Simple Fingerprint Minutiae Extraction Algorithm Using Crossing Number On Valley Structure

Sunny Arief SUDIRO, Michel PAINDAVOINE
LE2I-UMR CNRS 5158
University of Burgundy,
Dijon, France
{sunny-arief.sudiro,paindav}@u-bourgogne.fr

Tb. Maulana KUSUMA
Center for Multimedia Systems
Gunadarma University
Jakarta, Indonesia
{sunny,mkusuma}@staff.gunadarma.ac.id

***Abstract*— Most of the existing fingerprint extraction techniques currently available are based on ridge structure. The ridge usually has thicker structure than the valley, so that more processing time is needed to extract the ridge than extracting the valley. Taking the advantage of the thin structure of the valley, we proposed an algorithm that reduces the time needed for minutiae extraction. The algorithm was developed in Matlab environment using fingerprint images from FVC2004. In order to show the performance of the algorithm, numerical results are presented.**

Keywords-component; fingerprint, minutiae, ridge structure, thinning, valley structure.

I. INTRODUCTION

Research in biometric recognition system is growing continuously. *Biometric recognition* refers to the use of distinctive *physiological* (such as: face, retina, fingerprint, iris) and *behavioral* characteristics (such as: gait; signature), called *biometric identifiers or biometric characteristic* (or simply biometrics) for automatically recognizing individuals. Sometimes all biometric identifiers are a combination of physiological and behavioral characteristics and they should not be exclusively classified into either physiological or behavioral characteristics [1].

Biometric recognition system is widely used for commercial and public applications, such as:

1. Commercial applications: building access, computer system, ATM, etc.
2. Government applications: personal id, driver license, passport, etc.
3. Forensic applications: criminal investigation, terrorist identifications, etc.

One of biometric characteristic is fingerprint. In fingerprint recognition system, besides obtaining the characteristics, acquiring features such as fingerprint feature as a template is very important. This template will be used in identification or verification process.

Some requirements must be considered when developing recognition system based on biometric feature [1], as follows:

1. *Universality*, every body has those characteristics.
2. *Distinctiveness*, every two persons is different.
3. *Permanence*, the characteristic does not change over a period of time.
4. *Collect ability*, the characteristic can be easily collected and measured quantitatively.

In practice, other issues should be taken into account, such as p*erformance*, a*cceptability*, and c*ircumvention*.

A number of researches have been done in fingerprint recognition. However, this topic is still attractive for researchers and also challenging [2]. Fingerprint feature used for recognition are classified as global feature or as local feature. Global feature correspond to singular points called loop and delta. These features are similar to control point around which the ridge lines are "wrapped". Local feature, called minutiae correspond to ridge termination and ridge bifurcation. There are 60 to 100 minutiae points on the fingerprint. In order to obtain these features, many algorithms have been proposed in the literature [1].

In relation to robustness improvement, we focused our study on local features extraction. There is a fact that ridge structure is thicker than valley structure. Average ridge width (typically 6 pixels) is thicker than average valley width (typically 4 pixels). Minutiae extraction is obtained from binary images of fingerprint. This thinner binary image will improve the performance, because it is easier for skeleton computation and it increases the speed of the process [3].

Image acquisition and analysis from the fingerprint sensor determine the pixel width of the structure and the representation pixel value of the structure of fingerprint image as well as the image background. This characteristic must be considered when applying specific algorithm in fingerprint recognition system to have a good performance.

We present in this article an extension of known minutiae detection algorithm proposed initially by Rutovitz [4]. In order

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to improve minutiae extraction with a short time computation, our objective is to use the Rutovitz algorithm with binary pixel value adapted to the thinning process.

Our article is decomposed as follows. In the second section we describe the fingerprint feature and minutiae extraction that we have developed. In the section 3 we present the corresponding algorithm and finally, in section 4, we show the obtained result.

II. FINGERPRINT FEATURE AND MINUTIAE EXTRACTION

Minutiae points are various anomalies in terms of ridge bifurcations, ridge endings, ridge crossovers, and small ridges. This points, for automatic feature extraction and matching are usually restricted to two types of minutiae: ridge terminations/endings and ridge bifurcations (or the valley structure can be used for minutiae points, valley ending or valley bifurcations). A minutiae is identified by its position (x-y coordinate) and the angle of dominant ridge makes with the x-axis at the point of interest [3]. Type of minutiae (ridge/valley bifurcation or ridge/valley terminations) is also very important, this information increases the accuracy of the fingerprint identification. Figure 1 shows an image of the fingerprint structure.

A. Binarization and Thinning Process

Usually fingerprint sensor provides the grayscale image of fingerprint. Extraction process needs binary image, so binarization process must be applied. Then thinning process is performed to obtain the representation of one pixel width of fingerprint structure, especially for representation of pixel value '0' for the skeleton image. For thinning process, an algorithm developed by Zhang and Sue is used with modification for pixel value '0' as described in [5,6] and [7].

Figure 2 shows skeletonized image of fingerprint structure, and an example of skeletonized with improperly selected thinning algorithm (thinning algorithm based on pixel value representation '1' applied to image that have pixel value representation '0'). In figure 2 (d) thinning is applied on the background of the image.

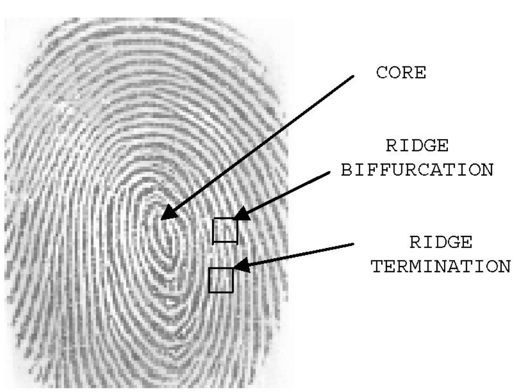
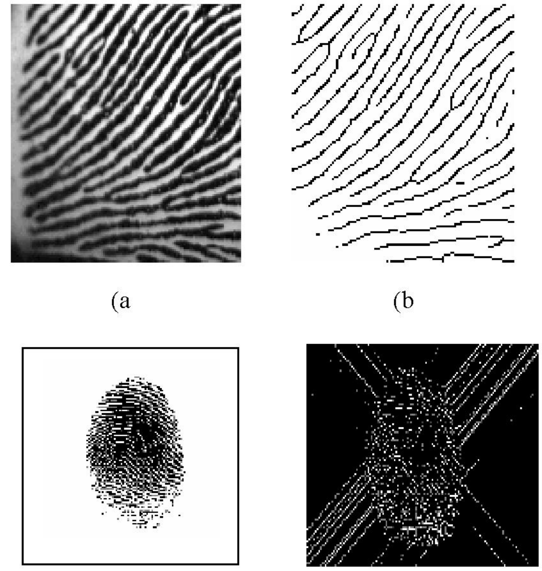


Figure 1. Structure of fingerprint image [1].



(a (b

(c) (d)

Figure 2. (a) binary image, (b) skeletonized image, (c) original image, and (d) skeletonized with pixel representation not adapted to thinning process.

B. Minutiae Extraction Process

Minutiae extraction is based on Crossing Number Algorithm described in [3,8]. This algorithm is working on pixel representation '1' or '0', but the decision of minutiae point can be selected for each pixel value.

Ideally, a good skeleton is strictly one pixel to obtain good result of minutiae points detection. Minutiae points extraction algorithm can be applied with crossing number (CN) at a point P and P_i is the binary pixel value in the neighborhood of P, expressed as:

$$CN = 0{,}5\sum_{i=1}^{8} | P_i - P_{i+1} | \text{ with } P_9 = P_1 \qquad (1)$$

P_4	P_3	P_2
P_5	P	P_1
P_6	P_7	P_8

With this formula, if CN=1 it corresponds to the End Point and if CN=3, it corresponds to Bifurcation Point of minutiae. Other properties of CN are described in table 1. In applying this algorithm, border area may be ignored, since there is no need to extract minutiae point on border area of the image that will give more false minutiae points.

TABLE I. PROPERTIES OF CROSSING NUMBER [3].

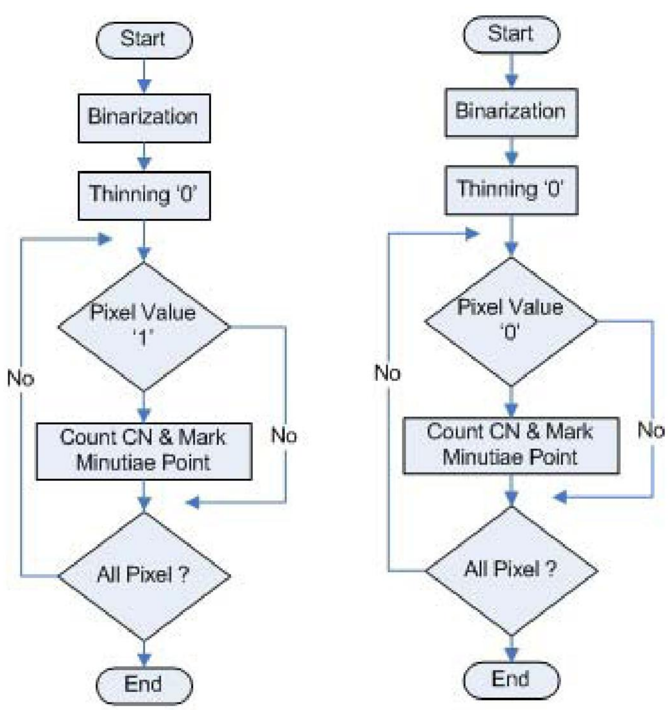
CN	Properties
0	Isolated point
1	Ending point
2	Connective point
3	Bifurcation point
4	Crossing point

III. PROPOSED ALGORITHM

The extraction process begins with image pre-processing, which consists of binarization and thinning on pixel representation of '0'. Proposed algorithm can be seen on figure 3. Minutiae point detection depends on pixel value ('0' or '1'). Two methods are possible: first method processes only pixel with '1' value and second method is dedicated for pixel with '0' value. Method 1 count Crossing Number value on pixel value '1' or P=1, and method 2 do this process on pixel value '0' or P=0. Pre-processing: binarization and thinning algorithm on pixel representation of '0' will precede the minutiae point detection process (on '1' pixel value or on '0' pixel value).

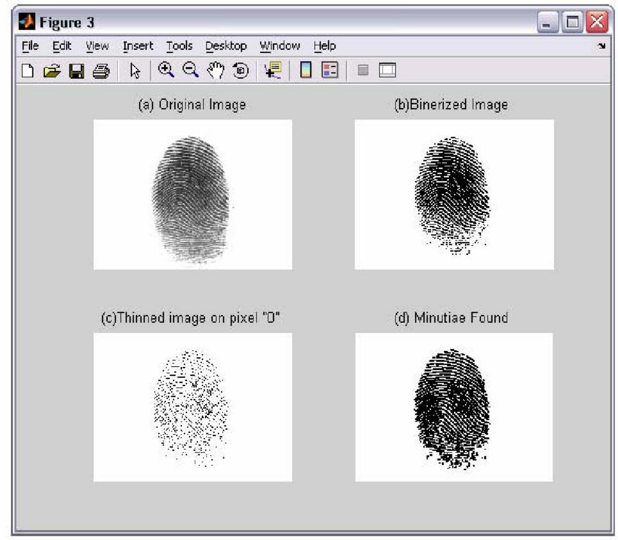
IV. EXPERIMENTAL AND NUMERICAL RESULT

Program corresponding to these methods have been written using Matlab and images for testing are from DB1_B FVC2004, we use 10 images from 10 fingerprints in that database. In tables 2 present computation time for method 1 and in tables 3 is for method 2. From these tables, basically we obtain the same pre-processing time (column 1 and 2), but there is little different in minutiae point extraction process (column 3). Table 4 gives number of minutiae points detected. Even though just small improvement from computation time 1.772 second for method 1 and 1.588 second for method 2, but from minutiae point detection, result from method 2 is closer to the number of real minutiae points. From this figure 4 and the table 2,3,4 we can see the improvement of the algorithm using the method 2.

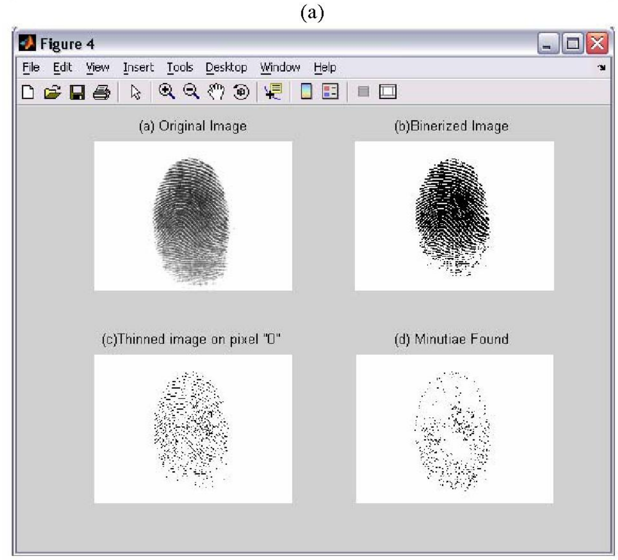


(a) (b)

Figure 3. Proposed algorithm, (a) method 1 and (b) method2



(a)



(b)

Figure 4. Results from (a) method 1, and (b) method 2.

Computation time is counting based on tic/toc command from Matlab, a command to start stopwatch timer and measure the time required for the operation between tic and toc statements. This counting exclude the interfacing process such as reading the fingerprint image and showing the figure, this counting focus on binarization, thinning and minutiae extraction process.

TABLE II. METHOD 1 COMPUTATION TIME USING TIC/TOC

No	File	Method 1			
		(1)	(2)	(3)	(4)
1	101_2.tif	0.03	0.88	0.77	1.68
2	102_2.tif	0.02	0.95	0.79	1.76
3	103_3.tif	0.02	1.08	0.80	1.90
4	104_4.tif	0.02	0.95	0.77	1.74
5	105_7.tif	0.02	0.92	0.78	1.72
6	106_4.tif	0.03	0.59	0.71	1.33
7	107_3.tif	0.02	0.85	0.75	1.62
8	108_5.tif	0.02	0.38	0.72	1.12
9	109_3.tif	0.02	1.50	0.74	2.26
10	110._2.tif	0.02	1.82	0.75	2.59
	Average	0.022	0.992	0.758	**1.772**

TABLE III. METHOD 2 COMPUTATION TIME USING TIC/TOC

No	File	Method 2			
		(1)	(2)	(3)	(4)
1	101_2.tif	0.02	0.90	0.59	1.51
2	102_2.tif	0.02	0.98	0.59	1.59
3	103_3.tif	0.02	1.08	0.59	1.69
4	104_4.tif	0.03	0.93	0.64	1.60
5	105_7.tif	0.03	0.90	0.60	1.53
6	106_4.tif	0.02	0.62	0.58	1.22
7	107_3.tif	0.02	0.86	0.60	1.48
8	108_5.tif	0.03	0.43	0.64	1.10
9	109_3.tif	0.02	1.07	0.60	1.69
10	110._2.tif	0.02	1.86	0.59	2.47
	Average	0.023	0.963	0.602	**1.588**

Note :(1) Binarization time in second, (2) Thinning time in second, (3) Minutiae points extraction time in second, (4) All process (1,2,3) in second

TABLE IV. TABLE 4. MINUTIAE POINT DETECTED.

No	File	Method 1			Method 2		
		(1)	(2)	(3)	(1)	(2)	(3)
1	101_2.tif	17145	33	17178	357	395	752
2	102_2.tif	22465	57	22522	194	1120	1314
3	103_3.tif	24170	96	24266	206	1064	1270
4	104_4.tif	20590	74	20664	206	803	1009
5	105_7.tif	20022	30	20052	314	450	764
6	106_4.tif	16158	18	16176	330	198	528
7	107_3.tif	21396	56	21452	397	662	1059
8	108_5.tif	16365	79	16444	375	164	539
9	109_3.tif	18180	32	18212	177	500	677
10	110._2.tif	21894	58	21952	55	1174	1229
	Average	19838	53	**19891**	261	653	**914**

Note: (1) Numbers of End Point Minutiae detected, (2) Numbers of Bifurcation Minutiae detected, (3) Total of minutiae points detected.

V. CONCLUSION AND PERSPECTIVES

Using the well-adapted algorithm for image pixel representation gives a best result of minutiae point detected (closer to the number of true minutiae). In the experiment, method 2 with small modification is better than method 1. In future work, post processing must be developed for eliminating false minutiae.

In order to avoid some broken structure of original fingerprint image, we will improve the thinning process. Finally in relation to time computation constraint, we intend to implement full algorithm using hardware system as FPGA device.

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