Mathematical Morphology Approach for Genuine Fingerprint Feature Extraction

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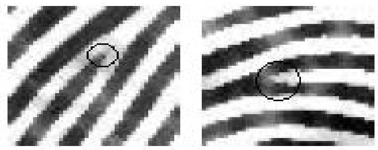
Abstract

Recognition systems based on biometrics (faces, hand shapes and fingerprints etc.) are finally taking off although it has taken a long way to come. Fingerprints have been a precious tool for law enforcement, forensics and recently in commercial use for over a century. Evaluate the performance of these emerging technologies is tricky problem. Most fingerprint verification algorithms rely on minutiae features, and these algorithms can only be as robust as the underlying minutiae features. Therefore, reliable minutiae extraction is vital to a system's performance. Most of the feature extraction techniques extract features from thinned images but while dealing with binarization and skeletization of image it introduces noise or superfluous information, which creates troubles for genuine feature extraction. In this paper we have used the mathematical morphology to remove the superfluous information for genuine feature extraction and measure the feature extraction performance through sensitivity and specificity.

Keywords: Feature Extraction, Morphology, Fingerprints, superfluous information etc.

1. INTRODUCTION

In an increasingly digital technology world, among the main innovation prospects and framework of future services like authentication that's why the use of biometric based technology get developed. This is new and emerging technology due its high degree of maturity and reliability. Biometric system having two important utility 1) authentication or verification and 2) Identification in which persons identity is verify by biometric sign (fingerprint, face, pam, iris etc.). In a recently published World Biometric Market Outlook (2005-2008), analysts predict that while the average annual growth rate of the global biometric market is more than 28%, by 2007. The technologies that would be included are fingerprint technology by 60%, facial & iris by 13%, keystroke by 0.5% and digital signature scans by 2.5% [1]. Fingerprint technology for recognizing fingerprints for identification purposes is proving as regards as reliable but efficient recognition is depending on the quality and the reliability of feature extraction of input fingerprint image. The fingerprint recognition system is basically divided into image acquisition, pre-processing, feature extraction, matching and decision. The reliable feature extraction stage is of great significance as it influences the performance of subsequent recognition algorithm therefore it is an essential step to obtain precise minutiae [2, 3, 4]. Minutiae are local discontinuities in the fingerprint pattern. The most important ones are *ridge ending* and *ridge bifurcation* illustrated in figure 1.



(a) ridge ending (b) ridge bifurcation
Figure 1: Example of minutiae

2. BACKGROUND

The feature extraction stage is concerned with the finding and measuring important similarities of the fingerprint that will be used to match it. And matching is the final goal of recognition system to find the identity of the persons whose input fingerprint has been submitted i.e. it compares the extracted features or similarities from two fingerprints and determine the possibility that they have been captured from the same finger.

Most of fingerprint recognition system is based on *minutiae* i.e. ridge ending and ridge bifurcation [2, 5, 6, 7, 8]. Reliable minutiae extraction plays imperative role in recognition system performance. There are two main approaches used to minutiae extraction. The first approach uses a thinned representation of the binary ridge structure, known as its *skeleton*. The second approach attempts to extract the minutiae locations from the grey-scale image itself.

In view of that, there have been several approaches proposed for features not based on minutiae. The cyclic structure of local fingerprint regions [9], shape signatures of fingerprint ridges [10] and directional micropattern histograms [11] have been proposed as alternative fingerprint features. Wavelets [12, 13, 14], texture features [15] and Gabor filters [16, 17, 18] have also been investigated as tools for feature extraction. Furthermore, experiments based on image verification [19, 20,21] and optical processing techniques [22, 23, 24] have also been conducted.

The most popular method for minutiae extraction is to use a binarized and skeletonised representation of the fingerprint. The task is to extract the minutiae from the thinned ridge map; any black pixel that has only one black neighbor is a ridge ending similarly any black pixel with more than two black pixel neighbor is ridge bifurcation as shown in figure 2.

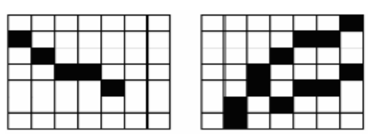


Figure 2: ridge ending and ridge bifurcation in a thinned ridge map

In some Automatic Fingerprint Identification Systems include a post processing stage to confirm that valid minutiae have been extracted, and this is known as minutiae verification. Minutiae extraction from ridge skeletons these algorithms generally consist of three main pre-processing stages: binarization, thinning or skeleton and minutiae extraction directly from the skeleton image. The advantage of this approach is the simplicity of extracting and labeling the minutiae when an accurate ridge skeleton can be found.

In this paper or approach is to remove the spikes, spurs, and dots etc. using mathematical morphology.

3. MATHEMATICAL MORPHOLOGY

Morphology is biological term refers to study of form and structure, in imaging; mathematical morphology refers to a branch of nonlinear image processing and analysis that concentrates on the geometric structure within an image, it is mathematical in the sense that the analysis is based on set theory, topology, lattice, random functions, etc. As well as mathematical morphology is considered as a powerful tool to extract information from images. [2, 25]

Erosion and dilation are considered the primary morphological operations. Erosion shrinks or thins object in a binary image where as Dilation grows or thickens objects. Erosion and Dilation constitute the basis for more complex morphological operators and can be defined as follows:

Let A: $z^2 \rightarrow z$ be a image and B: $z^2 \rightarrow z$ a structuring element. The erosion of A by B denoted by $(A\Theta B)$, is expressed as

$$(A\Theta B) = \{z \mid (B)_z \subseteq A\} \quad \text{………………………………………………………………………………}(1)$$

The dilation of A by B, denoted by $(A \oplus B)$, is defined as

$$(A \oplus B) = \{z \mid (\hat{B})_z \cap A \neq \phi\} \quad \text{…. ……………………………………………………………….………..}(2)$$

The dilation of A by B is the set of all displacements, z, such that $\hat{B}$ and A overlap by at least one element.

The morphological operators are designed as a composition of mathematical morphology elementary operators and express the user's knowledge about the specific problem. The mathematical morphology is comparing the objects contained in an image with known object called Structuring Element. It often happens that many false minutiae are detected due to spikes and broken ridges in the skeleton. Therefore careful processing is necessary to preserve genuine minutiae. In this experiment we have used the gray scale fingerprint images having some background noise, first we convert these images into binary images using Otus's threshold, a threshold method, which does not depend on modeling the probability density functions, developed by Otus [26] (see figure 3). After binarization we have done the skeleton of binary image by using morphological thinning operation.

(a) (b)

Figure 3: a) Original Image b) Binary Image,

The thinning algorithm rinds pixels from ridges until the ridges are one pixel wide. For this purpose the mathematical morphology is used for extracting a set of lines and obtaining the desired thinned ridge map. Morphological thinning operator is the subtraction between the input image and the sub-generating operator with structuring element defined as follows:

$A \otimes B = A-(A * B) = A \cap (A * B)$ ……………………………………………………………………(3)

Where, A is the original image and B is the structuring element sequence as shown in figure 4.

$\{B\}=(B^1, B^2, B^3, \ldots B^8)$ ………………………………………………………………….……………(4)

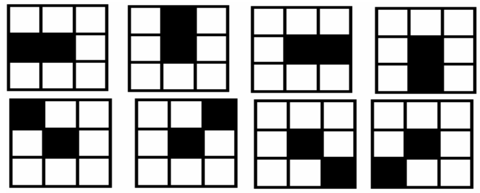


Figure 4: Structuring element B^1, B^2, B^3, B^4 (rotated by 90^O) B^5, B^6, B^7, B^8, (rotated by 90^O)

This operation removes pixels, which satisfy the pattern given by the structuring element.

(a) (b)

Figure 5: (a) Thinned image (b) spikes and dots removed images using mathematical morphology.

After thinning the presence of the superfluous spikes, breaks and dots in thinned ridge map may lead to detection of many spurious minutiae. So it is necessary to apply the ridge map depurator to remove these superfluous elements for removing small isolated lines; new designed structuring elements used. We have used the depurator spur and clean operator to remove this superfluous information and got promising result as shown in figure 5. The spur operator removes the spur pixels as shown in following figure 6, we have also used the clean operation to remove the isolated dots.

0	0	0	0		0	0	0	0
0	0	0	0		0	0	0	0
0	0	1	0	→	0	0	0	0
0	1	0	0		0	1	0	0
1	1	0	0		1	1	0	0

Figure 6: shows how morphological spur operation

4. EXPERIMENTAL RESULTS AND DISCUSSION

In this experimental work we have tested this algorithm on synthetic generated fingerprint images, these images are generated by using SfigGE v2.0 Synthetic Fingerprint Generator with background noise capacitive and optical [28]. We have tested the proposed algorithm using two quantities measure namely sensitivity and specificity which indicates the ability of the algorithm to detect the genuine minutiae and remove the false minutiae for fingerprint image [29, 30, 31]. We have compared result before and after post processing of proposed morphological algorithm; performance have been measured based on the numbers of missing and spurious minutiae before and after processing.

$$Sensitivity = 1 - \frac{\text{Missed Minutiae}}{\text{Ground Truth Minutiae}} \quad \text{.........(5)}$$

$$\text{Specificity} = 1 - \frac{\text{False Minutiae}}{\text{Ground Truth Minutiae}} \quad \text{.........(6)}$$

We have tested fingerprint images generated by Synthetic Fingerprint Generator (30 Images), also on FVC2002 database (80 Images), in our experiment. The Ground Truth Minutiae we have detected manually in each fingerprint image. Out of these some results we have presented in Table 1.

Images	Ground Truth Minutiae	Missed Minutiae		False minutiae	
		Before	After	Before	After
1	15	1	1	12	4
2	16	3	0	11	1
3	15	1	0	3	1
4	22	2	0	6	2
5	20	2	1	2	0

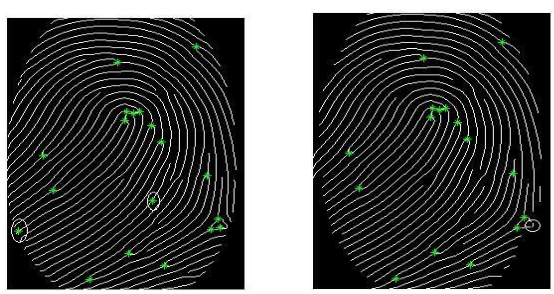
Table 1: performance of minutiae detection algorithm before and after morphological processing is shown.

Metric	Before	After
Sensitivity (%)	89	95
Specificity (%)	78	89

Table 2: overall statistics of Sensitivity and Specificity

In this experiment we got less number of false minutiae as compare to before processing. This result also reflects the average sensitivity that was 89% and 95% before and after post processing respectively. Similarly, for specificity, we got high specificity after preprocessing i. e. 89% as compare to before i.e. 78% as shown in table 2.

The figure 7 (a) demonstrates two minutiae (in small circle) is introduced while thinning process; but by using mathematical morphology we have removed spurious minutiae as shown in figure 7 (b) and also we can see still there is one missed minutiae as indicated by small circle.



(a) (b)

Figure 7. a) Feature extracted before processing b) feature extracted after processing.

5. CONCLUSION

In this paper, we have introduced a method for removing superfluous information for genuine fingerprint feature extraction using mathematical morphological operation. This algorithm removes the spikes, spurs and dots very effectively and extracts a clear and reliable ridge map structure from input fingerprint image. We have also compared the performance of before and after of this morphological algorithm by extracting features in terms of sensitivity and specificity. We got high sensitivity after applied of this morphological approach. In future this work may be extended for the other database and reduce the number of missed minutiae by improving the performance of extraction algorithm for better performance of automatic fingerprint recognition system.

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