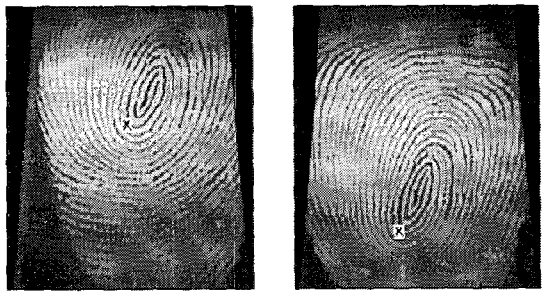

Fig. 7(a). The extraction outcome of the movement of the up, down.

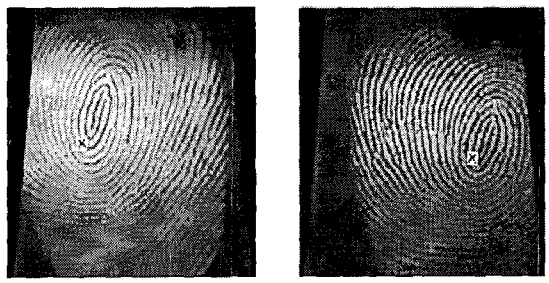

Fig. 7(b). The extraction outcome of the movement of the left, right.

of the fingerprint, up, down, left, and right.

With the 200 various of the fingerprint image databases like Arch, Tented arch, Left loop, Right loop, Whorl, we extracted the exact singular point at 192 fingerprints. The 8 errors in the fingerprint images result from pressing the image severely. Also, in case of the fingerprint whose delta point is close to core, the delta is recognized as the singular point.

We experiment on fingerprint image matching with coordinates created on the center of the extracted singular points. The process is as followings.

After creating the orthogonal coordinates on the base of the singular point coordinate values, we divided the image into the 4 parts on the center of the singular point. Therefore, we could compare the number of the minutiae (bifurcation) in the same domain of each divided part.

It is a defect that the method of the existing orthogonal coordinate is low in matching when the

fingerprint images are moving severly to up and down, left and right as shown in Fig. 7(a) and (b), and the rotation change rates of the images is inserted. The reason is that the orthogonal coordinate is created on the basis of only the singular points.

The outcome of the extracted ending point and the bifurcation is shown in Fig. 8 (a). The number of the bifurcation of each part calculated with the singular point coordinates, the nearest bifurcation coordinates, the distance, and the orthogonal coordinates is shown in Fig. 8(b)

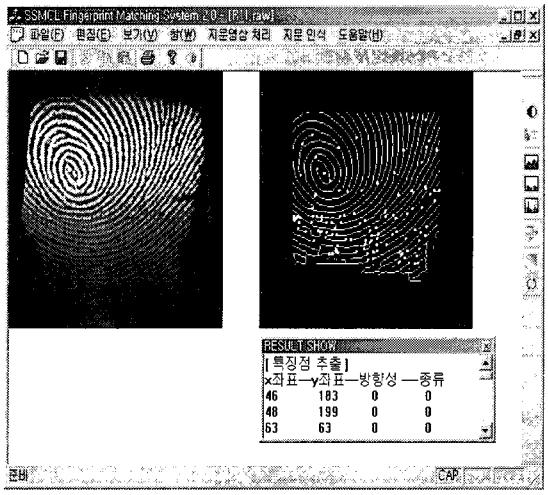

Fig. 8(a). Extraction of minutiae.

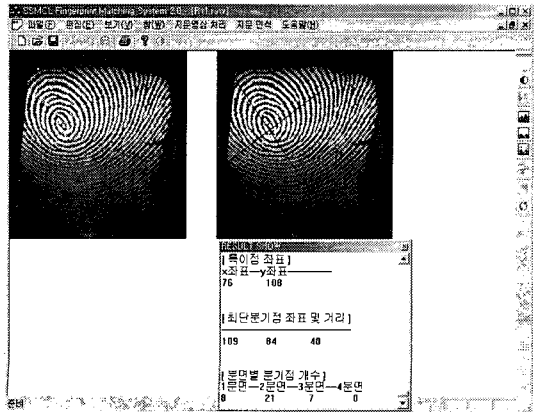

Fig. 8(b). The information output by means of the creation of the orthogonal coordinate.

Fig. 9(a). In inputting the right fingerprint, the creation of the orthogonal coordinate.

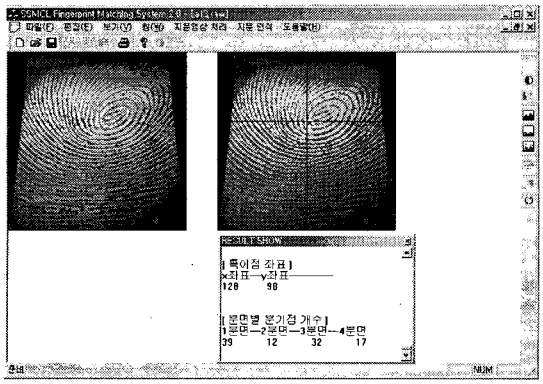

Fig. 9(b). In inputting the rotation change ratio, the creation of the orthogonal coordinate.

It is a defect that the method of the existing orthogonal coordinate is low in matching when the fingerprint images are moving severly to up and down, left and right as shown in Fig. 9 (a) and (b), and the rotation change rates of the images is inserted. The reason is that the orthogonal coordinate is created on the basis of only the singular points.

We experiment with 100 databases of the fingerprint images to match one-to-one. We registered the same fingerprints of 5 people at three times and compared the same 20 fingerprints with the best threshold values. The matching outcome of the proposed method showed the 76 % of accuracy and the 24 % of FRR(False Rejection Ratio).

The higher FAR happens, the more fatal the fin-

gerprint image matching system becomes because of the security. Our proposed method is close to 0% of FAR as shown in Table 2.

Table 1. Results of singular point extraction

Shape of Fingerprint	Number of sample	False Ratio of Extraction	Ratio of Extraction
Arch	45	(4) 8.88%	(41) 91.11%
Whorl	75	(1) 1.33%	(74) 98.66%
Loop	80	(3) 3.75%	(77) 96.25%
Fingerprint of the Whole	200	(8) 4%	(192) 96%

*( ) : Number of Data

Table 2. Agreement ratio fingerprint

Sample of Identical Fingerprint	Number of Sample		FRR	FAR
	1:1	1:N		
A1,A2,A3	20	80	(6) 30%	(0) 0%
B1,B2,B3	20	80	(4) 20%	(0) 0%
C1,C2,C3	20	80	(6) 30%	(1) 1.25%
D1,D2,D3	20	80	(4) 20%	(0) 0%
E1,E2,E3	20	80	(4) 20%	(0) 0%
Fingerprint of the Whole	100	400	(24) 24%	(1) 0.25%

*( ) : Number of Data

6. CONCLUSION

In this paper, we use the method of the direction information of the ridge to extract the singular points with the 256*256 size of the fingerprint image and divided the direction information into four direction by Soble mask method. The extracted direction information is set up the pattern of singular point in priority order and searched the singular point domain.

Therefore, our algorithm creates the orthogonal coordinates with the minutiae and nearest bifurcation. As to the high accuracy of the minutiae distribution, the fingerprint matching is guaranteed in spite of the rotation change rate and the position change.

In addition, if the fingerprint matching system contains the elimination algorithm of pseudo minutiae, it is expected to improve the matching rate of our system.

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