An Implementation of Optical Image Fingerprint Recognition System

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Abstract

Although there have been abundant research examining fingerprint recognition systems in the biometric recognition domain, recognition rate and speed remain significant problems. In order to achieve high recognition rates and real-time processing, a high-resolution image capturing device coupled with high speed processing is needed. As a potential solution, we propose a fuzzy identification method to get a higher recognition rate and increase recognition speed while avoiding deletion of necessary fingerprint features and removing unnecessary fingerprint features that do not affect recognition results. The images are cut into many small blocks, *statistics pixels*, and thresholds are set to judge the angles as eigenvalues. The FAR (False Acceptance Rate) and FRR (False Rejected Rate) are then tested by using multiple pieces of fingerprints on different people interactively. The results not only show a certain degree of recognition rate on low-quality fingerprint images, but also reduce the computational complexity on recognition rate. Additionally, there is a high requirement to request the accuracy of finger location, which indicates that there is still much space for system improvement.

Keywords: Fuzzy identification; Fingerprint recognition; False acceptance rate; False rejected rate.

1. Introduction

There are many biometric identification methods that appear in the literature including iris recognition, facial recognition, vein pattern recognition and fingerprint recognition. Fingerprint recognition is one of the earliest and fully developed identification systems. The applications of fingerprint recognition technology are wide and easy to operate. If we take automated Fingerprint Identification System into consideration, there are over 60% of global biometric recognition systems using fingerprint as an identification target, such as computer system logins, door access control system, data encryption, criminal investigation and prevention applications, mobile phone login system, electronic passports, etc. [1],[2]

Although there are over 60% of fingerprint recognition systems applying in the biometrics market, most of fingerprint recognition systems need a high-resolution scanning device or high-computing processors to improve the recognition rate. Previous research indicated that the resolution of the image is an important factor to affect the fingerprint recognition rate. The higher the resolution is, the better the recognition rate is. When the resolution is enhanced, the image post-production is also increased. Otherwise, it is not possible to achieve optimal images. Optimization is achieved by strengthening the contrast to enhance sharpness, but this can also lead to image distortion[3]. Although there is much research examining the fingerprint recognition system, there has been limited progress in increasing recognition rates and speed.. In order to achieve high recognition rates and real-time processing, a high-resolution image capturing device is necessary to increase image processing recognition and speed. In view of this, the main purpose of this study is to propose a solution of fuzzy identification method to get a higher recognition rate while avoiding deletion of necessary fingerprint features or increasing unnecessary fingerprint features that do not affect recognition results.

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2. Literature Review

There are two important features of fingerprints. One is that the "fingerprint is not changed by whole life," and the other is that the "fingerprint varies for each individual." The feature of "fingerprint is not changed by whole life" was proposed by the anthropologist Welker in 1856, who compared his own fingerprints at age 34 and age 75. He found that he had identical fingerprints regardless of age. The feature of "fingerprint varies for each individual" was proposed by Victor Balthazard in 1910, who was a professor at the University of Paris. He used a mathematical model to calculate that it will take 3.2 * 1049 years to find a duplicate fingerprint. Currently, computer recognition systems have replaced traditional manual recognition. There are many identification algorithms that have been developed, such as *Minutiae and Pores*, *Model-based Density Map*, *Hybrid Fingerprint Matcher*, *Level 3 features* and *Long digital straight segments*. The detail of each method is described as follows.

2.1 The method of Minutiae and Pores

The method of *Minutiae and Pores* was proposed by Zhang. The features of minutiae and pores include three main elements: the core, the ridge ends, and ridge bifurcation points, as shown in Figure 1. The recognition of minutiae and pores has high resolution and great security. However, when the image resolution rate is less than 500dpi, the recognition rate is low due to failed identification of the pores. Thus, this method is limited by high cost, image resolution interoperability and performance [5].

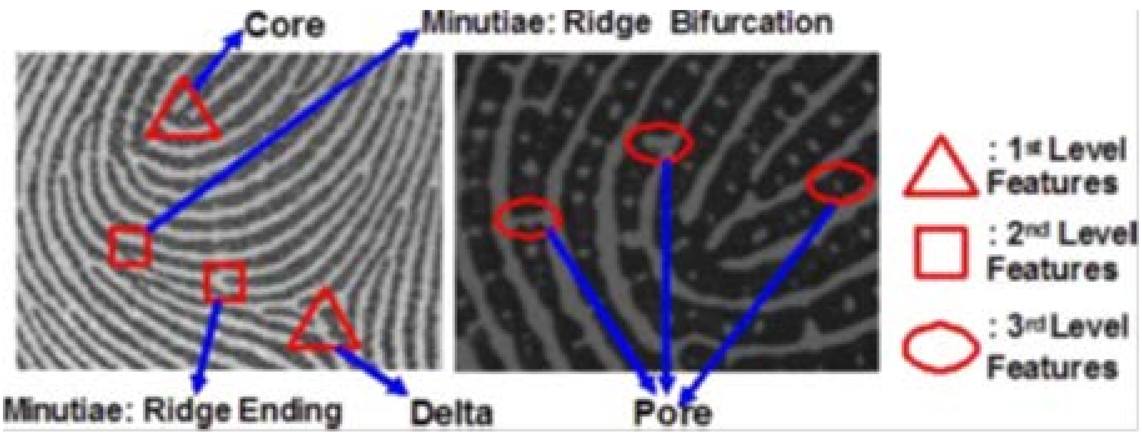

Figure 1. Three levels of fingerprint identification [5]

2.2 The method of Model-based Density Map

Model-based *Density Map* was first proposed by Wan and Zhou [6]. The method uses order polynomials to approximate fingerprint template density maps as the features of a new fingerprint, shown in Figure 2. Density maps allows more information to be obtained about the fingerprint, and performance is better than the *Minutae and*Pores method [6]. Although this identification method works, the recognition process is complex. The estimation of effective area and direction, enhancement of the fingerprint, coarse density mapping and polynomial approximations must all be calculated before getting the fingerprint density map.

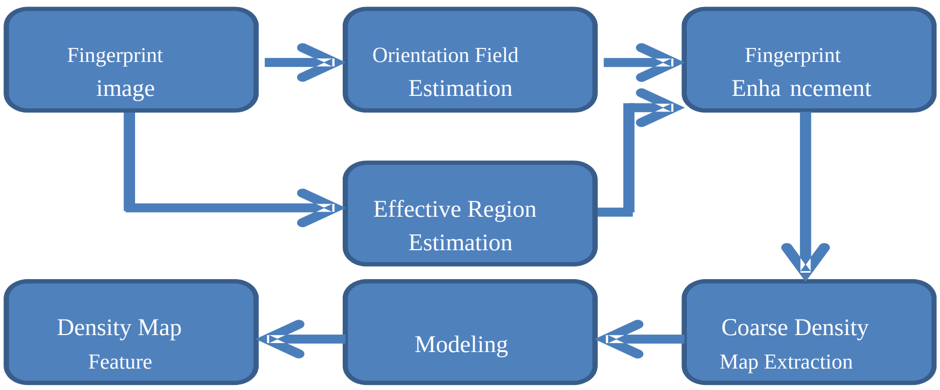

Figure 2. Calculated template density map [6]

2.3 The hybrid fingerprint recognition

The *hybrid fingerprint recognition* method is mixed with the details of the ridge and direction information. The method uses the Gabor filter to obtain the average distance of fingerprint ridge corresponding to spatial frequency to get the strength of direction. The acceptance rate is increased by 10% when compared to the *minutiae method*. Furthermore, there is a lower false acceptance rate in *hybrid fingerprint recognition* [7]. Although the *hybrid fingerprint recognition* method can increase the acceptance rate and reduce false acceptance rates, it may reduce the speed of recognition because of an overabundance in ways to obtain fingerprint information.

2.4 Three-layer feature recognition

In order to enhance fingerprint image resolution, previous research proposed a *three-layer identification* method. The first layer roughly determines the fingerprint pattern, the second layer includes the minutiae of the fingerprint, and the final layer is the discriminant pores and ridge contours. The advantage of three-layer identification method is an approximately 20% reduction of relative error rate [8]. However, there is a drawback at the pores identification stage of the last layer, which usually requires a relatively high-resolution scanning device to sweep out the pores and ridge contours.

2.5 Numeric straight line segment recognition and the Fuzzy identification method

The *numeric straight line segment recognition* method can accurately describe the overall structure of a fingerprint. The main slopes of fingerprint lines are used to estimate the different directional lines. It not only accurately estimates the grain direction of the straight line segment, but it can also be divided into four parameters: x coordinate, y coordinate, slope and length. By reducing image data to numerical information, it only needs 600 bytes to store fingerprint data [9]. A straight line is used to judge direction and angle, and a series of image processing systems then processes the lines for identification.

This identification method is the basis for the one we are proposing our paper. However, our proposed method uses statistical methods to reduce the image processing procedure. It can still recognize the identification direction and angle while enhancing the recognition rate and speed.

There are many algorithms for fingerprint recognition. Generally, they all go through the step of image processing, ie., getting rid of unnecessary background, filtering the noise, enhancing the image, binarizing, thinning, etc., to extract the important features for comparison. Therefore, most of fingerprint recognition systems need high resolution picture extracting devices and operation processing devices. With too much fingerprint image pre-processing it is easy to reduce the efficiency of recognition. Increased pre-processing also increases the chance of losing key image information [10].

Thus, we propose a *fuzzy identification method* applying statistical calculation methods to reduce the spurious features of fingerprint image generation and algorithm complexity. The method can reduce the resolution needed and the impact of algorithms for fingerprint recognition.

3. Methodology

This study uses the statistical pixels to set up threshold values for the automatic exclusion of interference from noise points in order to retain the original features of a fingerprint. By decreasing these false features, image distortion can be minimized and a reduction in unnecessary processing can be achieved. Thus, identification rate and speed can be maximized. The research methods and implementation steps can be roughly divided into the following steps: (3.1)Capturing the images, (3.2) image processing, (3.3) segmentation block, (3.4) angle determination, (3.5)storing and (3.6)creating a database.

3.1 Capturing the images

We choose an easy way to set up the optical image capturing device. This set up only requires a CCD, a light and a prism to get the fingerprint image, as shown in Figure 3. However, the results of this setup are variable because of the effect of glare from direct sunlight, which can make the images uneasy to recognize. Therefore, we modified the fingerprint image capturing device, as in Figure 4. The device reduces the issue of direct sunlight glare. By placing the CCD and light on the same side while also placing the lens in front of the light source, this modified device can avoid the issues associated with direct exposure to bright light.

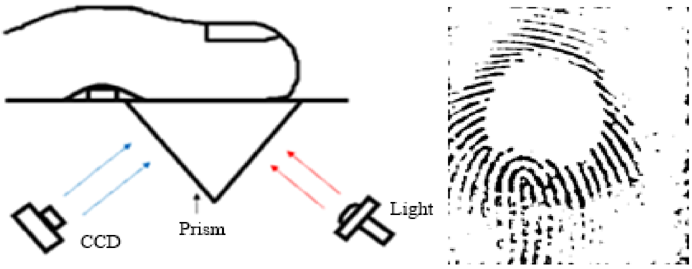

Figure 3. Traditional fingerprint image capture device setup.

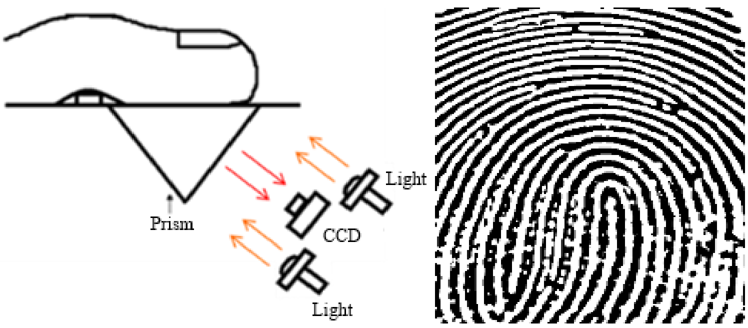

Figure 4. Modified fingerprint image capture device.

3.2 Image processing

Image processing includes convergence, Gaussian smoothing to filter out noise, image enhancement, binarization, thinning, etc. Over-processing reduces speed because it needs to read a whole pixel map after a processing. The benefit of our method is that it has minimal processing requirements. General image processing includes taking the fingerprint image and then in different stages, applying pre-treatment, binarization, noise removal, thinning, dummy feature removal and finally obtaining eigenvalues, shown in Figure 5. Image processing in the *Fuzzy identification* method includes taking the fingerprint image, applying a pre-treatment and then directly proceeding to binarization and obtaining the eigenvalues, as shown in Figure 6.

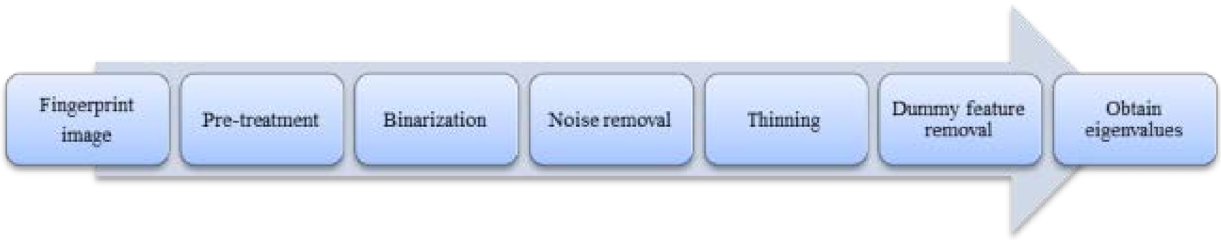

Figure 5. General image processing

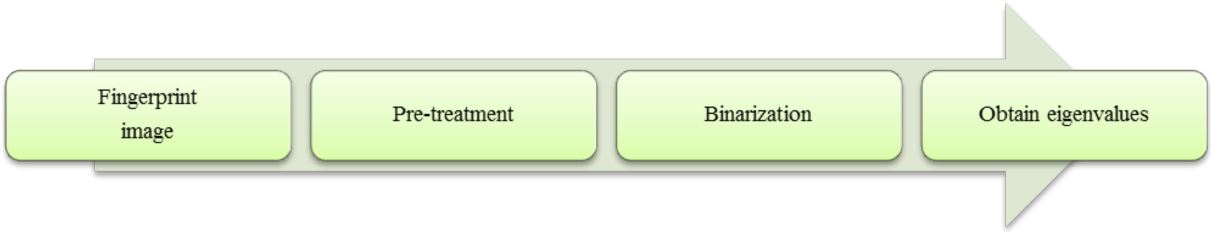

Figure 6. A fuzzy image processing

3.3 Segmentation block

After the fingerprint image is obtained, the image is divided into 13 x13 small blocks. Each small block is then broken into 30 x 30 pixels, as in Fig.7 (a). This allows an easy identication of the line slopes within each block. Slope is defined with 8 orientations as shown in Fig.7 (b).

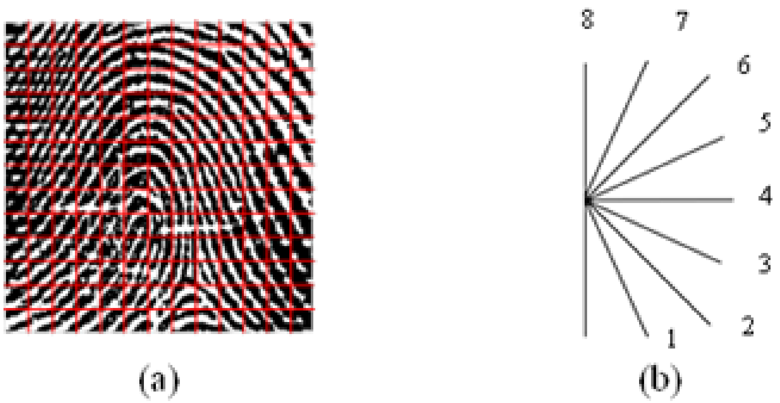

Figure 7. (A) The binarized image into each of 30 × 30 pixels (b) Direction is defined

3.4 Determining the angle

Our propose method is to count the pixels of each line within the calculated block. The calculation of a slope is complicated when the pixels of differing lines are included, a sub-pixel problem. We take the line with the most number of pixels as the correct slope of the block. However, there is an additional problem in that decimal point coordinates occur and the computer can accept only integer pixels. Thus, we rotated the image block 15 degree for 4 times, and counted the most pixels of the horizontal lines. This is the core fuzzy identification using statistical methods to convert a small block image to be a single slope as a fuzzy feature. Here are the problems we encountered in Figure 8 and solutions:

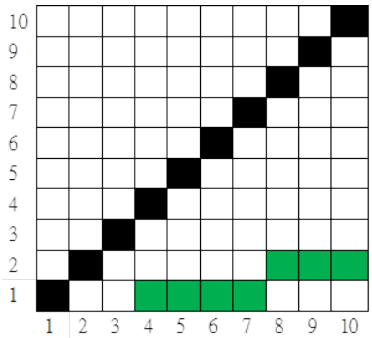

Figure 8. Angle discrimination problems

In the beginning, the slope was used to judge the angle. The slope equation is $m = \tan\frac{y}{x}$ and assumes $\tan^{-1}\frac{y}{x} = \theta$. When the values of x and θ were known, the y value can be calculated to know the degree of the angle. If we assume $\theta = 45°$ and image is 10 pixels*10 pixels, then x=1~10 was substituted into the equation $y = x\tan 45°$, which will produce 45 ° black block looks like a 45 degree angle lines. But doing so, it would lead to uneven pixel statistics and repeat the phenomenon. We assume $\theta = 15°$ and $\tan 15° \cong 0.2679$, then substituting it into equation $y = 0.2679 \times x$. We can use x=1~10 to obtain (x=1,y=0),(x=2,y=0) ,(x=3,y=0),(x=4,y=1) ,(x=5,y =1) ,(x=6,y=1) ,(x=7,y=1) ,(x=8,y=2) ,(x=9,y=2) ,(x=6,y=2). It can produce green blocks, shown in Figure 8. However, x=1~3 is null and thus can't be identified.

According to this question, we think the lines cut into very small piece fingerprints, each block of the lines is appraoching to a straight line at different angles. We use x = y to process the horizontal scan. It can avoid problems not an integer of $\tan\theta$. At this time we rotate the block into different angles, such as level, positive and negative 15 degrees, positive and negative 30 degrees, positive and negative s 45 degrees, positive and negative 60 degrees, positive and negative 75 degrees and vertical to scan the horizontal line for solving the coordinates which are not the problem of integer.

Counterclock coordinates rotation angle θ, as shown in Equation 1.:

$$x' = x\cos\theta - y\sin\theta$$
$$y' = x\sin\theta + y\cos\theta \qquad (1)$$

Equation 1 is to assume the split blocks of 10 * 10 pixels, then flipped a total of 10 pixel-by-column scanning for 10 times, as shown in Figure 9.:

Figure 9. 10pixel horizontal scan

If the scan pixel is greater than a certain threshold, fingerprint lines are straight lines. The pixel P0 ~ P9's black is 1 and white is 0, shown in equation 2:

$$\sum_{i=0}^{n} P_i > F\sum_{a=0}^{n} P_a \quad, F > \frac{1}{2} \qquad (2)$$

Discriminant 2: F represents the threshold, $\sum_{a=0}^{n} P_a$ is a line, $\sum_{i=0}^{n} P_i$ sweep to a few black spots

Fig. 10(a) is a small 30x30 finger block rotated for calculation the slope angle. Fig.10 (b) is the block rotation from 0 to 90 degrees with 15 degrees a step. In the testing procedure, the 45 degrees rotation has the largest horizontal pixels. Hence, the slope of the testing block is found at 45 degrees. Base on the slope features, the finger print module is fast and accurate for recognizing fingerprint features.

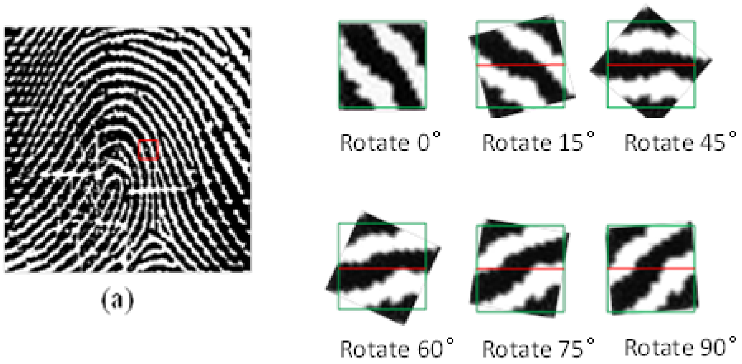

Figure 10. (a) A testing finger block (b) The block rotation from 0 to 90 degrees

3.5 Storage and creating a database

The fingerprint can be saved into 4 characters: the first character is a negative sign, the 2nd and 3rd characters are feature data, and the 4th character is the separation character. Because the image is converted into text storage, it only needs (300*300)/(50*50)*3+[(300*300)/(50*50)-1]=143 bytes for storage of a fingerprint image. Compared to other methods, the amount of storage is relatively small and the processing speed is relatively fast for short pattern matching of fingerprint features.

4. Discussion and Conclusions

The testing method uses equations 3 - 6 to estimate the recognition rate and false acceptance rate. Linear threshold sets to 80%, compared to 50% of the number of threshold settings. We tested 50 people, with each one testing 10 times with a different finger, and then used the non-I fingerprint to test 10 times. All the values were calculated by dividing the sum of 50. The identification rate is about 86.2% (recognition rate 1). If the system added more fingerprint samples of the same user, the recognition rate would up to 92.4% (recognition rate 2), but the False Acceptance Rate (FAR) would be 0.7% and the False Rejected Rate (FRR) would be 6.9%. This would not meet the requirements of market recognition. The main reason for this is the need for positioning adjustment before image grabbing.

Otherwise, when the finger slightly shifts or rotates, all angles will be changed.

$$\text{Recognition rate1} = \frac{\text{Correctly accepted}}{\text{Total}} \times 100\%. \quad (3)$$

$$\text{Recognition rate2} = \frac{\text{Correctly accepted} + \text{Rejected error}}{\text{Total}} \times 100\%. \quad (4)$$

$$\text{FAR} = \frac{\text{Error is accepted}}{\text{Total}} \times 100\%. \quad (5)$$

$$\text{FRR} = \frac{\text{Correctly Rejected}}{\text{Total}} \times 100\%. \quad (6)$$

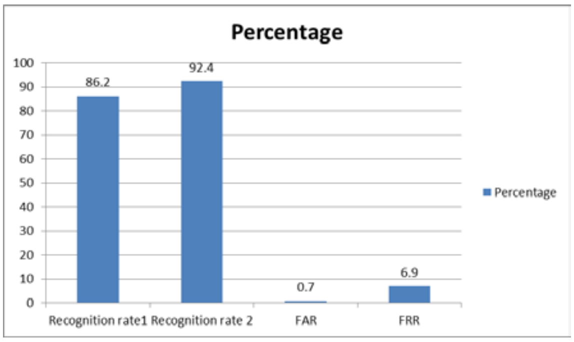

Figure 11. the testing results

General recognition rate of the FAR is less than 0.001%, and general recognition rate of the FRR is less than 3%. Our method results are displayed in Figure 11 (FAR of 0.7% and FRR of 6.9%). While it shows that the fuzzy identification method has superior recognition rates, the FAR and FRR are still unacceptably high. We believe the fuzzy identification method could be an important basis for further research, but there is still room for improvement at this time before it could be applied for market purposes.

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