Fingerprint Recognition System for Low Quality Images

Zin Mar Win[1] and Myint Myint Sein[2]

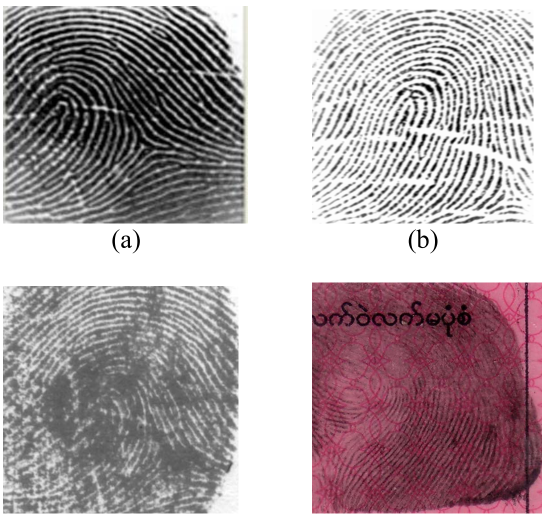
[1]University of Computer Studies, Yangon, Myanmar
zmwucsy@gmail.com
[2]Department of Research and Development
University of Computer Studies, Yangon, Myanmar
myintucsy@gmail.com

Abstract: Fingerprints are widely used in biometric techniques for automatic personal identification. In this paper, a fingerprint recognition system is developed to identify a person according to fingerprint image on Myanmar National Registration Cards (NRCs). It can be acquired only the low quality fingerprint image from NRC card. Generally, fingerprint identification approaches are minutiae-based and correlation-based. Although the minutiae-based method is popular and extensively used method for fingerprint identification, it shows poor performance for low quality images. In proposed system, the correlation-based approach for fingerprint recognition is developed by calculating the mean value of correlation factors. The mean value of correlation factors of input image and template image are computed and compared. If it is over a certain threshold the result of the matching process is positive otherwise negative. Before calculating correlation factor, fingerprint enhancement algorithm using gabor filters are applied for good ridge line feature extraction. Therefore, the proposed system can identify not only on the good quality fingerprint but also on the bad or poor quality fingerprint. The effectiveness of the proposed system can be confirmed through the experimental results.

Keywords: fingerprint recognition, correlation matching, gabor filter.

1. INTRODUCTION

Biometric systems operate on behavioral and physiological biometric data to identify a person. The behavioral biometric parameters are signature, gait, speech and keystroke, these parameters change with age and environment. However physiological characteristics such as face, fingerprint, palm print and iris remains unchanged throughout the life time of person [1]. Automatic fingerprint recognition systems (AFRS), as well-known biometric techniques, are nowadays widely used in various applications such as forensics and access control [2][3]. The qualities of fingerprint images are mainly depend on the acquisition devices.



(a) (b) (c) (d)

Fig.1 Different kinds of fingerprint images

The different kinds of fingerprint images are described in Fig.1. The high quality images acquired by digital device (Hamster Eye-D) and low quality ink image from paper are shown in Fig.1(a), Fig.1(b), and Fig.1(c), respectively. Fig.1(d) shows the poor quality fingerprint image. This image is scanned from NRC card and its quality is poor than the ink image. The background pattern of image is very complex and can't be seen clearly the ridge of the fingerprint. Several methods of automatic fingerprint identification have been proposed in the literature. They considered for first two types of the fingerprint images. In our research, the recognition of the poor quality image of NRC card is developed.

The minutiae-based and correlation-based approaches are usually applied for fingerprint identification. In minutiae-based approaches, a minutia detected in a fingerprint image can be characterized by a list of attributes that includes the minutia position, the minutia direction, and the type of minutia (ending or bifurcation) [4][5]. The representation of a fingerprint pattern thus comprises the attributes of all detected minutiae in a so-called minutiae set. Some minutiae types are termination or ending, bifurcation, lake, dot or island, spur, crossover etc. The minutiae sets may suffer from false, missed, and displaced minutiae, caused by poor fingerprint image quality and imperfections in the minutiae extraction stage [6].

A correlation-based image matching approach towards poor quality fingerprint recognition is developed in this research. The correlation based matching; a direct matching between the two fingerprint images is attempted. To do that, the images are superimposed and displacements and correlations of the rotations of the relevant sections are calculated. The maximum level of the correlation factor is interpreted as the matching sections for the images. In other words, the correlation value is the resemblance factor between the two images.

The rest of the paper is organized as follows: section 2 reports the overview of the proposed system. In section 3, the preprocessing steps of the proposed system are presented. Section 4 presents the correlation matching. Section 5 is experimental results. Finally, in section 6, the concluding remarks are given.

2. OVERVIEW OF THE PROPOSED SYSTEM

The overview of the proposed fingerprint recognition system is shown in Fig. 2. Firstly, fingerprint region is segmented from NRC card and image enhancing step is performed. Gray scale converting, noise filtering and edge detection processes are included in enhancing steps. To obtain the good ridge features, the feature extraction algorithm is developed by integration of the gabor filtering and two pass thinning. Before we apply gabor filter, we have to detect the ridge orientation flows of the fingerprint. The core point is extracted using the orientation direction of the ridge line. By using the core point as reference point, we calculate the correlation values and then determine the matching correlation scores of the two images.

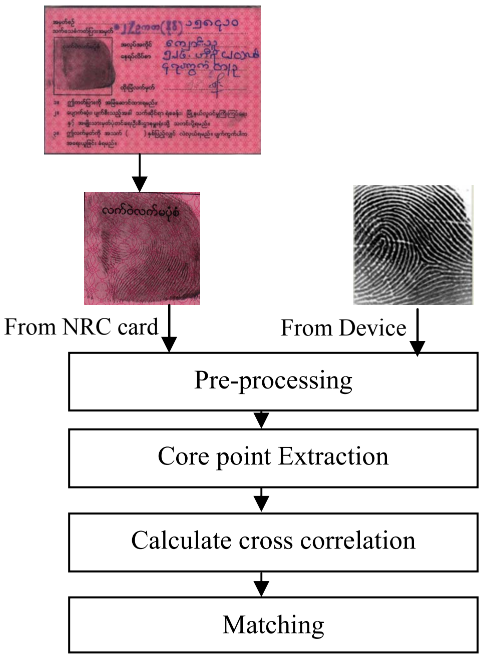


Fig.2 System Flowchart

3. PRE-PROCESSING

3.1 Fingerprint Enhancement

Fingerprint image enhancement is to make the image clearer for easy further operations [8]. The main steps involved in the image enhancing include: enhancement, segmentation and filtering etc. Since the fingerprint images acquired from the NRC cards are not assured with perfect quality, 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 to keep a higher accuracy to fingerprint recognition.

The input fingerprint image is pre-processed on both the spatial and frequency domain. In the spatial domain, histogram equalization technique was applied for better distribution of the pixel values over the image to enhance the perceptional information. In the frequency domain, the image was divided into small processing blocks (32×32 pixels) and the Fast Fourier transform (FFT) was applied in the following way –

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

where u = 0, 1, 2,...., 31 and v = 0, 1, 2,..., 31.

In order to enhance a specific block by its dominant frequencies, the FFT of the block as multiplied by its magnitude for a number of times. Here, the magnitude of the original FFT = abs(F(u,v)) = |F(u,v)|.

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

where F^{-1} (F(u, v)) is done by:

$$F(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(u,v).\exp\left\{-j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \quad (3)$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31. The value of k in equation (2) is an experimentally determined constant, however based on our experimentation a better result was found for k =0.5. So with an appropriate selection of k value, the ridges and the overall appearance of the image can be improved, which is useful for proper feature extraction and classification [7].

The enhanced image is segmented to extract the region of interest (ROI) which contains the desired fingerprint impression. In this work, the gradient based fingerprint segmentation approach [10] was used and the segmentation results were found satisfactory even for the low quality images.

3.2 Ridge Orientation

The ridge directions are used for determining the core point. The term orientation image often refers to the determination of local ridge orientation in the fingerprint image. The following steps are applied for finding orientations (Hong et al., 1998).

Let θ be defined as the orientation field of a fingerprint image. θ (x,y) is the least square estimate of the local ridge orientation at the block centered at pixel (x,y). Firstly, divide the fingerprint image into no-overlapping blocks of size wxw.

Compute the gradients $\partial_x(x,y)$ and $\partial_y(x,y)$ of each pixel (x,y) corresponding to the horizontal and vertical directions. The Sobel operator is employed in this work.

The local orientation of the (*x,y*) centered *wxw* sized block is calculated by:

$$V_y(x,y) = \sum_{u=x-W/2}^{x+W/2} \sum_{v=y-W/2}^{y+W/2} 2\partial_x(u,v)\partial_y(u,v) \qquad (4)$$

$$V_x(x,y) = \sum_{u=x-W/2}^{x+W/2} \sum_{v=y-W/2}^{y+W/2} \partial^2{}_x(u,v) - \partial^2{}_y(u,v) \qquad (5)$$

$$\theta(x,y) = \frac{1}{2} tan^{-1} \frac{V_y(x,y)}{V_x(x,y)} \qquad (6)$$

3.3 Filtering

The ridges and valleys in a small local neighborhood have well defined local frequency and local orientation properties [9]. A set of band pass filters can remove the undesired noise and preserve true ridge structures. Gabor filters have both frequency-selective and orientation-selective properties and have optimal joint resolution in both spatial and frequency domains. Gabor filters are used to remove the noise and preserve true ridge/valley structures. The filter applied at each pixel [x, y] has the form:

$$g(x,y:\theta,f) = e^{\left(\frac{-(x+y)^2}{2\delta^2}\right)} \cos[2\pi.f.(x.\sin\theta + y.\cos\theta)] \qquad (7)$$

where θ and f are the corresponding local orientation and frequency. To reduce the complexities and memory spaces, thinning process is performed for filtered fingerprint image. Two pass thinning approach is applied for this stage.

3.4. Core Point Detection

To be able to align two fingerprints, a core point is required. The core point is derived from orientation image. The Poincare index on the orientation field is used to determine the core point in the fingerprint. The core point of the fingerprint image is detected by calculating the Poincare Index value and then, the area near the centre point is extracted to be the ROI of the feature extraction. A digital closed curve, N, around each pixel is used to compute the Poincare index as defined below:

$$Poincare(x,y) = \frac{1}{2\pi} \sum_{k=0}^{N-1} \Delta(k) \qquad (8)$$

$$\Delta(k) = \begin{cases} \delta(k) if\ |\delta(k)| < \frac{\pi}{2} \\ \pi + \delta(k) if \delta(k) \le -\frac{\pi}{2} \\ \pi - \delta(k) otherwise \end{cases}$$

$$\delta(k) = \theta(x_{(k+1)\bmod N}, y_{(k+1)\bmod N}) - \theta(x_k, y_k)$$

θ is the orientation field, and $x_{(k+1)}$ and $y_{(k+1)}$ denote coordinates of the k^{th} point on the arc length parameterized closed curve *N*.

We Compute Poincaré index by summing up the difference in the direction surrounding the block P. For each block P_j, we compute the angle difference from 8 neighboring blocks along counter-clockwise direction. If the sum of difference is 180°, it is the core point.

3.5. Normalization

To reduce the effect of the fingerprint pressure differences and sensor noise, normalization is performed. It is a pixel based operation which does not change the clarity of the ridge and valley tracks on the fingerprint. It is performed on the subdivided images blocks. After calculating the mean and standard deviation of the blocks corresponding new pixel colors are obtained. The normalized pixel value (i.e., within the block) is calculated by the following equation using the sigmoid functions:

$$N(u,v) = 255 \times \frac{1}{1 + \exp\left(-\frac{I(u,v) - M(x,y)}{\sqrt{\delta(x,y)}}\right)} \qquad (9)$$

4. CORRELATION MATCHING

The correlation based analysis of the fingerprints is based on the aligned images where the gray-scale intensities re used. The cross correlation operation gives us the similarity percentage of the two images. We calculate the correlation value around the core point also called the reference point. Therefore, the best point where the two images best aligned is the narrow area around the reference point (not the whole image) and it reduce time cost dramatically. To calculate the correlation value, we have to determine the digital signatures to be used.

The set of digital signatures are formed by means of Eq 10 and 11 which correspond to the set of points of the various radius values on the normalized input and template fingerprint image.

$$V_{r\theta}^{T(x_t,y_t)} = \frac{1}{9} \sum_{u=-1}^{1} \sum_{v=-1}^{1} N^T(x'+u, y'+v) \qquad (10)$$

$x' = x_t + r.\cos\theta$ $\quad r \in \{5,10,15,\ldots,60\}$

$y' = y_t - r.\sin\theta$ $\quad \theta \in \{0,1,2,3,\ldots,359\}$

$$V_{r\theta}^{I(x_m,y_m)} = \frac{1}{9} \sum_{u=-1}^{1} \sum_{v=-1}^{1} N^I(x'+u, y'+v) \qquad (11)$$

$x' = x_m + r.\cos\theta$ $\quad r \in \{5,10,15,\ldots,60\}$

$y' = y_m - r.\sin\theta$ $\quad \theta \in \{0,1,2,3,\ldots,359\}$

where x_t, y_t, x_m, y_m represent the reference point coordinates of the template and input image, respectively, while r,θ corresponds to the radius and angular values and finally, $V_{r\theta}^{T(x_t,y_t)}$ stands for the set of digital signatures obtained from the values with the r radius and θ angle from the x_t,y_t reference point of the template image.

By taking the core point as the reference, a block of the size $w\times w$ (16×16) is taken, then by shifting the reference point, the differential sum of the square of the digital signatures of both images for different placements are calculated. The best matching point for the images as Eq.12 gives is where the sum of squared differences are minimum. The coordinate values of this point are saved to be used in the next steps.

$$SSD(T,I)=\frac{1}{w^2}\sum_{u=-w/2}^{w/2}\sum_{v=-w/2}^{w/2}\left(V^I(x_m+u,y_m+v)-V^T(x_t,y_t)\right)^2 \qquad (12)$$

The digital signature of the input image are obtained by rotating the image by Δθ = [-15˚, 15˚] with the incremental steps of 1˚. Following for each rotation, the normalized cross correlation values of both images are calculated using Eq.13.

$$CC_i(T,I)=\frac{\sum_{r,\theta}^{N1,N2}\left(V_{r\theta}^{I(x_m,y_m)}-\overline{V_{r\theta}^{I(x_m,y_m)}}\right)\left(V_{r\theta}^{T(x_t,y_t)}-\overline{V_{r\theta}^{T(x_t,y_t)}}\right)}{\left\{\sum_{r,\theta}^{N1,N2}\left(V_{r\theta}^{I(x_m,y_m)}-\overline{V_{r\theta}^{I(x_m,y_m)}}\right)^2\sum_{r,\theta}^{N1,N2}\left(V_{r\theta}^{T(x_t,y_t)}-\overline{V_{r\theta}^{T(x_t,y_t)}}\right)^2\right\}^{1/2}} \qquad (13)$$

$r\in\{5,10,15,\ldots,60\}$, $N1=60$, $\theta\in\{0,1,2,3,\ldots359\}$, $N2=359$, $\sum_{r,\theta}^{N1,N2}=\sum_{r=5}^{N1}\sum_{\theta=0}^{N2}$

Here, for each rotation value, 12 different correlations are obtained. The mean value of which is calculated by Eq.14. The maximum correlation value within this set is then used to determine the matching score of the images.

$$S(T,I)=\max_{\Delta\theta}\frac{1}{12}\sum_{i=0}^{11}CC_i\left(T,I^{\Delta\theta}\right) \qquad (14)$$

From the obtained normalized cross-correlation coefficients, the highest value obtained is the final value of the matching. For a little degradation in the similar fingerprint, there is no way of changing in the inner part of the fingerprint image, so there is some degradation seen in the correlation peak. Correlation coefficients of two different fingerprints are lower.

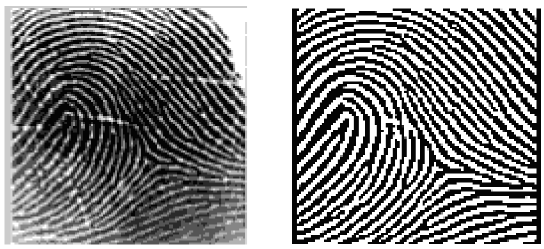
5. EXPERIMENTAL RESULTS

The experiments are executed on database that contains more than 300 captured images grabbed from fingerprint device. All images in the database were 256×256 in size and had been captured using an inkless fingerprint.

For testing process, the current image is applied an image grabbed by digital device. The low quality images such as the ink image and image from NRC card are considered as source image. It means that the recognition is performed for four different cases. The first one is the recognition of type A (device image) with type A. The remaining cases are the recognition of type A (device image) with other finger print type B, C and D, respectively. Especially, fingerprint type D from NRC card is more noisy and complex image and need more computation for ridge line enhancement.

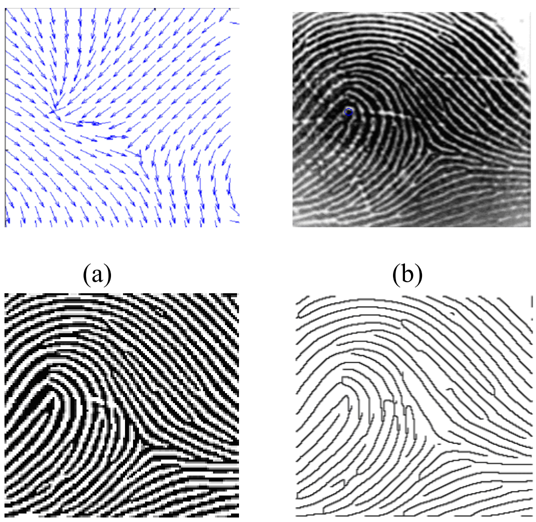
The experimental results show that determination of the reference point is very important. In the case of low quality images this is rather difficult. Therefore, we first apply the fingerprint enhancement using the bank of gabor filters.

Enhancement results are showed in Fig.3. The orientation image and detected core point are shown in Fig.4 and also show the binary image resulted from the filtered image and thinned image. As it may be observed, due to the correct determination of reference point, the mean correlation value is high. Determining fingerprint correctly provides high performance accuracy for the proposed system. Fig.5 shows the matching result of the fingerprint type A (Device image) and type D (NRC card). Nearly 10 % of the recognition error is occurred due to the unremoved noisy and quality of images.



(a) (b)

Fig.3 (a) original image (b) filtered image



(c) (d)

Fig.4(a) Ridge orientation image (b)Reference point (c)binary image (d) Thinned image

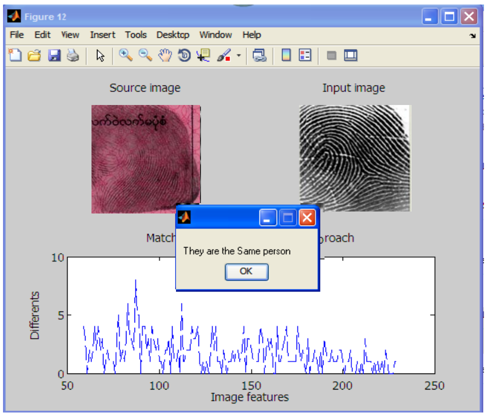


Fig.5 The matching result

A false acceptance occurs when two images from different fingers are matched, and a false rejection occurs when two images from the same finger are not matched. The ROC curve is a false acceptance rate (FAR) versus false rejection rate (FRR) curve. For a given distance threshold, FRR and FAR can be calculated. Fig.6 represents the ROC results, which measures the accuracy of fingerprint matching process and shows the overall performance of an algorithm. The obtained results are considerably promising since very low FAR and FRR and high accuracy i.e. approximately 97%.

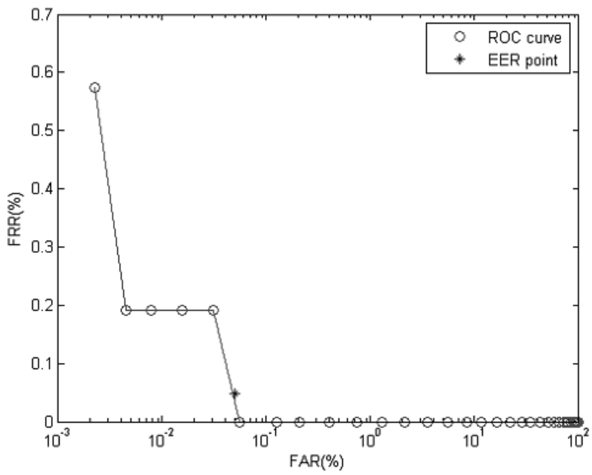


Fig.6 ROC curve

6. CONCLUSION

The fingerprint recognition system for the low quality images is presented in this paper. The recognition processes are performed among the current good quality image (device image) and other low quality images (ink image, NRC card). The proposed approach is very simple compared to minutia point pattern matching algorithm. Because we apply the Gabor filtering to enhance the fingerprint before doing other processing steps, the proposed system can identify not only the fingerprint image from device but also the low quality image on printed paper. The effectiveness of the proposed approach can be confirmed through the experimental results with acceptable errors.

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