JOURNAL OF MEDICAL INFORMATICS & TECHNOLOGIES Vol. 13/2009, ISSN 1642-6037

fingerprint, reference point, IPAN99

Krzysztof WRÓBEL*, Rafał DOROZ*

NEW METHOD FOR FINDING A REFERENCE POINT IN FINGERPRINT IMAGES WITH THE USE OF THE IPAN99 ALGORITHM

This study presents a new method for finding a reference point in fingerprint images. The proposed method is based on the IPAN99 algorithm, which detects high curvature points on a contour of a graphical object. This algorithm was adjusted in the study to detect high curvature points on friction ridges. It allows locating a reference point on a fingerprint image. Since the IPAN99 algorithm requires that the thickness of an analysed contour should be of one pixel, each fingerprint image was adequately prepared before submitting to the analysis with the IPAN99 algorithm. Evaluation of the efficiency of the method consisted in comparing the distances between coordinates of reference points determined with the use of the proposed method and indicated by an expert. The developed method was compared with other algorithms used for determining a reference point.

1. INTRODUCTION

The methods of verifying people's identity based on fingerprint recognition are becoming some of the safest methods of authentication [5,6,7,12]. They prove their usefulness in the era of very high requirements set for security systems. This results to a large extent from the fact that biometric data cannot be stolen or lost. A reliable system of person identification and verification allows avoiding errors that case material losses as well as a loss of confidence in a company or an institution.

Fingerprint images contain friction ridges. After adequate transformations, friction ridges can be treated as sequences of points with specific coordinates, and can be processed with the use of image analysis methods. An analysis of unique patterns (minutiae), which form friction ridges, allows establishing people's identity [6].

Two images of fingerprints of the same finger taken in a certain time interval are nearly always slightly different - they will be shifted, rotated through a certain angle, etc. Therefore, many methods for recognizing people on the basis of fingerprints require finding a reference point on the fingerprint, around which minutiae are being analysed [5,10,11]. This reference point is defined as a place on a fingerprint, in which the curvature of friction ridges is the highest.

In this study, the IPAN99 algorithm, which detects high curvature points on a contour of a graphical object, was used for finding a reference point [1]. The usability of this algorithm in the process of determining a reference point on fingerprint images has not been studied so far.

2. IMAGE PREPARATION

The fingerprint images tested within the study contained friction ridges with a thickness higher than one pixel. Since the IPAN99 algorithm requires that the thickness of a contour being analysed should be of one pixel [1], the tested images were adequately prepared.

In the first phase, the fingerprint images were submitted to an operation that aimed at improving their quality [4,6,9]. This operation consisted of a few stages, which were discussed in detail in other studies. In the presented study, there was used a quality improvement method, which gave a binary image as a result [9]. Sample fingerprint images before and after the operation improving their quality are presented in Fig. 1.

* University of Silesia, Institute of Computer Science, 41-200 Sosnowiec, Będzińska 39, Poland, krzysztof.wrobel@us.edu.pl, rafal.doroz@us.edu.pl

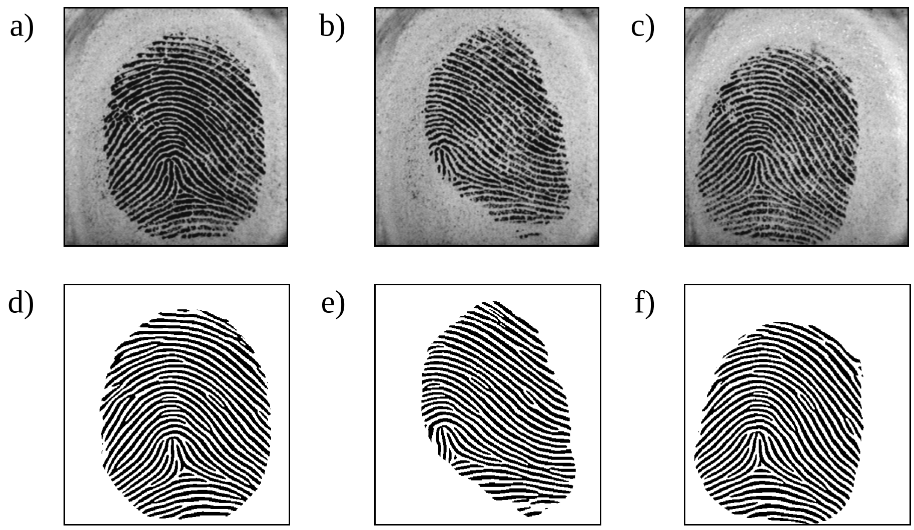

Fig. 1. Sample fingerprint images before a-c) and after d-f) the operation improving their quality.

Thanks to the operation improving the quality of the analysed images, the visibility of friction ridges was better, which facilitated the further analysis. In the last stage, the fingerprint images were submitted to a skeletonization process. There was used the Pavlidis algorithm described in the study [8]. Sample images after the skeletonization are presented in Fig. 2.

Fig. 2. Sample images after the skeletonization.

Having the images prepared in such a way, each friction ridge could be recorded as a sequence of points with specific coordinates. In this study, the method described in the paper [3] was used for finding the sequence of points.

During the research work it appeared that the IPAN99 algorithm had detected high curvature points in bifurcations of friction ridges. This could result in an incorrect detection of a reference point. Examples of incorrect detection of reference points in bifurcations of friction ridges are presented in Fig. 3. These points were marked with a circle on the drawings. The reference point indicated by an expert were additionally labelled with a cross mark.

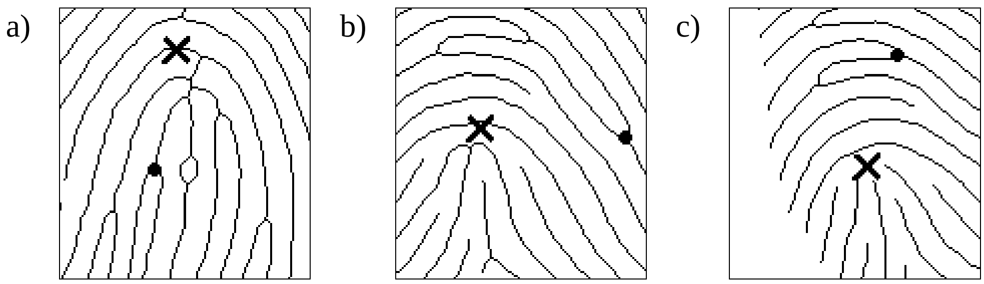

Fig. 3. Fragments of fingerprint images with some incorrectly detected reference points (circle) and the reference points indicated by an expert (cross).

In order to prevent the above-mentioned situation, modifications were made, which consisted in removing a fragment of an image with a size of $k \times k$ pixels, containing a given bifurcation. A sample image fragment before and after removal of all bifurcations is shown in Fig 4. The value of the k parameter was 5.

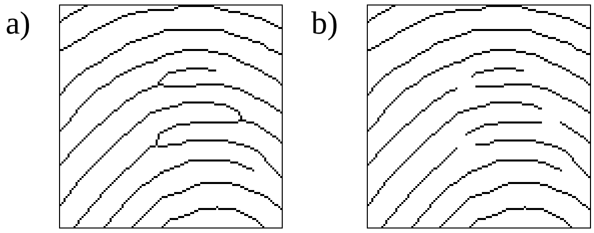

Fig. 4. Sample fragment of a fingerprint image: a) before removal of bifurcations, b) after removal of bifurcations.

As a result of using the above methods, a set of curves representing friction ridges was obtained for each fingerprint. These curves had a thickness of one pixel, and in the further part of the study were analysed with the use of the IPAN99 algorithm in order to find high curvature points.

3. IPAN99 ALGORITHM

Detection of the highest curvature points with the use of the IPAN99 algorithm takes place in two stages [1]. In the first stage, the point **p** of the curve is taken as a corner, if it is possible to inscribe a triangle with a specific opening angle and different lengths of sides ($\mathbf{p}^-$, $\mathbf{p}$, $\mathbf{p}^+$) in this curve (Fig. 5).

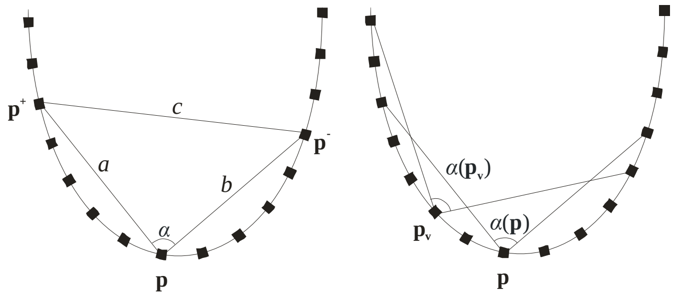

Fig. 5. Detection of the highest curvature points based on the IPAN99 algorithm.

Triangles are constructed according to the following conditions:

$$d_{\min}^2 \le \left|\mathbf{p}-\mathbf{p}^+\right|^2 \le d_{\max}^2 \tag{1}$$

$$d_{\min}^2 \le \left|\mathbf{p}-\mathbf{p}^-\right|^2 \le d_{\max}^2 \tag{2}$$

$$\alpha \le \alpha_{\max} \tag{3}$$

where:

$d_{\min}$ – parameter specifying the minimum length of triangle sides,

$d_{\max}$ – parameter specifying the maximum length of triangle sides,

$\alpha_{\max}$ – critical angle, which determines the value of the angle of a triangle inscribed in the curve in a given point in order to classify this point as a candidate for a corner.

$\left|\mathbf{p}-\mathbf{p}^+\right| = |a| = a$ – distance between **p** and $\mathbf{p}^+$ points,

$\left|\mathbf{p}-\mathbf{p}^-\right| = |b| = b$ – distance between **p** and $\mathbf{p}^-$ points,

$\left|\mathbf{p}^+-\mathbf{p}^-\right| = |c| = c$ – between $\mathbf{p}^+$ and $\mathbf{p}^-$ points,

$\alpha \in [-\pi, \pi]$ – opening angle of a triangle, defined as follows:

$$\alpha = \arccos\frac{a^2+b^2-c^2}{2ab} \tag{4}$$

Inscribing a triangle at any point **p** is started with determining the smallest possible lengths of triangle sides. Then, next triangles are created by increasing the lengths of their sides. The algorithm is stopped, if a triangle does not meet one of the conditions 1-3. From among all acceptable triangles in a given point **p,** the triangle with the smallest opening angle $\alpha(\mathbf{p})$ is selected.

In the second stage, the point **p** is rejected, if in its neighbourhood there is a point $\mathbf{p}_v$, which has a smaller opening angle:

$$\alpha(\mathbf{p}) > \alpha(\mathbf{p_v}) \qquad (5)$$

The point $\mathbf{p_v}$ belongs to the neighbourhood of the point $\mathbf{p}$, if it fulfils the condition $|\mathbf{p}-\mathbf{p_v}|^2 \le d_{\min}^2$.

Depending on the values of the $d_{\min}$, $d_{\max}$, $\alpha_{\max}$ parameters, the IPAN99 algorithm detected a different number of high curvature points on each friction ridge. The result of operation of the algorithm was the n set of $\{\mathbf{p}_1, \mathbf{p}_2, \ldots, \mathbf{p}_n\}$ points for each friction ridges on a single fingerprint. For the needs of this study it has been accepted that the $\mathbf{p}_r$ reference point is defined as follows:

$$\mathbf{p}_r = \min(\alpha(\mathbf{p}_i)) \quad for \quad i = 1, \ldots, n \qquad (6)$$

The reference points on fingerprint images determined with the use of the IPAN99 algorithm, as well as the reference points indicated by an expert are shown in Fig. 6.

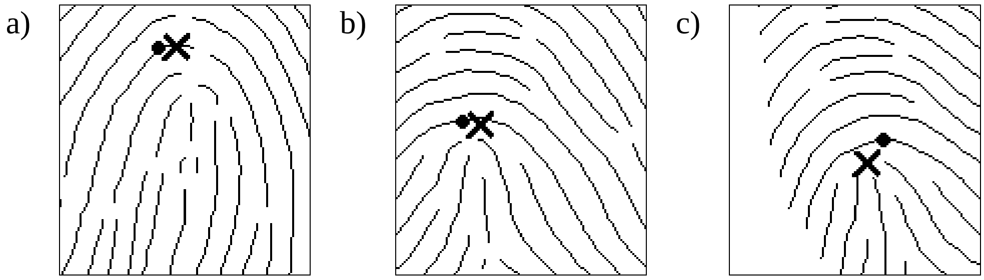

Fig. 6. Example of operation of the IPAN99 algorithm on fingerprint images.

4. THE COURSE AND RESULTS OF THE STUDIES

The tests were performed on a set of images coming from FVC database [2]. Sample test images are presented in Fig. 7.

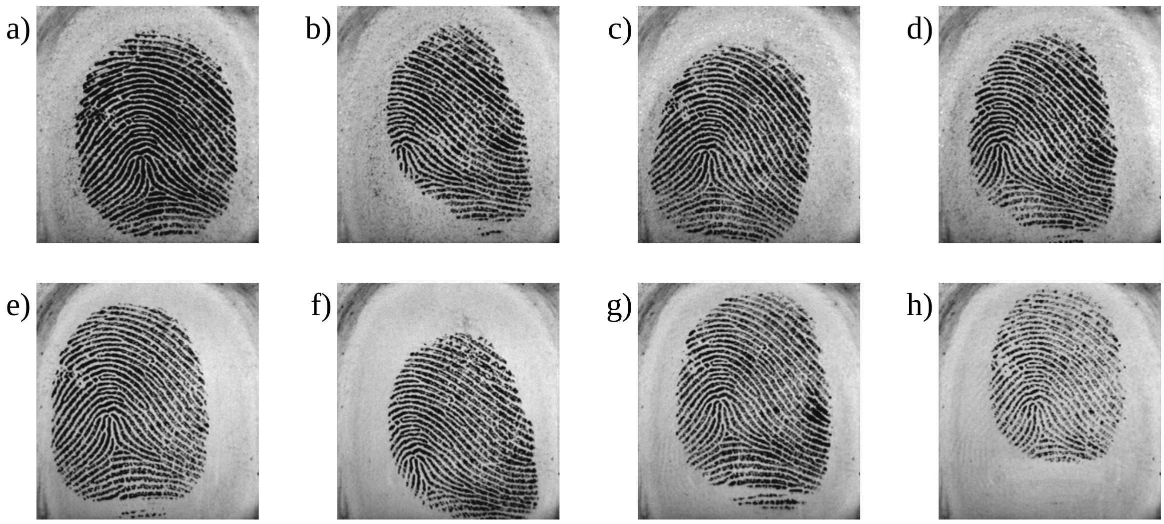

Fig. 7. Sample images used in the tests.

Evaluation of the efficiency of the method consisted in comparing the coordinates of reference points determined with the use of the proposed method and indicated by an expert. Euclidean distance were determined between the points being compared. On the basis of the values of the distance, the efficiency of the method was evaluated.

For the IPAN99 algorithm, the following parameters were experimentally selected: $d_{\min}$=17, $d_{\max}$=19, $\alpha_{\max}$=150. The value of the k parameter was set at 5 pixels. Additionally, the results of the tests were compared with other methods. The results of tests for the sample fingerprints presented in Fig. 7 were given in Table 1.

Table 1. Results of the studies

Image	A – Expert's assessment $\mathbf{p}_r^e = \left[x_r^e, y_r^e\right]$	B – Algorithm 1 $\mathbf{p}_r^1 = \left[x_r^1, y_r^1\right]$ [11]	Distance D1=A-B	C – Algorithm 2 $\mathbf{p}_r^2 = \left[x_r^2, y_r^2\right]$ [10]	Distance D2=A-C	D – Our method $\mathbf{p}_r^{new} = \left[x_r^{new}, y_r^{new}\right]$	Distance D3=A-D
a)	[218, 310]	[220, 301]	9,22	[214, 313]	5,00	[225, 307]	7,62
b)	[132, 287]	[130, 274]	13,15	[137, 291]	6,40	[111, 281]	21,84
c)	[137, 301]	[139, 283]	18,11	[148, 302]	11,05	[154, 300]	17,03
d)	[124, 285]	[130, 274]	12,53	[137, 291]	14,32	[132, 280]	9,43
e)	[149, 273]	[148, 265]	8,06	[159, 269]	10,77	[155, 269]	7,21
f)	[159, 357]	[157, 346]	11,18	[170, 357]	11,00	[163, 340]	17,46
g)	[163, 245]	[166, 238]	7,62	[181, 247]	18,11	[176, 242]	13,34
h)	[205, 246]	[193, 238]	14,42	[203, 247]	2,24	[204, 245]	1,41

An analysis of the results presented in Table 1 shows that in three cases ("d", "e" and "h" images), the proposed method gives results more close to the expert's indications than other methods compared with it. Also in three cases, the proposed method gives results more close to the expert's indications than one of other methods ("a", "c" and "g" images). Whereas in other cases, the results are worse than in the compared methods.

5. CONCLUSIONS

The conducted studies demonstrated that the presented method is usable for finding a reference point. The obtained results are comparable with other methods and only slightly differ from expert's indications.

Next stages of the research will involve tests performed on databases containing a larger number of fingerprint images and in different quality. Other parameters of the IPAN99 algorithm will be tested too. It is planned to develop new methods that allow eliminating incorrectly detected high curvature points within bifurcations and other types of minutiae.

BIBLIOGRAPHY

[1] CHETVERIKOV D., SZABO Z., Detection of high curvature points in planner curves. In 23rd Workshop of the Austrian Pattern Recognition Group, pp. 175–184, 1999.

[2] Fingerprint Verification Competition: http://bias.csr.unibo.it/fvc2006

[3] GOŁUCH P., Charakteryzacja konturu 2D przy pomocy punktów brzegowych o największej krzywiźnie (in polish), praca licencjacka, promotor: W. Kotarski, Uniwersytet Śląski, Sosnowiec, 2003.

[4] GREENBERG S., ALADJEM M., KOGAN D., DIMITROV I., Fingerprint image enhancement using filtering techniques. Proceedings of the 15th International Conference on Pattern Recognition (ICPR'00), Vol. 3, pp. 322–325, Barcelona, Spain, 2000.

[5] JAIN A.K., PRABHAKAR S., JONH L., PANKANTI S., Filterbank-based fingerprint matching. IEEE Transactions on Image Processing, Vol. 9, No. 5, pp.846–859, 2000.

[6] MALTONI D., MAIO D., JAIN A.K., PRABHAKAR S., Handbook of Fingerprint Recognition. Springer professional computing series, NY, 2003.

[7] PARK U., PANKANTI S., JAIN A.K., Fingerprint verification using SIFT features. SPIE Defense and Security Symposium, paper 6944-19, Orlando, USA, 2008.

[8] PAVLIDIS T., A thinning algorithm for discrete binary images. Computer Graphics and Image Processing, Vol. 13, pp.142–157, 1980.

[9] PORWIK P., WIĘCŁAW Ł., The New Efficient Method of Fingerprint Image Enhancement. International Journal of Biometrics, Vol. 1, No. 1, pp. 36-46, Inderscience Publisher, 2008.

[10] PORWIK P., WIĘCŁAW Ł., Fingerprint Reference Point Detection Using Neighbourhood Influence Method. Advances in Intelligent and Soft Computing, Vol. 45, Computer Recognition Systems, pp. 768-794, Springer-Verlag, 2007.

[11] PORWIK P., WRÓBEL K., The new algorithm of fingerprint reference point location based on identification masks. Advances in Intelligent and Soft Computing, Vol. 30, Computer Recognition Systems, pp. 807-814, Springer-Verlag, 2005.

[12] WANG R., BHANU B., Predicting fingerprint biometrics performance from a small gallery. Pattern Recognition Letters, Vol. 28, No. 1, pp.40–48, 2007.