SEGMENTATION BASED FINGERPRINT PORE EXTRACTION METHOD

David Asatryan, Grigor Sazhumyan

Abstract: *In this paper, an algorithm for a fingerprint closed pore extraction is proposed. A closed pore is considered as a segment of binarized fingerprint image. Segment contains maximal information about a pore shape, orientation or other significant features. The proposed algorithm is based on the consecutive performance of some simple and well known image processing procedures, namely image binarization, segmentation, inversion, whitening etc. Segmentation is a process of splitting an image into non-overlapping partitions with connected pixels of the same intensity interval. After segmentation a pore is presented as a white segment in a black background. Inversion transforms the white pore segment into a black segment. Whitening is an operation to change pixels of the segment of certain size to pixels of intensity 255. This operation deletes black pores from the inverted image. Thus we can extract all the pores by comparing the intermediate images. The proposed algorithm consists of mentioned operations applied by appropriate choosing of thresholds. An example of application of described algorithm to show the effectiveness of our approach to the pore extraction problem is given.*

Keywords: *fingerprint, closed pores, segmentation, binarization, inversion.*

ACM Classification Keywords: *Image Processing and Computer Vision*

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) [Jain, 2007]. Most existing automated fingerprint recognition systems (AFRS) utilize only level one and level two fingerprint features for personal identification [Maltoni, 2003]. Level-three fingerprint features like pores, though seldom used, are also very distinctive [Stosz, 1994]. 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. The pore extraction algorithm can be broadly classified into two classes: the first class of algorithms extract pores by tracing fingerprint skeletons (Stosz, 2004, Kryszczuk, 2004]), the second class of algorithms extracted pores directly from gray scale image (Jain, 2007). The review of pore extraction methods are considered in [Zhao, 2010].

In this paper, a pore extraction algorithm from the second class is proposed.

The algorithms of second type use some standard operations, namely binarization, segmentation, filtration etc. It is known that the procedures of pore extraction usually are computationally expensive. The concrete algorithm depends on the problem to be solved. In many AFRS it is enough to determine only the coordinates of detected pores to use them for fingerprint recognition purposes. However the literature analysis shows that in certain cases it can be important to extract a pore as a segment to have maximal information about a pore size, shape, orientation, mutual disposition or other features.

In this work we consider the pore extraction procedure as a special segmentation method using relatively simple operations. The procedure is based on the repeatedly application of the hierarchical segmentation algorithm created by authors earlier [Asatryan, 2007], combining it with other simple processing algorithms.

The rest of paper is organized as follows. At first we describe the hierarchical segmentation method and software system proposed in [Asatryan, 2007]. Then we introduce some operations for fingerprint image processing and closed pores extraction algorithm based on that operations. In final part of the paper we describe an experiment for pore detection in a fingerprint image.

Hierarchical Segmentation Method

We consider an image of format Gray Scale (8 bit). So image S of size $N \times M$ has pixels of intensity $w(m,n) \in \{0,1,\ldots,255\}$, where $m = 0,1,\ldots,M-1; \quad n = 0,1,\ldots,N-1$.

Let $S' \in S$ be a set of pixels. A path $P(A,B)$ between two pixels $A,B \in S'$ is a sequence of $n > 1$ pixels $A, A_1, A_2,\ldots, A_n = B$ such that any two successive pixels of the sequence are adjacent. A set of pixels $S' \in S$ is called *connected*, if for any pair of pixels $A,B \in S'$ there exists a path $P(A,B)$ such that the sequence of pixels $A, A_1, A_2,\ldots, A_n = B$ belongs to $S' \in S$.

Let $0 < L < 255$ be an integer, and the intervals $I_1 = [0, \theta_1]$, $I_2 = [\theta_1 + 1, \theta_2],\ldots,$ $I_{L+1} = [\theta_L + 1, 255]$ are formed by thresholds $\theta_1, \theta_2,\ldots,\theta_L$. We say that a pixel A belongs to interval I_ℓ , if $w(A) \in I_\ell$, $\ell = 1,2,\ldots,L+1$. We say that a set $S' \in S$ belongs to interval I_ℓ , $\ell = 1,2,\ldots,L+1$, if all pixels of $S' \in S$ belong to the same interval I_ℓ . Then the connected set $S' \in S$ is called *segment* of intensity interval I_ℓ , if it belongs to the interval I_ℓ . So the *coherent segmentation* of image S results in the set of segments $S_1, S_2,\ldots,S_K$, which satisfy the following properties

$$S = \sum_{i=1}^{K} S_i \, , \; S_i \cap S_j = 0 \, , \text{ when } i \neq j \, , \; i,j = 1,2,\ldots,K \, .$$

The thresholds $\theta_1, \theta_2,\ldots,\theta_L$ can be determined in various ways coming from the image histogram properties. This problem is not considered in this paper. We use, as a rule, the thresholds $\theta_1, \theta_2,\ldots,\theta_L$, which are determined by dividing of interval $[0,255]$ into $L+1$ approximately equal intervals by the following formula

$$\theta_\ell = \left[\frac{255}{L+1} \right] \times \ell, \; \ell = 1,2,\ldots,L \, .$$

This segmentation procedure and corresponding software tool *Image Repair* are described in [Asatryan, 2007]. The name of that software shows that it can be used for damaged image repair purposes. The repairing process is based on the possibility to change the content of any obtained segment. Some operations can be done automatically. In this paper we apply the segmentation procedure to a binary image at $L = 1$ and use the whitening operation described below. All segments and the number of pixels of corresponding segments are available as output parameters of the software tool.

Pore extraction procedure

The procedure for a fingerprint pore extraction includes the following operations:

1. Binarization of a fingerprint image.

2. Segmentation. We use the procedure of segmentation described above for $L = 1$. Let $S_1, S_2, \ldots, S_K$ be the resulted segments. Denote by n_k the number of pixels of segment S_k, $k = 1,2,\ldots,K$.

It is necessary to note that the hierarchical segmentation process can be applied to the initial fingerprint twice. The first application can be performed at $L > 1$ then the segmented image is simplified by averaging of the pixels of every segment and changing the intensities of all pixels by the average value. This process can be interpreted as a special preliminary filtration method. After simplification the resulted image can be considered instead of the initial fingerprint.

3. Segment whitening procedure changes the intensities of all “black” pixels of a segment S_k to 255 if $n_k \leq t_1$, where t_1 is a prior chosen integer. As a result we get ”white” segment S_k^1 with the same number n_k of pixels of intensity 255.

4. Inverting of an image is a well known procedure, which substitutes a pixel of intensity I by a pixel of intensity $255 - I$.

5. Subtraction of two images is an operation which obtains an image from two another images by subtracting of intensities of that images. In general, this operation must be used correctly to provide the visualization of resulted image. In this paper the correctness of the procedure is provided automatically.

Pore extraction algorithm. Let F be an initial fingerprint image with pores. The pore extracting algorithm consists of the following steps.

Step 1. **Binarization** of the fingerprint image F. Binarization is performed using a threshold by Otsu method [Otsu, 1974] or other method for well distinguishing the pores in the image. Denote by F_B the binarized image F.

Step 2. **Segmentation** of the image F_B by using the software tool *Image Repair* at $L = 1$. Let K be the number of segments, and $S_1, S_2, \ldots, S_K$ be the segments. The program *Image Repair allows* the visualization of the segmented image and any segment S_k by choosing a point within the segment. Thus, we can estimate the maximal size of pores which we want to extract from the image F. Denote by t_1 the maximal size of extracting pores.

Step 3. **Inversion** of the segmented image F_B. Denote it by F_B^I.

Step 4. **Whitening** the image F_B^I at threshold value of $t_0 - 1$. Let’s denote the whitened image by $F_B^I(t_0)$.

Step 5. **Whitening** the image $F_B^I(t_0)$ at threshold value of $t_1 + 1$. Let's note that after this operation all the black segments of size between t_0 and t_1 of the image F_B^I will be whitened. Let's denote the whitened image by $F_B^I(t_0, t_1)$.

Step 6. **Subtraction** of the image $F_B^I(t_0)$ from the image $F_B^I(t_0, t_1)$. The closed pores will be presented in the resulted image as white segments on the black background. Denote it by $\Delta F(t_0, t_1)$.

Results of an experiment

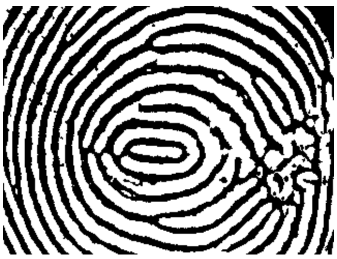
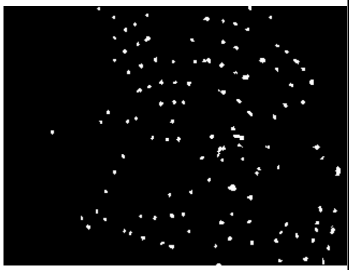
Before application of above described algorithm it is necessary to determine the interval of pixel number for pores which corresponds to a fingerprint scanner resolution. Starting from the literature information [Busselaar, 2010], we can be oriented to pores size of 60–220 micron, which corresponds to 8-30 pixels per pore for 1000 ppi scanned fingerprint image. Therefore we can choose the segments which include correctly determined 8-30 pixels.

The pore extraction algorithm can be illustrated by the following experiment.

Experiment. Original fingerprint image fragment and results of the experiment are shown in Table. Binarization of the image F (a) is performed at threshold value of 108 (b). Whitening of segments of binarized and inverted image is performed at $t_0 - 1 = 7$. The image $F_B^I(t_0)$ is shown in (d). Then the image $F_B^I(t_0)$ was whitened at threshold $t_1 + 1 = 31$ (e). The resulted image $\Delta F(t_0, t_1)$ after subtraction is shown in (f).

All extracted pores are clearly seen in the black background.

Table. Fingerprint pore extraction results at each step of the algorithm

		
(a) Original image	(b) Step1. Binarization (108)	(c) Steps 2 and 3
		
(d) Step 4 ($t_0 = 7$)	(e) Step 5 ($t_1 = 31$)	(f) Step 6

The accuracy of proposed procedure can be checked by comparing the locations and the number of pores detected by visual analysis in the original fingerprint image and in the image of right bottom cell of Table 1.

Conclusion

The proposed algorithm for closed pore extraction from a fingerprint image is based on the consecutive performance of above specified simple image processing procedures, namely image binarization, segmentation, inversion, whitening etc. The algorithm consists of mentioned operations applied by above described steps. The described example of pores detection and extraction results shows the effectiveness of our approach to the pore extraction problem. The proposed algorithm can be easily included into automated fingerprint recognition systems.

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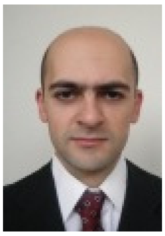
Authors' Information

David Asatryan *– Professor, Head of group of the Institute for Informatics and Automation Problems of NAS Armenia, 1, P.Sevaki Str., 0014, Yerevan, Armenia, e-mail: dasat@ipia.sci.am.*

Major Fields of Scientific Research: Digital signal and image processing.



Grigor Sazhumyan *– Candidate of Technical Sciences, Software Engineer, Institute for Informatics and Automation Problems of NAS Armenia, 1, P.Sevaki Str., 0014, Yerevan, Armenia, e-mail: grigorsazhumyan@gmail.com .*

Major Fields of Scientific Research: Digital signal and image processing, Software developing.