FINGER PRINT IMAGE ENHANCEMENT USING FFT FOR MINUTIA MATCHING WITH BINARIZATION

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Abstract: **In this paper we discuss about the enhancement of the finger print image for fingerprint recognition. This target can be mainly decomposed into image preprocessing, feature extraction and feature match. For each sub-task, some classical and up-to-date methods in literatures are analyzed. Based on the analysis, an integrated solution for fingerprint recognition is developed for demonstration. MATLAB is used in this project. For the program, some optimization at coding level and algorithm level are proposed to improve the performance of this fingerprint recognition system. These performance enhancements are shown by experiments conducted upon a variety of fingerprint images. Also, the experiments illustrate the key issues of fingerprint recognition that are consistent with what the available literatures say.**

Keywords: *Image Processing, Fast Fourier Transform, Signal Processing, Image Analysis, Feature extraction*

1. Introduction

A fingerprint is the feature pattern of one finger (Figure 1). It is believed with strong evidences that each fingerprint is unique. Each person has his own fingerprints with the permanent uniqueness. So fingerprints have being used for identification and forensic investigation for a long time.

Figure-1: A Fingerprint image acquired by an Optical Sensor

A fingerprint is composed of many ridges and furrows. These ridges and furrows present good similarities in each small local window, like parallelism and average width.

However, shown by intensive research on fingerprint recognition, fingerprints are not distinguished by their ridges and furrows, but by Minutia, which are some abnormal points on the ridges (Figure 2). Among the variety of minutia types reported in literatures, two are mostly significant and in heavy usage: one is called termination, which is the immediate ending of a ridge; the other is called bifurcation, which is the point on the ridge from which two branches derive.
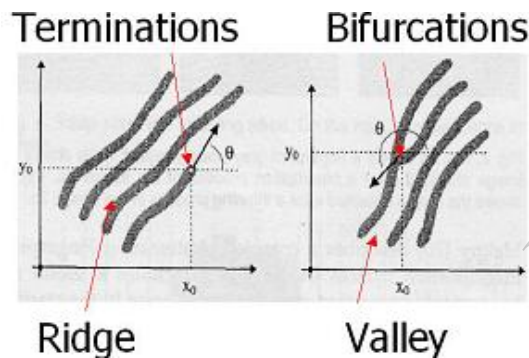

Figure-2: Ridges and Valley

The fingerprint recognition problem can be grouped into two sub-domains: one is fingerprint verification and the other is fingerprint identification (Figure-2). In addition, different from the manual approach for fingerprint recognition by experts, the fingerprint recognition here is referred as AFRS (Automatic Fingerprint Recognition System), which is program-based.
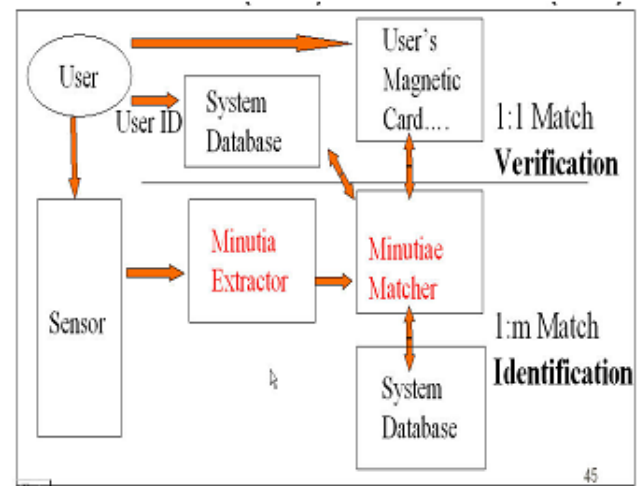

Figure-3: Automatic Finger Recognition System

Fingerprint verification is to verify the authenticity of one person by his fingerprint. The user provides his fingerprint together with his identity information like his ID number. The fingerprint verification system retrieves the fingerprint template according to the ID number and matches the template with the real-time acquired fingerprint from the user. Usually it is the underlying design principle of AFAS (Automatic Fingerprint Authentication System).

To implement a minutia extractor, a three-stage approach is widely used by researchers. They are preprocessing, minutia extraction and post processing stage [Figure 3].

For the fingerprint image preprocessing stage, we use Fourier Transform to do image enhancement [9]. And then the fingerprint image is binaries using the locally adaptive threshold method [12]. The image segmentation task is fulfilled by a three-step approach: block direction estimation, segmentation by direction intensity [4] and Region of Interest extraction by Morphological operations.

Most methods used in the preprocessing stage are developed by other researchers but they form a brand new combination in this paper through trial and error
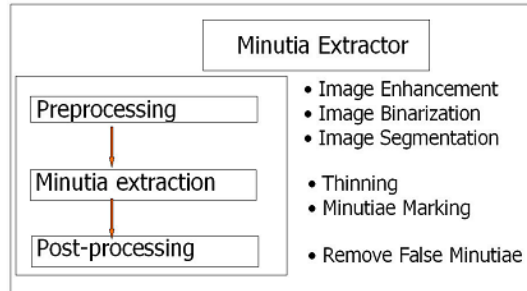

Figure-4: Automatic Fingerprint Recognition System Extractor

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1.1 Fingerprint Image Enhancement

Fingerprint Image enhancement is to make the image clearer for easy further operations. Since the fingerprint images acquired from sensors or other medias are not assured with perfect quality, those enhancement methods, for increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink, are very useful for keep a higher accuracy to fingerprint recognition.

2. Fingerprint Enhancement by Fourier Transform

We divide the image into small processing blocks (32 by 32 pixels) and perform the Fourier transform according to:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp\left\{-j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\}$$

for u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31.
In order to enhance a specific block by its dominant frequencies, we multiply the FFT

of the block by its magnitude a set of times. Where the magnitude of the original FFT = abs(F(u,v)) = |F(u,v)|.
Get the enhanced block according to

$$g(x,y) = F^{-1}\left\{F(u,v) \times |F(u,v)|^{k}\right\} \quad (2),$$

Where F^{-1}

(F(u,v)) is done by:

$$f(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(u,v) \times \exp\left\{j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\}$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.

The k in formula (2) is an experimentally determined constant, which we choose k=0.45 to calculate. 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. Figure 5. Presents the image after FFT enhancement (left side)
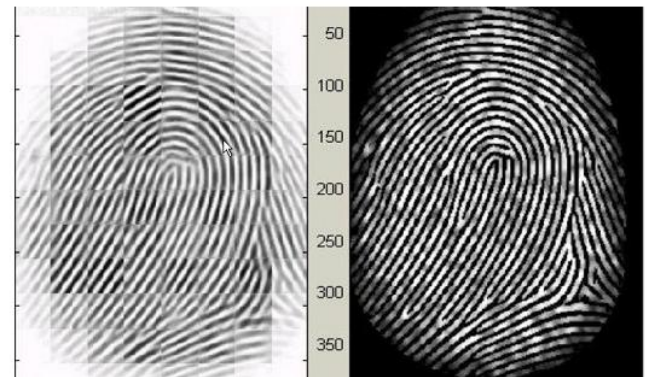

Figure 5: Fingerprint image enhanced by FFT

The enhanced image after FFT has the improvements to connect some falsely broken points on ridges and to remove some spurious connections between ridges. The shown image at the left side of figure 5 is also processed with histogram equalization after the FFT transform. The side effect of

each block is obvious but it has no harm to the further operations because I find the image after consecutive binarization operation is pretty good as long as the side effect is not too severe.

3. Fingerprint Image Binarization

Fingerprint Image Binarization is to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After the operation, ridges in the fingerprint are highlighted with black color while furrows are white. A locally adaptive binarization method is performed to binarize the fingerprint image. Such a named method comes from the mechanism of transforming a pixel value to 1 if the value is larger than the mean intensity value of the current block (16x16) to which the pixel belongs [Figure 6].
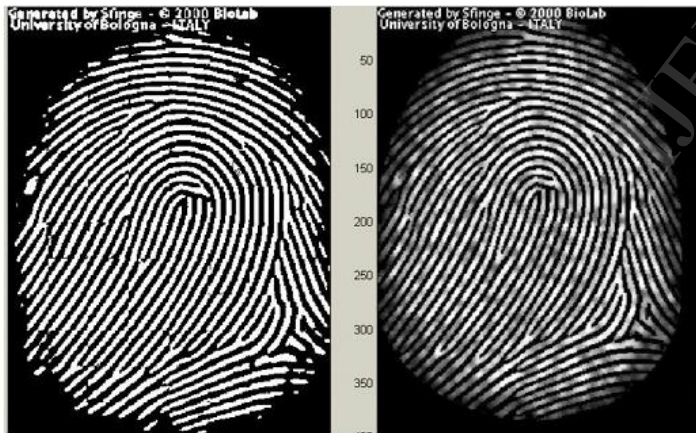

Figure -6: Binarization

4. Fingerprint Image Segmentation

In general, only a Region of Interest (ROI) is useful to be recognized for each fingerprint image. The image area without effective ridges and furrows is first discarded since it only holds background information. Then the bound of the remaining effective area is sketched out

since the minutia in the bound region is confusing with those spurious minutias that are generated when the ridges are out of the sensor. To extract the ROI, a two-step method is used. The first step is block direction estimation and direction variety check [1], while the second is intrigued from some Morphological methods.

5. Block direction estimation

Estimate the block direction for each block of the fingerprint image with WxW in size (W is 16 pixels by default). Calculate the gradient values along x-direction (gx) and y-direction (g_y) for each pixel of the block. Two Sobel filters are used to fulfill the task.

For each block, use following formula to get the Least Square approximation of the block direction

$$tg2\beta = 2 \sum\sum (g_x * g_y) / \sum\sum (g_x^2 - g_y^2) \text{ for all the pixels in each block.}$$

The formula is easy to understand by regarding gradient values along x-direction and y-direction as cosine value and sine value. So the tangent value of the block direction is estimated nearly the same as the way illustrated by the following formula.

$$tg2\theta = 2\sin\theta\cos\theta / (\cos^2\theta - \sin^2\theta)$$

After finished with the estimation of each block direction, those blocks without significant information on ridges and furrows are discarded based on the following formulas

For each block, if its certainty level E is below a threshold, then the block is regarded as a background block. The direction map is shown in the following diagram. We assume there is only one fingerprint in each image.

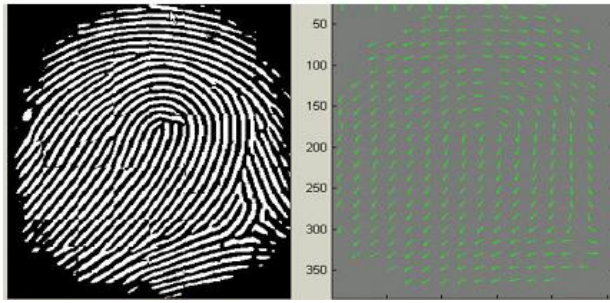$$E = \{2 \sum\sum (g_x * g_y) + \sum\sum (g_x^2 - g_y^2)\} / W*W*\sum\sum (g_x^2 + g_y^2)$$

Figure -7: Biniarized Direction Map

6. Conclusion

This paper has combined two methods to enhance the image of finger print for further process especially to build a minutia extractor and a minutia matcher which was the continuation and future scope of this paper. The combination of two methods that we discussed in this paper comes from a wide investigation into research papers. These two methods gives a novel result that can be used for further process like segmentation using Morphological operations, minutia marking and matching in the unified x-y coordinate system which is in further study.

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