New Technique for Analysis of Fingerprint Poroscopical Map

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ABSTRACT

During last decades the interest of investigators grows to the problem of using the third level features for increasing of identification accuracy in automated fingerprint recognition systems. It is specified that the poroscopical maps carry important information about the represented images of the fingerprint pores, their number, sizes, coordinates, etc. However, there arises a number of problems in the automated identification process in connection with impossibility of using directly the pixel-by-pixel comparison methods of corresponding images. In this paper, a technique for poroscopical maps comparing, based on using of the investigated earlier measure for images structural proximity assessment, which is determined using the gradient field of images, is proposed. The poroscopical map is determined using some known algorithms of image processing, namely binarization, segmentation, etc. The results of poroscopical maps and comparative analysis of some items from the database of Hong Kong Polytechnical Institute are given. It is shown that the proposed technique for poroscopical maps processing can be used in AFRS for increasing the accuracy of fingerprint identification.

Keywords

Fingerprint, third level, pores, poroscopical map, gradient field, image proximity assessment.

1. INTRODUCTION

Fingerprint recognition is widely popular but a complex pattern recognition problem. The information contained in a fingerprint can be categorized into three different levels, namely, Level 1 (pattern), Level 2 (minutia points), and Level 3 (pores and ridge contours) [1]. Most existing automated fingerprint recognition systems (AFRS) utilize only level one and level two fingerprint features for personal identification [2]. Level-three fingerprint features like pores, though seldom used, are also very distinctive [3]. During last decades more and more researchers are exploring how to extract and use level-three features in AFRS.

Several methods have been proposed for pore detection, extraction and matching. Large class of algorithms for extracting the pores directly from Gray scale image are proposed [1]. The review of pore extraction methods are considered in [4]. Usually a pore is considered as extracted when the pore center coordinates become known. Then the coordinates of two fingerprint pores are compared by overlapping of corresponding maps of pores positions as it is shown in Figure 1. Then the proximity of coordinates is estimated by visual analysis.

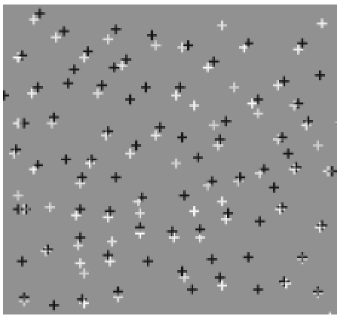

Figure 1. Overlapped positions of two fingerprint pores (Fragment from [5]).

The following important problem is poroscopy, i.e. the study of the configuration, size, and relative positions of the pores. Poroscopy also involves a comparative study of the pores visible in impressions left at the site of a crime and in the fingerprints of an identified person.

The comparative study usually is performed by visual comparison of the positions of the pores on the poroscopical maps which are overlied in an appropriate manner. Using measures based on the mean-squared variance doesn’t solve the problem due to uncertainty of the coordinates of pixels of compared pores. This fact is especially important in AFRS. Unlike such measures the human visual system (HVS) can solve the poroscopical maps comparing problem. In some papers it is noted that HVS extracts substantive and/or structural information from an image (see, for example, [6]). Therefore in many cases HVS can have certain advantage vs formal methods. During last decades there proposed some formal methods in the scientific literature which give the results comparable with HVS results [6, 7].
An approach to image quality assessment based on structural properties, is investigated in [8]. A measure using the information of two image gradient magnitude distributions is offered, which gives the results similar to the HVS

perception. Some applications of the mentioned measure show its low sensitivity to image scaling or/and rotations [9]. This paper is devoted to testing the ability of that measure for poroscopical investigations.

In Section 2 the closed pore extraction and poroscopical map creating technique is described which is based on segmentation procedure using also Otsu method for image binarization. Section 3 is devoted to the application of method [8] to the poroscopical maps comparison problem. Section 4 includes some experimental results obtained by the proposed technique.

2. PORE EXTRACTION TECHNIQUE

We use the technique for closed pore extraction described in [10]. A closed pore assumed as a segment, i.e. it is a set of pixels which satisfy the following requirements:

- It consists of connected pixels, i.e. every pixel of the set has neighbors only from the same set.
- The intensity of the set pixels and intensity of the neighbor pixels from outside of that set belong to different value intervals.

The extracting algorithm consists of following steps.

Step 1. The Gray Scale image is binarized by Otsu method [11]. This method allows good enough binarization of fingerprint and is applied in many papers on image processing. As a result we have a new image, each pixel of which is equal "0" or "255".

Step 2. The binarized image is inverted. This means that the black pixels of binarized image turned to white and vice-versa. This operation is performed to have the extracted pores of black color in the white background (it is more convenient for printing processes).

Step 3. The binarized and inverted image is fully segmented. As a result we get K segments with pixels of two intensities. Thus, the close pore will look as a black segment.

Step 4. Let n_k be the number of pixels of k-th segment, $k = 1,2,...,K$. Let (T_{min}, T_{max}) be the interval of acceptable sizes for closed pores. This interval must be determined by prior consideration of fingerprint scanner resolution and known sizes of closed pores from special investigations. For example, according to [12] for scanner with resolution of 1200 dpi $T_{min} = 3, T_{max} = 30$. More detailed analysis of fingerprint scanner resolution requirements and corresponded pores sizes is given in [13].

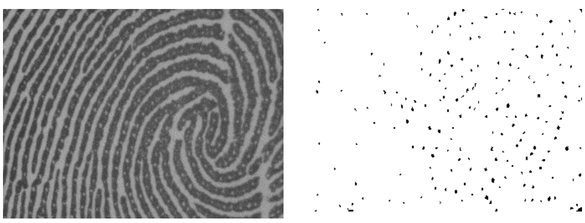

Figure 2. Fingerprint 5-1-1 and its poroscopical map ($T_{min} = 3, T_{max} = 30$).

Step 5. Extracting the pores, i.e. all segments with $T_{min} \le n_k \le T_{max}$, $k = 1,2,...,K$. Creating the poroscopical map by locating the images of pores on the map of fingerprint sizes. Figure 2 shows an example of a fingerprint and corresponding poroscopical map.

We check the size of each pore, i.e. the number of pixels it does contain. The size of chosen pores varies within the pre-specified range of valid pore size (from 3 to 30 pixels in our experiments). General number of extracted pores is 194, average size is $\bar{x} = 5.85$, which corresponds to pore diameter of about 60 micron. If $T_{min} = 7$, the average pore diameter increases up to 74 micron. The frequency polygon of sizes of 194 extracted pores is shown in Figure 3.

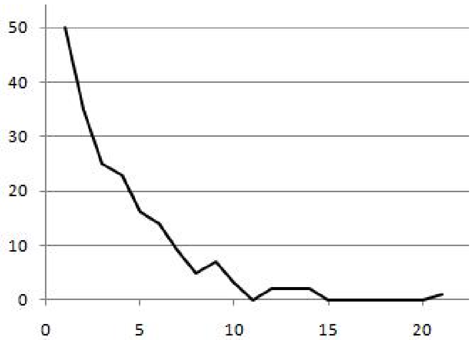

Figure 3. Frequency polygon of sizes of extracted pores.

3. COMPARISON OF POROSCOPICAL MAPS OF TWO FINGERPRINTS

The method originates in a new approach to the problem of image quality assessment, described in [8]. According to that approach the set of gradient magnitudes is considered as a feature of an image. The measure for quality assessment is created to use the information contained in two image gradient magnitude distribution. Such measure gives the results similar to the HVS.

Let's describe briefly the above mentioned quality assessment measure. The related algorithm consists of the following steps.

Step 1. Calculate the gradient magnitudes $\|\Delta_j(m,n)\|$, for both considered images, $j = 1,2$, $m = 0,1,...,M_j$, $n = 0,1,...,N_j - 1$;

Step 2. Assume that the gradient magnitudes $\|\Delta_j(m,n)\|$ are two-dimensional independent random variables with Weibull distributions $F_1(x;\eta_1,\sigma_1)$ and $F_2(x;\eta_2,\sigma_2)$. Parameters $\eta_1, \sigma_1, \eta_2, \sigma_2$ are estimated by the gradient magnitude samples of two images;

Step 3. Calculate the proximity of the images by formula

$$W^2 = \frac{\min(\eta_1,\eta_2)\min(\sigma_1,\sigma_2)}{\max(\eta_1,\eta_2)\max(\sigma_1,\sigma_2)}, \quad 0 < W^2 \le 1. \qquad (1)$$

The measure (1) is invariant to sizes and rotations [9]. It has been tested for certain images and showed the results more corresponding to HVS, than usual mean-square measure.
The main purpose of this paper is to demonstrate a method of comparing the two poroscopical maps to estimate its proximity.

4. EXPERIMENTAL RESULTS

Fingerprints with pores in the series of experiments were chosen from High-Resolution-Fingerprint (HRF) Database of The Hong Kong Polytechnic University (PolyU [14]). The fingerprints in this database were captured by resolution of 1200 dpi.

Table 1. Values of proximity measure W^2 between different maps for transformed items of the same fingerprint.

	2-1-1	*2-1-2*	*2-1-3*	*2-1-4*	*2-1.5*
2-1-1	1	0.859	0.81	0.876	0.874
2-1-2		1	0.942	0.753	0.984
2-1-3			1	0.71	0.927
2-1-4				1	0.766
2-1-5					1

We have performed two series of experiments. In the first series we have chosen five transformed issues of the same fingerprint. The poroscopical maps of these fingerprints are determined by the method described in Section 2 and shown in Table 3. The pixel-by-pixel comparison of these maps does not give any reason to identify the corresponding
fingerprints, while the proximity measure W^2, described in Section 3, shows high proximity between the mentioned items (see Table 1).

Table 2. Values of proximity measure W^2 between maps of different fingerprints.

	2-1-1	*4-1-2*	*69-1-5*	*54-2-5*	*58-2-2*
2-1-1	1	0.078	0.392	0.026	0.179
4-1-2		1	0.199	0.334	0.435
69-1-5			1	0.067	0.457
54-2-5				1	0.146
58-2-2					1

Then, different fingerprints from the same database are collected in Table 4. The proximity measure between poroscopical maps of these fingerprints are given in Table 2.

The values of proximity measure W^2 are significantly less than those presented in Table 1. Though in Tables 1 and 2 there are presented only a few samples from the specified database, the considered results show that the poroscopical maps can be processed by the proposed technique and being used in AFRS will increase the recognition accuracy.

5. CONCLUSIONS

In this paper, a technique for poroscopical maps creating and analyzing is proposed. It is assumed that a closed pore is a segment in the fingerprint image which can be extracted and simplified after binarization and inversion of the fingerprint. Binarization threshold can be estimated by Otsu method. The size of the segments are preliminary determined with a glance of fingerprint scanner resolution that must be enough high. Thus, all the extracted segments are put to the map which is considered as a poroscopical map. The proximity of two chosen maps is estimated by the technique described in Section 2.

The results obtained by experiments show that the information containing in the poroscopical map can be used for AFRS investigations being processed with fingerprint features of Levels 2 and 3 and have a resource for increasing the accuracy of fingerprint recognition.

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Table 3. Transformed items of the same fingerprint and its poroscopical maps ($T_{min} = 3, T_{max} = 30$).

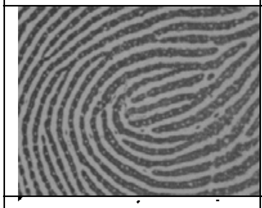
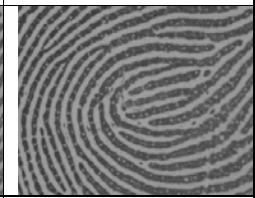
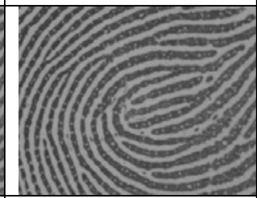
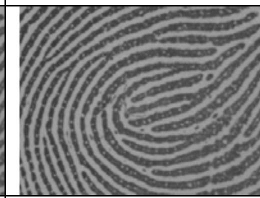
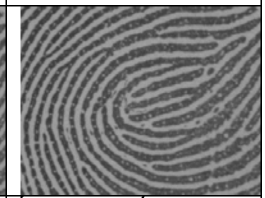
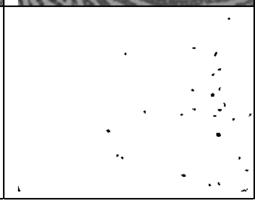
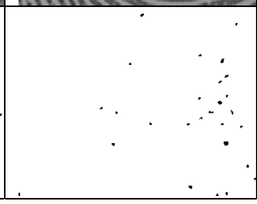
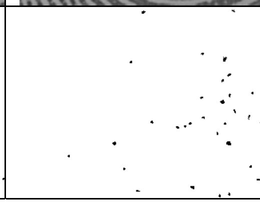
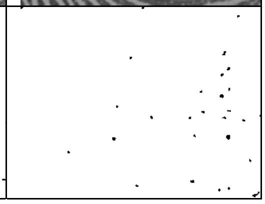
2-1-1	2-1-2	2-1-3	2-1-4	2-1-5
				
				

Table 4. Different fingerprints and their poroscopical map ($T_{min} = 3, T_{max} = 30$).

2-1-1	4-1-2	69-1-5	54-2-5	58-2-2