NOVEL METHOD FOR ANALYSIS OF FINGERPRINT POROSCOPICAL MAPS

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Abstract: During last decades grows the interest of investigators to the methods of using the third level features for increasing identification accuracy in automated fingerprint recognition systems. It was noticed that the poroscopical maps carry important information about fingerprint pores, namely, their number, sizes, coordinates etc. However, at creation of automated identification technique, there arises a problem in connection with impossibility of using directly the pixel-by-pixel comparison methods of corresponding images. In this paper, we propose technique for comparison of poroscopical maps, based on using investigated earlier structural proximity assessment measure, which was determined using the gradient field of images. The poroscopical map is determined using some known algorithms of image processing, namely binarization, segmentation etc. The results of poroscopical maps processing 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.

ACM Classification Keywords: Image Processing and Computer Vision

Introduction

Fingerprint recognition is widely popular but is 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) [Jain, 2007]. Most existing automated fingerprint recognition systems (AFRS) utilizes only level one and level two fingerprint features for personal identification [Jain, 2003]. Level-three fingerprint features like pores, are also very distinctive, though they are seldom used [Stosz, 1994]. During last decades more and more researchers are exploring how to extract and use level-three features in AFRS.

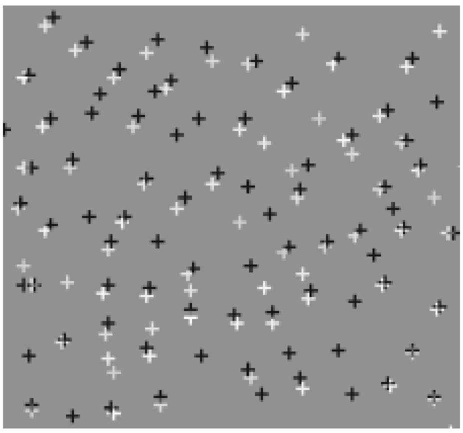


Figure 1. Overlapped positions of two fingerprint pores

Many methods have been proposed for fingerprint pore detection, extraction and matching. Large class of algorithms for pore extracting directly from a Gray scale image has been proposed in [Jain, 2007]. A review of pore extraction methods are considered in [Zhao, 2010]. Usually a pore is considered as extracted when the pore center coordinates becomes known. Then the coordinates of two fingerprint pores are compared by overlapping corresponding maps of pores positions as it is shown in Figure 1 (a fragment from the map of [Parsons, 2008]). Then the proximity of corresponding coordinates is estimated by using visual analysis.

The next important problem is poroscopy, which means study of the configuration, size, and relative positions of extracted 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 overlie in an appropriate manner. Using measures based on the mean-squared error doesn't solve the problem due to uncertainty of the coordinates of centers of pores. This fact is especially important in AFRS. Unlike to such measures the human visual system (HVS) can solve the poroscopical maps comparing problem. In several papers it is noted that HVS extracts substantive and/or structural information from an image (see, for example, [Bovik, 2002]). Therefore in many cases HVS can have certain advantages vs. formal methods. During last decades there proposed some formal methods in the scientific literature which give the results comparable with HVS results [Bovik, 2002; Bovik, 2004].

An approach to image quality assessment based on structural properties, is investigated in [Asatryan, 2009]. 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 [Asatryan, 2010]. This paper is devoted to testing the ability of the specified measure for poroscopical investigations.

In Section 2 the closed pore extraction method and a technique for poroscopical map creating is described which is based on segmentation procedure using also Otsu method for image binarization. Section 3 devoted to application of method [Asatryan, 2009] to the poroscopical maps comparison problem. Section 4 includes some experimental results obtained by proposed technique.

Proposed Technique for Fingerprint Pore Extraction

We use the technique for closed pore extraction, which is described in [Asatryan, 2012]. A closed pore assumed to be 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 from the set has neighbors only from the same set;
- The intensity of the pixels from the set and the intensity of the 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 [Otsu, 1979]. This method allows good enough binarization of fingerprint and is applied in many papers on image processing. As a result of binarization we have new image with pixels of intensity “0” or “255”.

Step 2. The binarized image is inverted. This means that the black pixels of binarized image turned into 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 closed 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 [Zhang, 2010] $T_{\min} = 3, T_{\max} = 30$ for scanner with resolution of 1200 dpi. More detailed analysis of fingerprint scanner resolution requirements and corresponding pores sizes is given in [Busselaar, 2010].

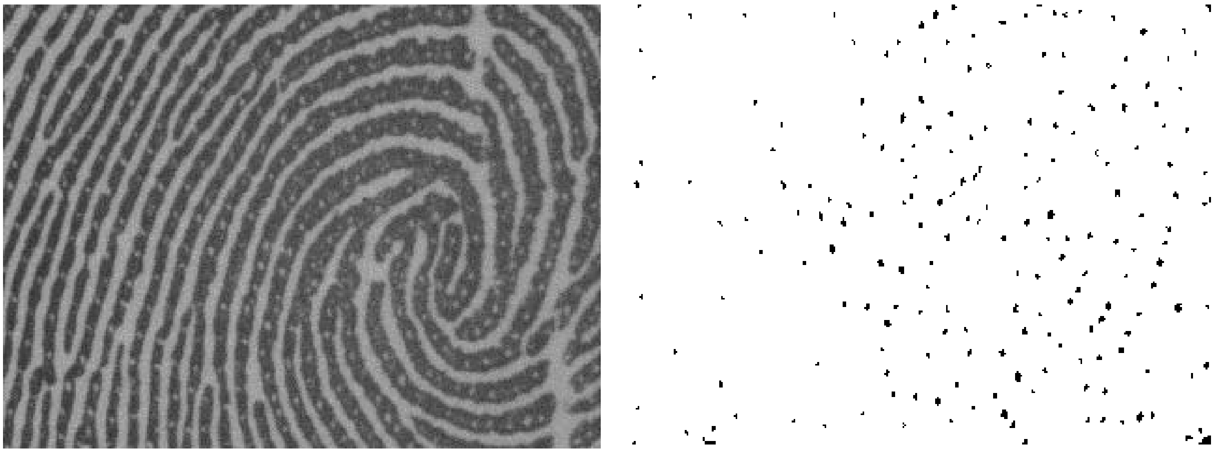


Figure 2. Fingerprint 5-1-1 and its poroscopical map ($T_{\min} = 3, T_{\max} = 30$)

Step 5. Extracting 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 fingerprint and corresponding poroscopical map.

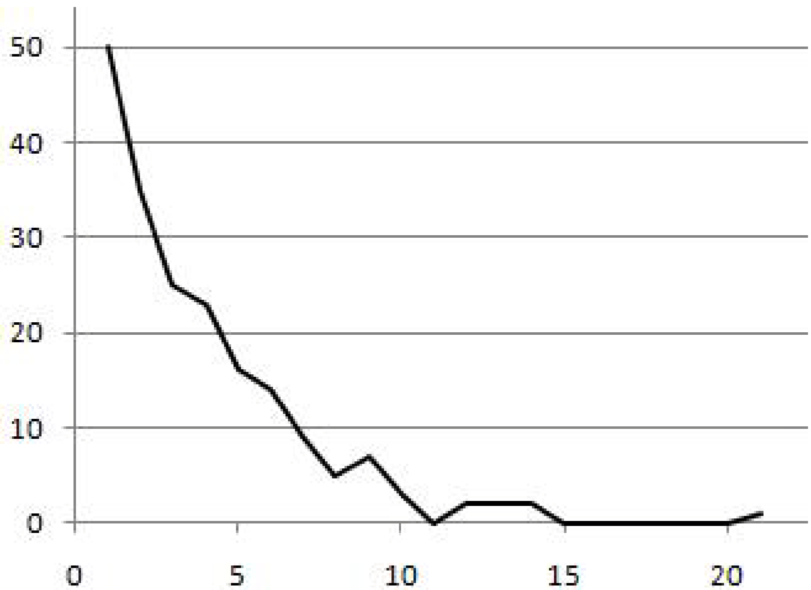


Figure 3. Frequency polygon of sizes of extracted pores

We check the size of each pore, i.e. the number of pixels it contains. 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.

Comparison of Poroscopical Maps of Two Fingerprints

The method originates in a new approach to the problem of image quality assessment, described in [Asatryan, 2009]. According to that approach the set of gradient magnitudes is considered as a feature of an image. A 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 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, $j = 1,2$, $m = 0,1,\ldots,M_j$, $n = 0,1,\ldots,N_j - 1$.

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 η_1,σ_1, η_2,σ_2 are estimated by the gradient magnitude samples of two images.

Step 3. Calculate the proximity of the images by formula

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

The measure (1) is invariant to sizes and rotations [Asatryan, 2010]. It has 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 comparison of two poroscopical maps to estimate its proximity.

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 [Hong Kong]). The fingerprints in this database were captured by resolution of 1200 dpi.

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 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 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

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 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 proposed technique and being used in AFRS will increase the recognition accuracy.

Conclusion

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 depicted in the map which is considered as a poroscopical map. The proximity of two chosen map is estimated by 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.

Table 3. Transformed items of the same fingerprint and corresponding poroscopical maps

$$T_{\min} = 3, T_{\max} = 30$$

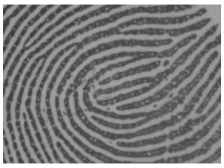
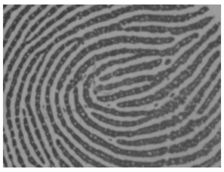
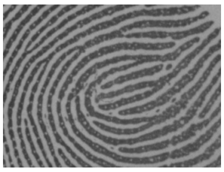
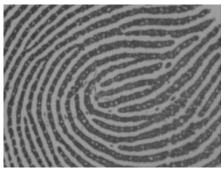
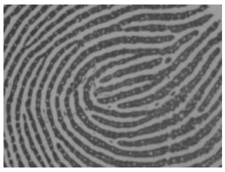
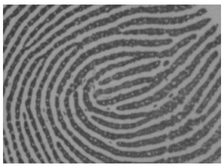
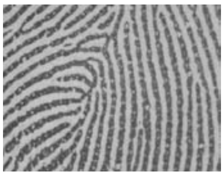
2-1-1	2-1-2	2-1-3	2-1-4	2-1-5
				
				

Table 4. Different fingerprints and corresponding poroscopical maps ($T_{\min} = 3, T_{\max} = 30$)

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

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