A COMBINED TECHNIQUE FOR FINGERPRINT MATCHING

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ABSTRACT

This paper reports the investigation a hybrid technique for fingerprint identification (matching). The combination of NCC template matching with minutiae matching offer better performance compared to individual application. NCC is basically image-based matching, a technique of which no requirement in reference point availability. Minutiae matching, in contrast, requires smaller database but tends to offer lower accuracy when the number of minutiae points is small. To reduce the database size, the proposed technique stores the binary images where the template matching is also performed in this domain. After the coarse matching provided by NCC, the fine matching is performed using minutiae points. This proposed two-stage matching offers superior performance over existing algorithms. The obtained 0% FAR is good and acceptable. However 10% FRR seems to need some further refinement. To confirm this achievement we need more robust testing by increasing the number of fingerprint images in the database. Setting the threshold value for pass/fail decision is also crucial to the performance of the algorithm.

I. INTRODUCTION

As machine-based data processing becomes more and more important in the decade of information technology, there are several vital needs in data consistency and data security. Moreover, the importance of the tracking (or tracing) is also extended to the person who is the owner of such data, no matter the one who sends it or the one who receives it. Personal identification by mean of fingerprint pattern is one of the most popular and reliable use biometric techniques. This is because fingerprint holds many desirable features such as universality, permanence, collectability, and distinctiveness. Personal identification based on fingerprint matching is now, therefore, popular in wide range of applications.

Fingerprint characteristics are divided into two general groups, i.e., Local characteristics and Global characteristics. Global characteristics are a general feature of any fingerprint based on which classification of fingerprints into one of defined classes is performed before matching. This will cause the matching operation to be performed easily and with higher speed. Classes are generally classified into: Left loop, Right loop, Whorl (including dual loop), Arc, and Tent. Another important fingerprint feature is the local ridge characteristics. There are two prominent local ridge characteristics: ridge ending and ridge bifurcation. Both of them are referred to as minutiae or minutiae point. Spurious ridge structure may change the individuality of input fingerprints. However, with less effect and generally ignored or filtered out.

As shown in Fig.1, a fingerprint pattern is the pattern of ridges and valleys on the surface of a fingerprint. Minutiae are local discontinuities in the fingerprint pattern. Ridges and valleys in a local neighborhood form a sinusoidal-shaped plane wave, which has a well-defined frequency and orientation. The core point (as well as delta point) has played important roles in many fingerprints identify techniques. The success of the identification (or matching) process is very much relied on the image quality. In most cases, the algorithm has assumed the good quality images. This is quite optimistic. In many practical cases, fingerprints are with numerous discontinuous ridges upon different circumstances (dry, wet, damped, scars and smudges). The main difficulty for feature extraction is that fingerprint quality is often too low, thus noise and contrast deficiency can produce false minutiae or hide valid ones. Even high quality images can also yield false minutiae, for example, when the person has cuts or scars in his/her fingers.

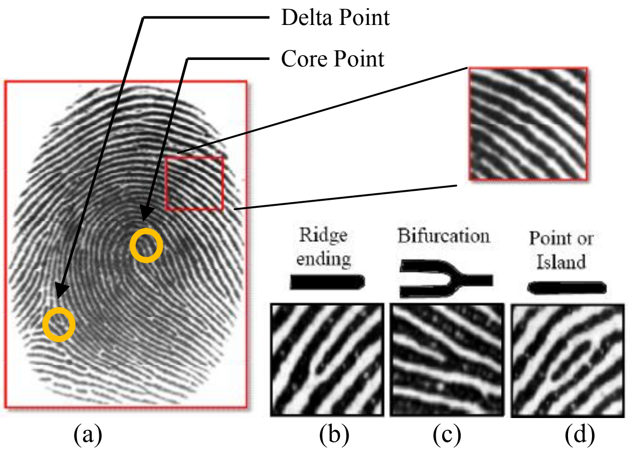

Figure 1. Fingerprint feature definition
(a) Whole pattern, (b) Ridge ending, (c) Bifurcation (d) Point of Island

There are two main streams of fingerprint pattern matching (or fingerprint matching in short); minutiae-based and image-based. Compared to the image-based technique, a minutiae-based matching relies on less information and offers better performance as the matching area is larger. Correlation matching [1], [2] is less tolerant to rotational and translational variances of the fingerprint. Direct minutiae matching [3], [4] and [5] are certainly the most well known and widely used method for fingerprint matching according to its higher recognition accuracy. The last family is a spectrum matching which is based on a local texture analysis where the fingerprint area of interest is tessellated with respect to the core point and feature obtained [6]. Although, the obtained spectrums (features) are not as distinctive as minutiae, these features may be used in conjunction with minutiae to increase system accuracy and robustness.

Image-based matching, on the other hands, offers good registration in particular when the matching area is fairly small. However, the technique consumes large storage and computing resources. The technique works regardless the availability of the standard points; neither core point nor minutiae point. Variance feature of orientation field matching has been proposed by in [7]. Wavelet based matching methods proposed by [3] and [8] have shown their better recognition rates. Normalized cross correlation (NCC) has been applied together with group delay spectrum (GDS) and dynamic programming (DP) for line scan matching [9].

The performance of a fingerprint recognition method involves a tradeoff among different performance measures, i.e.; accuracy, efficiency, template size, and so on. Different applications desire different properties in the fingerprint matching algorithms (e.g., template size, matching speed, memory requirements, etc.) With this regard, a hybrid fingerprint matching has combined both minutiae-based and image-based technique. It tries to make best use of each approach. Kim [10] has studied the form and size of binary image as trying to reduce the database size. The matching is performed by image operation.

In this paper a different method for hybrid matching is proposed. To reduce noise as well to improve image quality we first do the image enhancement via directional filtering method. However to reduce the amount of data, the NCC template matching in the binary domain is applied to measure the similarity of a stored image and an image under test. This coarse matching provides first screening candidates. Images pass this screening round are matched again via minutiae-based matching procedure. In section II, the combined technique for matching is explained in details. Experiment result is given in section III before the conclusion of the work.

II. A TEMPLATE MATCHING

In this section, the procedure of template matching is reviewed in brief. The main purpose of using this procedure is to evaluate the coarse matching of two patterns. For best matching result, size and orientation of the detail image are assumed to be the same. Generally, a correlation method is a technique which can show how strongly pairs of variables are related. The result is indexed by correlation coefficients value of which -1.0 to +1.0. The closer range of +1, the more closely one variable is related to the other. The correlation between two signals (cross-correlation) is a standard approach to find out how the two signals are related. It has shown its good applications in pattern recognition and cryptanalysis. Of its kinds, normalized cross correlation (NCC) has also been used extensively in machine vision for industrial inspection including defect detection in complicated images.

Shown in Fig. 2. Let f be a test image (source image) and t be a template image. We want to seek any similarity of the template t to any portion of test image f. In this particular case, the image size t is smaller or equal to f. A simple method for measuring similarity or mismatch performed by taking the absolute difference between template image t and given test image f over a specific region.

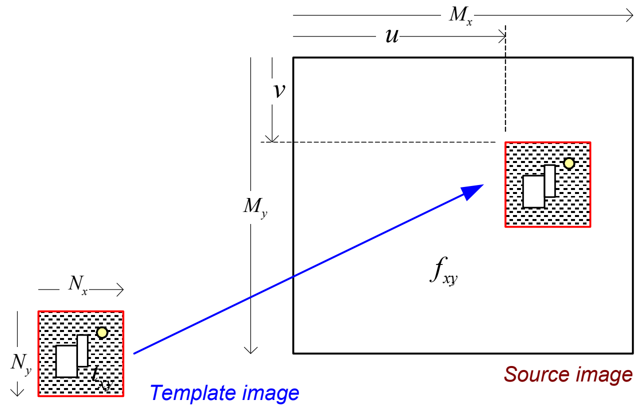

Figure 2. Matching of template t into the source image f

The maximum value of absolute difference gives the similarity measure. If we take the sum of difference square between template t and given image f over a region offset by u and v in each dimension, then we can get

$$d_{f,t}^2(u,v) = \sum_{x,y} \left[f(x,y) - t(x-u,y-v) \right]^2 \quad (1)$$

The above equation (1) can be expanded to,

$$d_{f,t}^2(u,v) = \sum_{x,y} \begin{bmatrix} f^2(x,y) - 2f(x,y)t(x-u,y-v) \\ +t^2(x-u,y-v) \end{bmatrix} \quad (2)$$

The term $\sum_{x,y} \left[t^2(x-u,y-v) \right]$ is fixed for a given template image. Likewise, the term $\sum_{x,y} \left[f^2(x,y) \right]$ is also approximated to be fixed. Then the cross correlation expression given in eq. (3) will give the degree of similarity.

$$c(u,v) = \sum_{x,y} \left[f(x,y)t(x-u,y-v) \right] \quad (3)$$

Direct implementation of eq (3) leads to a problem that image intensity may vary from region to region. The obtained result is not consistent. To avoid such a problem, both means and variances are taken into account. The resulted eq (4) is known as normalized cross correlation (NCC).

$$\gamma(u,v) = \frac{\sum_{x,y} \left[f(x,y) - \bar{f}_{u,v} \right] \left[t(x-u,y-v) - \bar{t} \right]}{\sqrt{\sum_{x,y} \left[f(x,y) - \bar{f}_{u,v} \right]^2 \sum_{x,y} \left[t(x-u,y-v) - \bar{t} \right]^2}} \quad (4)$$

where

$\bar{f}_{u,v}$ and $\bar{t}$ are the means of $f(x,y)$ and t respectively.

$$\bar{f}_{u,v} = \frac{1}{N_x N_y} \sum_{x=u}^{u+N_x-1} \sum_{y=v}^{v+N_y-1} f(x,y)$$

and

$$\bar{t} = \frac{1}{N_x N_y} \sum_{x=u}^{u+N_x-1} \sum_{y=v}^{v+N_y-1} t(x,y)$$

In practice to avoid excessive computation, fast and approximated techniques are used to compute eq. (4) [11], [12] and [13]. This technique can be also well applied to fingerprint images.

III. Matching Procedures and Results

There are two folds in the procedure, database construction and matching the test image to the database. Details are given as follows:

A. Database Construction

i) The raw image is enhanced with Gabor filtering.

ii) the core point of the enhanced imaged is located using Poin' care technique.

iii) the image is binarized and thinging.

iv) Define the circle of interest of which the radius of 100 pixel. The core point is taken as a center of this circle.

v) Draw a box of 15x15 pixels around the core point.

vi) The lines connected between the box and the circumstance of the circle are considered for angle measurement. Average values were taken.

vii) Three parameters which are: binary image, core point location and angle are stored as database for later matching.

B. Matching Procedure

i) Perform step i) to iii) given above which are applied for database construction.

ii) For the aligned core point, the test image is rotated with the amount of degrees difference between the two images.

iii) Two images are then cropped with the size of 128x128 pixels (a core point is at the center).

iv) The test image is then divided into 4 sub-images; 64x64 pixels each.

v) Each sub-image is used to find the similarity between itself and the database. NCC template matching is the key method involved. Each matching score must be equal or greater than the set threshold (0.3 in this experiment). Scores are summed up (1.2 in this case). Images with score above the threshold can pass this coarse matching.

vi) Candidate images obtained from v) and an database images are fed into the binarization and minutiae extraction process. Minutiae extraction offers a distance from the core point and an leverage angle, $g(r,\theta)$.

vii) Count the corresponding minutiae with in a boundary of error values set; ($r \pm 3$ pixels and $\theta \pm \frac{\pi}{12}$ radians).

Regarding the procedure given above, there are few points to be noted.

a) Although it is not the best filter, Gabor filtering can be nicely applied for directional filtering with filtering performance and computation times trade-off. It performance is also sensitive to the selection of filter's parameter; i.e. sigma (or standard derivation).

b) There are several techniques for core point identification; i.e. Geometry region technique (GR), Detection of curvature technique (DC), and Poin' care technique. According to its simplicity, Poin' care has been chosen for our proposal. In most case, the core point can be allocated within the error of 10 pixels. The core point can be hardly applied to the pattern with slow change turn over ridge such a lower ten or arc pattern. We have compensated the core point location error by adding a box of 15x15 pixels around the found core point.

c) To compensate the image orientation, we have rotated the image to have the same angle with that of the database. However, we have restricted ourselves to some certain maximum degree of rotation.

d) The discrepancy of radius and angle given in vii) can be turn for optimum performance.

Figure 3. An input image and the corresponding image after enhancement

Figure 4. A binarized image and its corresponding after thinning (core point shown)

Figure 5. A circle image and an image with a box around the point shown

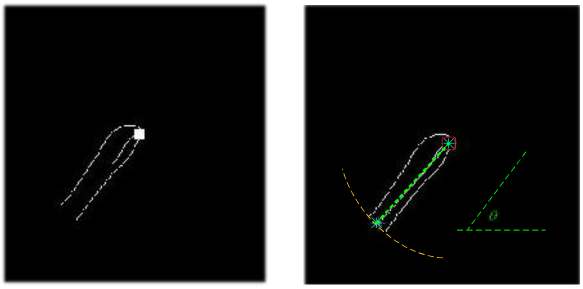

Figure 6. A connecting image and the corresponding angle estimation

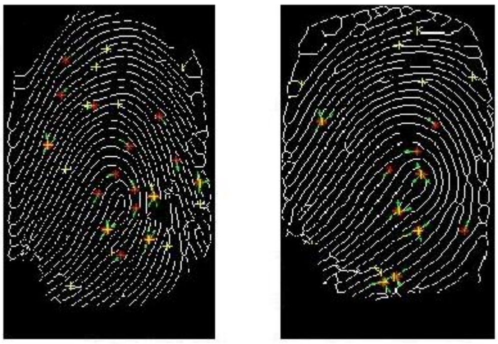

Figure 7. Minutiae matching of two fingerprint images

C. Results

To test the matching algorithm detailed in previous section, we have applied it to test 40 images, 10 of each patters. Those patterns as whorl, left loop, right loop, and tent. Of each pattern, an image is randomly selected to be a test image whilst the rest (including the test image) are considered as member of database set. We used the FVC 2004 database DB1 set A. The matching result is shown in the table below.

TABLE I: Matching results of several patterns

Pattern	False Accept	False Reject
Whorl	0	0
Right loop	0	1
Left loop	0	2
Tent	0	1

According to the results shown in Table I, we can see that what we have obtained is fairly good. The false reject rate is not so severe and considered to be a positive error, since those reject samples could be re-examined by some other methods even by using an expert. We can also use the given below evaluating equation to compare our technique with other proposed algorithm. That is:

$$FAR = \frac{false\_accept\_num}{total\_matching\_num} \times 100\% = \frac{0}{40} = 0\%$$

$$FRR = \frac{false\_reject\_num}{total\_matching\_num} \times 100\% = \frac{4}{40} = 10\%$$

Our method is superior over the standard techniques [14],[15] and [16] but cannot compete the one proposed in [17]. We hope that we can improve the FRR after patient fine tuning the threshold as well as increasing the total matching number.

IV. CONCLUSION

In this paper we have proposed an alternative hybrid fingerprint matching. Normalized cross correlation matching is employed in the coarse matching state. Minutiae matching, on the other hand, is used in the second state matching. To avoid the huge data to be stored as database, the binarized images are stored rather that gray scale images. To speed up the matching process, the images are cropped to the size of 128x128 pixels and the core point is assumed to be the center of this square. Based on the preliminary investigation, 0% FAR and 10% FRR have been obtained. Of the high percentages of FRR, some refinement is needed such that the figure could be improved. Although the currently obtained matching performance is quite impressive we need further confirmation by increasing the number of the images in the database.

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