International Journal of Research in Advent Technology, Vol.3, No.6, June 2015
E-ISSN: 2321-9637

Minutia Cylindrical Code Based Approach for Fingerprint Matching

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Abstract- Impression from the fingers and its matching is one of the important task of law enforcing body. Minutia extraction from the fingerprint image decides the accuracy of the matching. Method presented in this paper is also very efficient in matching the algorithm. Minutia cylindrical code(MCC) which is local descriptor of the fingerprint image is used for matching the fingerprint image. MCC, codes the local direction and distance between the minutia and hence invariants to the scale and rotation. False Acceptance ratio (FAR) and False Rejection ration(FRR) is also computed to test the accuracy of the proposed method.

Index Terms- Minutia, FFT, MCC, Euclidean distance

1. INTRODUCTION

Recognition of fingerprint is one of the complicated pattern recognition problems which is being studied for the last 40 years.

Though various efficient algorithm have been designed for fingerprint matching, it cannot be concluded that this problem has solved. Accuracy, interoperability and computational efficient algorithm are still an open issue [1] in fingerprinting matching.
Most of the current fingerprint matching algorithms are based on the minutia. Special ridge pattern are called minutia. Ridge ending and ridge bifurcation are some of the minutia.
In the past, minutia matching is considered as the two dimensional pattern matching problem for aligning the two minutia pair. This forced the researcher to find all the possible transformation for two minutia matching. Hough transform is one of the solution of this problem[2][3]. High computational cost and lack of robustness are some the problems of the global minutia matching algorithm.
In the last few years, these problem is addressed by introducing the local minutia descriptor and its matching.
The characteristics of the local minutia descriptor is such that it is invariants to the global transformation and therefore appropriate for matching without the need of global alignment.
Since local minutia descriptor based matching is based on the arrangement of the local property therefore it excludes the global feature and give better results. Global matching algorithms have some of the benefits which is not possible in case of local descriptor based matching and hence an hybrid approach can be applied to get the benefit of both the algorithm.
In this types of approach, first of all the local structure is used to match the minutia quickly and robustly. In the next step, matching at global level is performed for validation purpose.
The evaluation of the minutia matching based on the local structure passed in three stages. Stage one correspond to the earlier approach in which local structure are formed by considering the minutia lies inside some regions. In this approach no global validation was performed [4][5]. The approach adopted by the [6] and [7] comes in the second stage. [6] and [7] were the first to establishe a relationship between minutia and its neighbourhood in term of invariant angle distance and structure. In this stage, global validation was also performed .
Third stage comprises of the method proposed by Jiang and Yau[6] and Ratha [7]. These methods are variants of the method proposed by the same author. In this phase they extend the feature set of the fingerpring by incorporating local ridge, local frequency, shape its. [1] contain the exhaustive review in fingerprint matching and recognition. For further reference reader may go through the [8]-[33].
Two types of local minutia structure were proposed. First one is based on the nearest neighbourhood while the other one is based on the fixed radius. In the nearest neighbourhood [6] approach, centre minutia is characterized by the K- closest minutia which are spatially arranged. This gives the fixed length descriptor which can be matched very efficiently. The later approach is given by the [7]. In this approach, neighbours are defined as the all the neighbours which are inside the radius R of the centre minutia. In this approach, the length of the descriptor is not fixed making it difficult to match the fingerprint locally. But this approach shows better tolerant against missing and spurious minutia.

2. PROPOSED METHODOLOGY

In this paper local descriptor based fingerprint recognition is presented. Minutia cylinder code is used as local descriptor. Block diagram of proposed methodology is shown in figure 2.

First of all, with the help of scanner, Fingerprint image of the input finger is registered. Minutia extraction block is used to extract out the minutia from the image.

With the help of minutia, a cylindrical code for minutia is formed. Minutia cylindrical code represent minutia local structure of the minutia distribution. Once, minutia cylindrical code is generated for each finger print then a database is created which contain the minutia cylindrical codes of all the fingerprint image. The last step of this method is matching or testing. Next section describe the functioning of last four block of this algorithm.

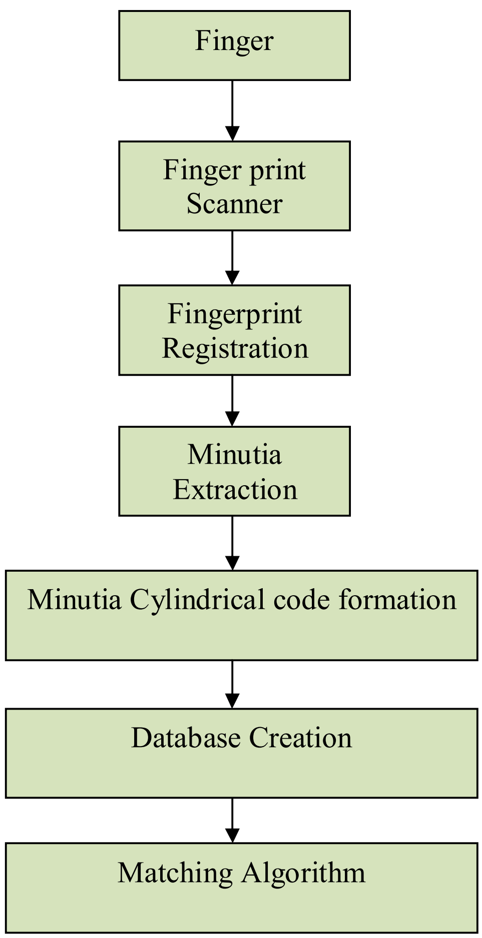

Fig.1 Basic Flow Diagram of Proposed Method

2.1. *Minutia Extraction Process*

In any fingerprint recognition system, Minutia extraction is one of the important phase because the performance of any fingerprint recognition system depends on the how accurately minutia are extracted. In this algorithm following steps have been adopted for minutia extraction.

2.2 FP Image Enhancement

First step in any fingerprint recognition system is the enhancement of the fingerprint image. This step is adopted to improve the quality of the fingerprint image so that all the minutia points become more clear and extraction of the minutia points become easier. Generally, Fingerprint image obtained by the fingerprint scanner is noisy and of poor contrast. Ridge and furrows are not visible due to the poor contrast. Image enhancement increase the contrast of ridge and furrows and also joined some of the broken line which occurred in fingerprint image due to sensor deficiency.

2.3 Histogram equalization

Histogram equalization basically adjust the intensity distribution of the histogram and with this approach it improve the global contrast of the image. This step helps the lower contrast region to gain a higher contrast while keeping the global contrast intact. This method basically spread out the most frequently occurred intensity value. Figure 3 represent the histogram before and after applying histogram equalization.

2.4 Fast Fourier Transform.

This process is accomplished for connecting the ridge broken line . In this process first of all, Fingerprint image is divided in to a block of 32 * 32 pixel and then Fourier transform of this block is computed using following formula.

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

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

2.5 Image Binarization

This process is performed to convert the 8-bit gary image to 1 bit image. In this, 0 represent the ridge and 1 represent the furrows. This step highlight the ridge and furrows clearly in the image. A local adaptive binarization method is used for this purpose.

2.6 Fingerprint Segmentation

This process is accomplished to extract out the region of interest from the fingerprint image. In fingerprint image, some of the area is not useful and carry insignificant ridge and furrows. It is necessary to discard this area . Segmentation process consist of two part i.e. Estimation of block direction, extraction of region of interest by applying morphological operation.

2.7 Estimation of Block Diagram

Block direction estimation is performed to separate out background and foreground information. In finger print image, foreground is represented by the ridges and furrows while the background represent the no information.

In order to compute the block diagram estimation, a block of 16 *16 pixel is chosen and then block direction is computed by using below mentioned formula

$$\tan 2\beta = \frac{2\sum\sum (g_x * g_y)}{\sum\sum (g_x^2 - g_y^2)}$$

here

g_x= Gradient along x-direction

g_y= Gradient along y-direction

Certainity level for each block is then computed using formula-

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

Here

W= size of block (i.e. 16 in this case)

The value of E is compared with the threshold value to decide whether the block comes under the background(if E<threshold) or foreground (i.e if E>threshold).

2.8 Morphological Operation for ROI extraction

In the last step morphological operation “opening” and “closing” is applied to to extract the region of interest.

2.8.1 Ridge Thinning

This operation is applied to make the ridge width 1 pixel wide. This is performed by thinning operation.

2.8.2Minutia Marking

Next step is applied to mark the minutia by applying a 3*3 window.

2.8.3False Minutia Removal

Inter-ridge distance is used for eliminating the false minutia points which may affect the over all accuracy of the fingerprint recognition system.

2.8.4Minutia Marking

At the final step each true minutia is marked with three element. i.e. x-coordinate, y-coordinate and the minutia direction or angle.

2.9 Minutia Cylindrical Code Information

Once the minutia information is obtained then the next step is to form the minutia cylindrical code. In minutia cylindrical code, a cylinder with 6 different layer is used to represent the relative direction and distance among different minutia. One such cylinder is shown in figure 3.

Figure 3 represent the cylinder associated with the minutia m={xm, ym, θm}. Radius of the cylinder is R and xm and ym is the center of this cylinder. As shown in the figure, a cuboid encloses the cylinder whose base is aligned as per the direction of the minutia i.e θm. The cuboid is divided in to a N_c cell where

$$N_s = N_s \times N_s \times N_D$$

The size and height of each cell is $\Delta_s \times \Delta_s$ and Δ_D respectively.

Where

$$\Delta_s = \frac{2R}{N_s}$$

$$\Delta_D = \frac{2\pi}{N_D}$$

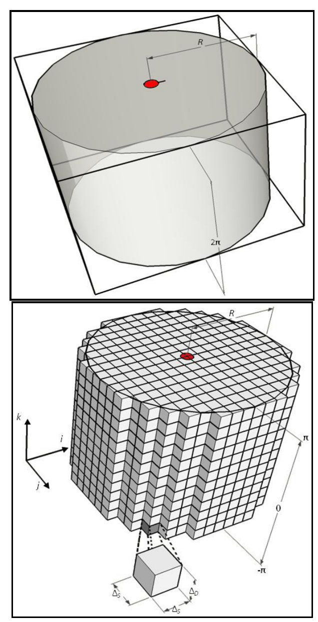

Fig.2 Minutia Cylinder

Each cell of the cylinder can be accessed by three coordinate i.e. i, j, k which represent the position of the cell inside the cylinder. The value of i and j is between 1 and Ns while the k takes the value between

1 to Nd. The height k of the cylinder represent the angle which is represented by the

$$d\varphi_k = -\pi + \left(k - \frac{1}{2}\right).\Delta_d$$

If

$$p^m{}_{i,j} = \begin{bmatrix} x_m \\ y_m \end{bmatrix} + \Delta_s \begin{bmatrix} \cos(\theta_m) & \sin(\theta_m) \\ -\sin(\vartheta_m) & \cos(\theta_m) \end{bmatrix} \begin{bmatrix} i - \frac{N_s + 1}{2} \\ \frac{j - N_s + 2}{2} \end{bmatrix}$$

Represent the centre of the cell having indices i,j.
In MCC, the contribution of each minutia m_t for each cell is computed and is given by

$$C_m(i,j,k) = \begin{cases} \varphi\left(\sum_{m_t \in N_{p^m{}_{ij}}} \left(C^s{}_m\left(m_t, p^m{}_{i,j}\right) . C^D{}_m(m_t, d\varphi_k)\right)\right) & if\ \varepsilon_{m(p^m{}_{i,j})=valid} \\ invalid & otherwise \end{cases}$$

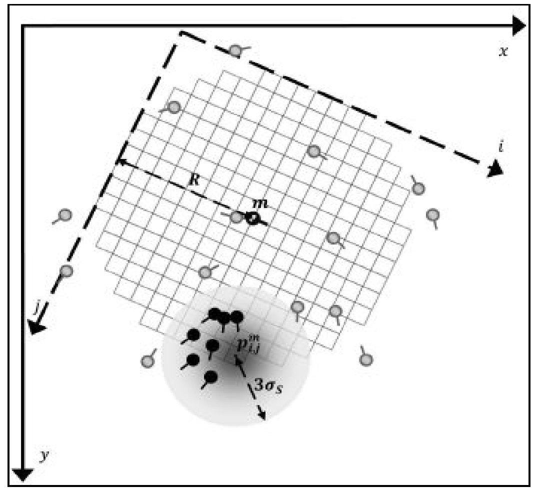

Fig.3 Neighbourhood Radius

Which is computed by the spatial contribution $C^s{}_m\left(m_t, p^m{}_{i,j}\right)$ and directional contribution $C^D{}_m(m_t, d\varphi_k)$

Where spatial contribution is given by

$$C^s{}_m\left(m_t, p^m{}_{i,j}\right) = G_s\left(ds\left(m_t, p^m{}_{i,j}\right)\right)$$

$$G_s(t) = \frac{1}{\sigma_s\sqrt{2\pi}}\left(\frac{-t^2}{2\sigma_s{}^2}\right)$$

And directional contribution is given by

$$C^D{}_m(m_t, d\varphi_k) = G_D\left(d\emptyset\left(d\varphi_k, d_\theta(m, m_t)\right)\right)$$

$$G_D(\alpha) = \frac{1}{\sigma_D\sqrt{2\pi}} \int_{\alpha - \frac{\Delta_D}{2}}^{\alpha + \frac{\Delta_D}{2}} e^{-\frac{t^2}{\sigma_D{}^2}} dt$$

And

$$N_{p^m{}_{i,j}} = \left\{m_t \in T; m_t \neq m, ds(m_t, p^m{}_{i,j}) \leq 3\sigma_s\right\}$$

Is the neighbourhood of the $p^m{}_{i,j}$.

Here σ_s is the neighbourhood radius and ds (p, m) represent the Euclidean distance between minutia m and point p as shown in the figure given below-

Once the MCC for all the fingerprint image is obtained then a database of MCC is created.

2.10 Fingerprint Matching

In order to match the two fingerprint MCC, Euclidean distance is computed between two fingerprint MCC as given in the below

$$Ed = \sqrt{(MCC_a)^2 - (MCC_b)^2}$$

Where

MCC_a= MCC of the testing fingerprint image
MCC_d= MCC of the database.
MCC for each fingerprint image is rotation and scale invariants therefore it gives better result in even if the fingerprint image is rotated or scaled.
The database MCC for which the value of Ed is less than the certain threshold is considered as the matching one and corresponding fingerprint image is considered as the matching image

3. EXPERIMENTAL RESULTS

A database of fingerprint images comprises of the 200 different fingerprint images are created for testing the performance of the proposed method. A simulation program is designed with the help of MATLAB ver 2009B. The simulation program is tested in a core2duo processor computer with 2GB RAM.

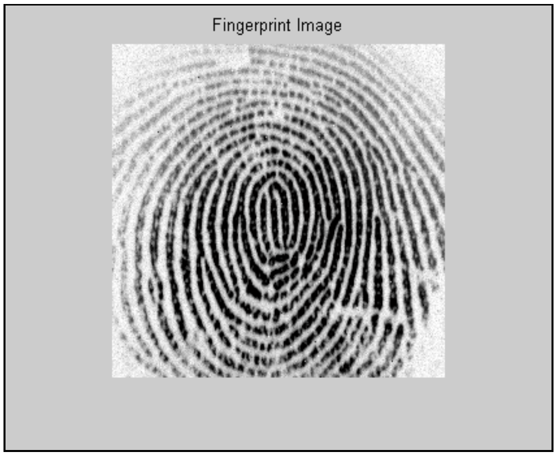

Fig.4 Original Fingerprint Image

Figure 5 display the original fingerprint image while figure 6 display the extracted minutia points of the fingerprint image.

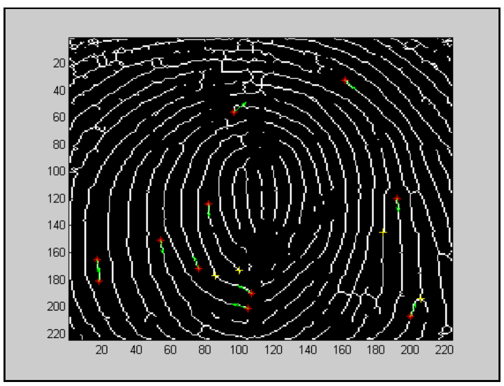

Fig.5 Extracted Minutia Points in fingerprint image

In order to evaluate the performance of this method, statistical measure like FAR(False acceptance Ratio) and FRR(False rejection ratio) is also computed and tabulated in table 1.

Fr AR is computed using following formula

$$FAR = \frac{Number\ of\ False\ attempt\ accepted}{Total\ Number\ of\ false\ attempt}$$

$$FRR = \frac{Number\ of\ True\ attempt\ rejected}{Total\ Number\ of\ True\ attempt}$$

Table 1 FAR and FRR for different value of Threshold (Without Rotation)

Threshold Value	FAR(in %)	FRR(in %)
6	6.9	0.07
7	7.4	0.05
8	9.2	0.05
9	11.9	0.03
10	13.1	0.02

Table2 FAR and FRR of rotated fingerprint image for different value of Threshold

Threshold Value	FAR(in %)	FRR(in %)
6	6.3	0.12
7	7.6	0.08
8	10.1	0.07
9	12.1	0.03
10	13.9	0.03

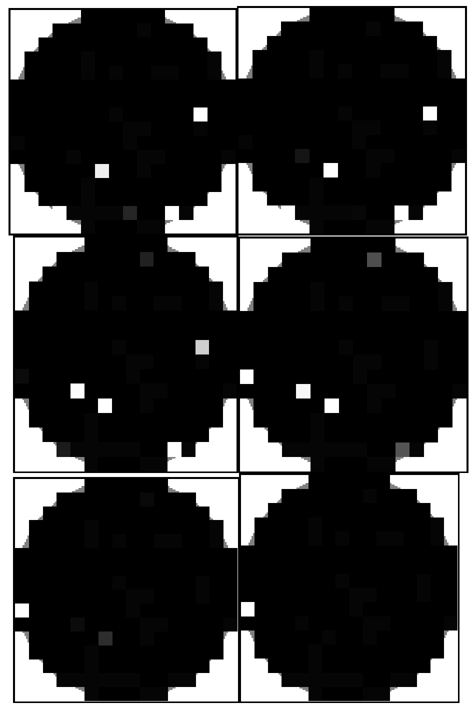

Fig.6 Minutia Cylindrical Code of the fingerprint image shown in figure 5

4. *CONCLUSION*

Since from its inception, finger-print matching area has been in the search of some robust technique for matching the fingerprint accurately. The requirement of rotation , scale invariants re the need of the hour. In this paper a MCC based fingerprint matching algorithm is implemented and presented. The performance of the proposed system is satisfactory as clear from the table 1. Even after rotating and scaling the fingerprint, proposed system is able to achieve good accuracy.

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