Fingerprint Image Enhancement

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Abstract

The performance of fingerprint recognition algorithms is highly affected by the quality of the input fingerprint images. Fingerprint images are rarely of perfect quality. They may be degraded and corrupted due to variations in skin and impression conditions. Thus, image enhancement techniques are often employed to reduce the noise and enhance the definition of ridges against valleys.

The objective of this paper is to present a fingerprint image enhancement approach. Two methods are adopted for Image Enhancement: the first one is based on Fourier Transform and the other is Histogram Equalization. The input images are fingerprint images from FVC2002 database. The experiment results suggest that our enhanced algorithm achieves visibly good results with relatively modest computation time.

Keywords: *Fingerprint, enhancement, minutiae, segmentation, contextual filtering.*

1- Introduction

Fingerprint is a unique feature to an individual. It stays with the person throughout his life. This makes the fingerprint a very reliable kind of personal identification because it cannot be forgotten, misplaced, or stolen. Fingerprint authorization is potentially the most affordable, easy and convenient method of verifying a person's identity.

A fingerprint pattern is composed of a sequence of ridges and valleys. The ridges are the raised skin; while the valleys are the lowered skin [1]. In fingerprint image, the ridges appear as dark lines while the valleys are the light areas between the ridges (Figure-1).

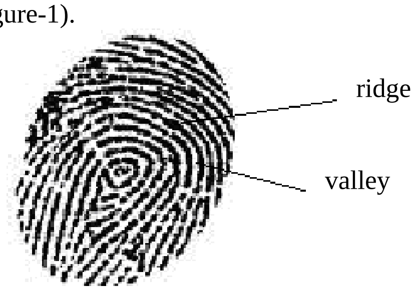

Figure 1: Fingerprint Pattern

Fingerprints are fully formed at about seven months of fetus development and finger ridge configurations do not change throughout the life of an individual except due to accidents such as bruises and cuts on the fingertips [2].

Fingerprint patterns structures can be discussed from global and local levels.

- **At the global level,** the global ridge structure and singularities or singular regions are concerned.

Singular regions may be classified into three typologies: *loop*, *delta*, and *whorl*[1] (figure-2).

[1] Sometimes whorl singularities are not explicitly introduced because a whorl type can be described in terms of two facing loop singularities.

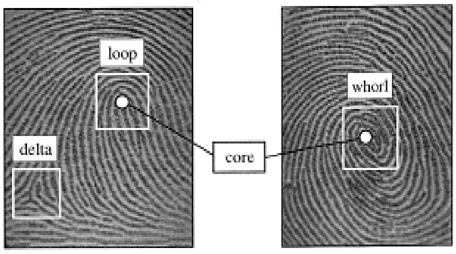

Figure-2: Singular regions

- **At the local level,** structures, called minutiae, refers to various ways that the ridges can be discontinuous. For example, a ridge can suddenly come to an end (termination), or can divide into two ridges (bifurcation). It is these features that Automatic Fingerprint Identification Systems (AFISs) extract and compare for determining a match.

The quality of input fingerprint images plays an important role in the performance of the finger-print matching algorithms. So, it is necessary to employ image enhancement techniques prior to fingerprint recognition stage.

In this paper we propose a fingerprint image enhancement method that can be used in fingerprint recognition system. Our method involves two basic stages:

- Image Segmentation to separate the foreground regions in the image from the background regions. Separating the fingerprint area is necessary to avoid extraction of features in noisy areas of the fingerprint and background.
- Image Enhancement based on Fourier Transform and Histogram Equalization.

2- Segmentation

Segmentation is the process of separating the foreground regions in the image from the background regions. Separating the fingerprint area is necessary to avoid extraction of features in noisy areas of the fingerprint and background.

In a fingerprint image, the background regions generally exhibit a very low gray-variance value, whereas the foreground ns have a very high variance [3,4]. Hence, a method based on variance thresholding can be used to perform the segmentation. For this, the whole image is divided into blocks of size w×w and the variance of each block is computed. The variance is then compared with a threshold value. If the variance of a block is less than the threshold value, then it is deleted from the original figure. This process is carried out for the whole image.

The block size is defined experimentally. We used the histogram of variance values to define the threshold value. The obtained result of segmentation is shown in the figure -3.

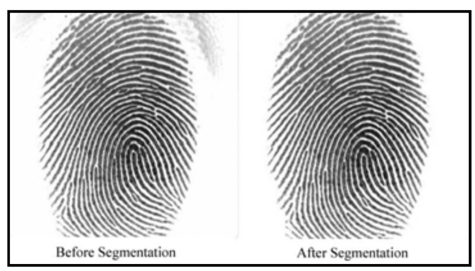

Figure-3: Segmentation result

3- Image Enhancement

The performance of a fingerprint minutiae extraction and matching algorithm depends critically upon the quality of the input

fingerprint image. The "quality" of a fingerprint roughly corresponds to the clarity of the ridge structure in the fingerprint image.

Due to the non-stationary nature of the fingerprint image, general-purpose image processing algorithms are not very useful in this regard but serve only as a preprocessing step in the overall enhancement scheme [2]. Pixel oriented enhancement schemes like histogram equalization [5], mean and variance normalization, Wiener filtering improve the legibility of the fingerprint but do not alter the ridge structure [6].

The most widely used technique for fingerprint image enhancement is based on the use of contextual filters. In conventional image filtering, only a single filter is used that operates on the entire image. In contextual filtering, the filter parameters change according to the local ridge frequency and orientation.

O'Gorman et al. proposed the use of contextual filters for fingerprint image enhancement for the first time [6]. They defined a mother filter whose major axis is oriented parallel to the ridges. The local ridge frequency is assumed constant, so the context is defined only by the local ridge orientation. They recomputed the filter in 16 directions. The image enhancement is performed by convolving each point of the image with the filter in the set whose orientation is best matches the local ridge orientation.

Our approach is based on the technique proposed by Waston, Candela and Grother (1994) and Willis and Myers (2001) [2]. It is able to perform a sort of contextual filtering without requiring explicitly computing ridge orientation and frequency.

The image is divided into windows 32 × 32. Each 32 × 32 block is enhanced separately; the Fourier transform of the block is multiplied by its power spectrum raised to a power *k*:

$I_{enh}[x,y]=F^{-1}\{F(I[x,y])|F(I[x,y])|^{k}\}$

The power spectrum contains information about the underlying dominant ridge orientation and frequency. Multiplying the FFT of the block by its magnitude a number of times has the effect of enhancing. The "*k*" in the equation is an experimentally determined constant. While having a higher "*k*" improves the appearance of the ridges, filling up small holes in ridges, having too high a "*k*" can result in false joining of ridges. Thus a termination might become a bifurcation. We choose *k* = 0.45.

To accelerate the process we use nonoverlapping blocks. We expect that the 'block' effects have no harm to the further operations.

The visualization effect of the output image is enhanced using the second algorithm: histogram equalization.

Histogram Equalization aims to expand the pixel value distribution of an image so as to increase the perceptional information. The histogram after the histogram equalization occupies all the range 0 to 255 and the visualization effect is enhanced [5].

Figure-4 shows the result of the image enhancement algorithms.

The enhanced image has the improvements to connect some falsely broken points on ridges and to remove some spurious connections between ridges.

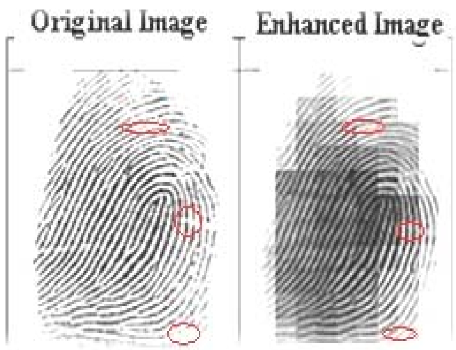

Figure-4: Enhancement result

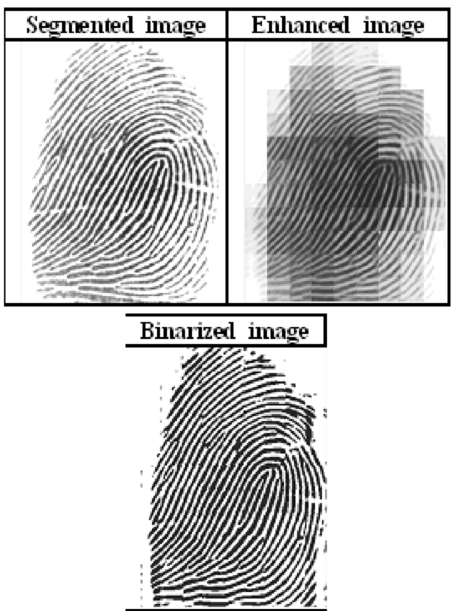

Figure -5: Result of banirization with Enhancement

Most automatic fingerprint recognition systems are based on minutiae matching. Most minutia extraction methods require the fingerprint image to be converted to binary image. To evaluate the efficiency of enhancement and show that the block effect has no harm we performed binarization process on the enhanced image (figure-5). The side effect of each block is obvious on the enhanced image but it has no harm to the further operation

Conclusion

In this paper, a simple yet effective image enhancement approach is proposed. First fingerprint segmentation is performed to separate the fingerprint image from the background. This allowed reducing the image size to be processed by the following step. Enhancement approach involves two algorithms: a contextual filtering based on Fourier Transform without requiring computing local ridge orientation and frequency, and Histogram Equalization. The results obtained are quite promising. The approach will be used to develop a fingerprint recognition system.

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