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Fingerprint Verification Using Gabor Filter

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***Abstract*— Finger print recognition is a widely popular but a complex pattern recognition problem. It is difficult to design accurate algorithms capable of extracting salient features and matching them in a robust way. The real challenge is matching fingerprint affected by i) high displacement or rotation which results in smaller overlap between template and query fingerprints, ii) Non-linear distortion caused by the finger plasticity, iii) Different pressure and skin condition and iv) Feature extraction errors which may results in spurious or missing features. In this paper a novel method is presented for generation of a fixed length square finger code of size16x16x4. It uses a set of Gabor filters for extracting fingerprint features from gray scale image cropped in the size of 128x128 pixels using its core point as the center. Experimental results show that the recognition rate based on the Euclidean distance between the two corresponding Gabor filter finger codes with verification accuracy of 93%. Since the fingerprint matching is based on the Euclidean distance between two corresponding finger codes, it is extremely fast. This reveals that by setting the parameters to appropriate values, the finger code generated is more efficient and suitable than conventional methods for a small-scale fingerprint recognition system.**

***Key Words* - Fingerprint verification, gabor filter, fingercode, Euclidean distance..**

I. INTRODUCTION

The main objective of this paper is to implement a pattern matching fingerprint recognition technique. The newly developed ISO/IEC-Standard 19794-3 [29] provides three possibilities:

• Quantized co-sinusoidal triplets
• Discrete Fourier transform
• Gabor filters

The method using quantized co-sinusoidal triplets has been patented by Bioscrypt Inc.as mentioned in [3]. In several publications,[21] see [25] and , it has been mentioned that using a Gabor filter provides better fingerprint enhancement results than using a Fourier transform. Therefore, the Gabor filter technique was selected. This section describes the different processing steps from pre-processing to matching as the final step of the fingerprint authentication. In the first step the fingerprint is segmented, which crops areas of the recorded image, which do not contain any relevant information. Subsequently reference point detection works on non-enhanced fingerprint images as well as on enhanced. Therefore, any further enhancement is not required for the subsequent processing steps. The next step is the detection of the reference point .After that, the fingerprint image is filtered using a Gabor filter. Now take its average absolute distance and it is matched in the subsequent matching step with of other average absolute distance of other fingerprints

The result of the matching is then displayed

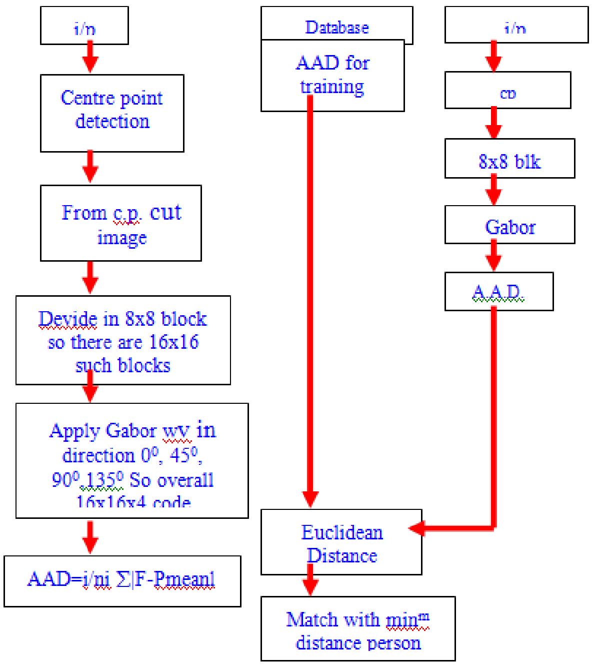


Fig.1flowchart

II. REFERENCE POINT DETECTION

The reference point has to be located at the same position in every impression of the finger to receive accurate information for this reason; this section describes the detection of the reference point.

The reference point detection algorithm described in this section works as follows: First of all, the fingerprint image is divided into blocks of 8x8 sizes. After that, the gradient of every block is computed and an estimation of the orientation field is calculated by using the gradients. The subsequent step creates a continuous vector field out of the orientation field. Then, the vector field is filtered and a smoothed orientation field is created. After that, the reference point is detected by selecting the pixel with the most neighboring pixels with different orientations. The reference point is defined as the point where the ridges of the fingerprint have the highest curvature. Thus, it is necessary to determine the curvature of the ridges. For this purpose it is necessary to compute the orientation map of the fingerprint. The orientation map is a representation of the fingerprint, which illustrates the local orientation of the ridges like a vector field as shown in Figure 3.3. The orientation is defined as the sharp angle relating to the horizontal line, which represents an orientation of 0

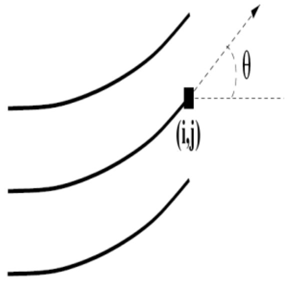


Figure 2: Orientation angle of pixel (i,j)

The steps for computing the orientation map are as follows

1. The fingerprint input image I(i, j) is divided into non-overlapping blocks of size 8 x 8, which are centered at pixel (i, j). In practice, the best compromise between orientation map granularity, which requires quite small blocks, and fast computation speed, which requires big blocks, is needed. The size of the blocks depends also on the computation power of the system. The division into blocks is necessary, because pixels, which do not belong to a ridge, do not possess any orientation. Therefore, every pixel in a block is assigned to the dominant orientation of the ridges in the block, which is shown in the next processing steps.

2. For each pixel (i, j), compute the gradients ∂x(i, j) and ∂y(i, j). To compute those gradients an edge detection algorithm is needed. In [11] and [7] it is proposed to compute∂x(i, j) and ∂y(i, j) by using the edge detection operator

During tests it turned out that quite good results are achieved by simply adding up the differences in gray level in horizontal direction to get ∂x (i, j) and in vertical direction to get ∂y (i, j). This operator is known as the symmetric difference operator:

$$\partial x\,(i,j) = I\,(i,j) \begin{pmatrix} 0 & 0 & 0 \\ -1 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\begin{pmatrix} 0 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

3. The local orientation of each block, centered at pixel (i, j), is then estimated using the following equations taken from

$$V_x(i,j) = \sum_{u=i-\omega/2}^{i+\omega/2} \sum_{u=j-\omega/2}^{j+\omega/2} 2\partial_x(u,v)\,\partial_y(u,v)$$

$$V_x(i,j) = \sum_{u=i-\omega/2}^{i+\omega/2} \sum_{v=j-\omega/2}^{j+\omega/2} (\partial^2_x(u,v)\,\partial^2_y(u,v,$$

$$O(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{V_y(i,j)}{V_x(i,j)}\right)$$

Vx (i, j) and Vy (i, j) are the elementary orientations in x and y direction. The orientation map O is a matrix which contains the orientation angle for every pixel (i, j) of the input fingerprint. The equation for computing the orientation map O (i, j) derives from the mathematical definition of the tangent.

The orientation field is now smoothed using the particular local neighborhood by using equations from [11]

1. To be able to smooth the orientation it has to be converted into a continuous vector field:

$$\phi_x(i,j) = \cos(2\,o(i,j))$$

$$\phi_y(i,j) = \sin(2\,o(i,j))$$

whereas ϕ_x and ϕ_y are the x and y component of the vector field.

2. This vector field is low-pass filtered as follows:

$$\Phi'_x(i,j) = \sum_{u=-\omega_\Phi/2}^{\omega_\Phi/2} \sum_{v=-\omega_\Phi/2}^{\omega_\Phi/2} W(u,v).\Phi_x(i-u, j-v)$$

$$\Phi'_y(i,j) = \sum_{u=-\omega_\Phi/2}^{\omega_\Phi/2} \sum_{v=-\omega_\Phi/2}^{\omega_\Phi/2} W(u,v).\Phi_y(i-u, j-v)$$

W(u, v) is a two-dimensional low-pass filter with size (wϕx wϕ) In practice, the filter of the size 9×9 (wϕ=9) provides the best compromise between slick smoothing and fast processing speed.

$$W(u,v) = 1/169 \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 4 & 3 \\ 2 & 3 & 4 & 5 & 6 & 5 & 4 \\ 3 & 4 & 5 & 6 & 7 & 6 & 5 \\ 4 & 5 & 6 & 7 & 8 & 7 & 6 \\ 5 & 6 & 7 & 8 & 9 & 8 & 7 \\ 4 & 5 & 6 & 7 & 8 & 7 & 6 \\ 3 & 4 & 5 & 6 & 7 & 6 & 5 \\ 2 & 3 & 4 & 5 & 6 & 5 & 4 \\ 1 & 2 & 3 & 4 & 5 & 4 & 3 \end{pmatrix}$$

The factor in front of the matrix is the scaling factor, which levels the sum of the multiplications to one. This is done because the vector field has to be smoothed on the same level, the global gray level value remains the same.

3. The smoothed orientation field O'(i, j) is now computed using the following equation, which derives from the mathematical definition of the tangent:

$$O'(i, j) = \frac{1}{2} \tan^{-1} [\, \Phi'_y(i, j)/\Phi'_x(i, j)]$$

Tests on a database of 320 fingerprints have shown that on almost all non-plain-arch fingerprints with 2acceptable quality the reference point is detected with a very high accuracy. The reference point was located on the exact position or only up to 3 pixels distance away from the exact position, which would be selected by hand as the correct position. This accuracy is high enough to use the automatically located reference point for the calculation of average absolute deviation. As mentioned before, only fingerprints with low quality or fingerprints of the plain arch class interfere with the reference point Detection.

III. GABOR FILTER USED FOR FEATURE EXTRACTION

The true ridge and furrow structures of a fingerprint image can be greatly accentuated by applying properly tuned Gabor filters. These accentuated ridges and furrow structures constitute an efficient representation of a fingerprint image. The general form of a 2D Gabor filter is defined by

$g(x, y, f, \theta_k, \delta x, \delta y) =$

$$\exp\left[\frac{-1}{2}\left(\frac{x_{\theta_k}^2}{\delta_x^2}+\frac{y_{\theta_k}^2}{\delta_y^2}\right)\right]\times \exp\left(2\pi\ j\ f\ x_{\theta_k}\right)$$

where

$$x_{\theta k} = x \cos\theta_k + y \sin\theta_k$$
$$y_{\theta k} = x \cos\theta_k + y \sin\theta_k$$

and *f* is the frequency of the sinusoidal plane wave along the direction

ϕ_k is the orientation of the Gabor filter,

∂x and ∂y specify the Gaussian envelope along *x* and *y* axes, which determines the bandwidth of the Gabor filter To analyze the Gabor filter in terms of the even symmetric and odd symmetric (1) can be expressed in complex form as

$$g(.) = g_{even}(.) + j\, g_{odd}(.)$$

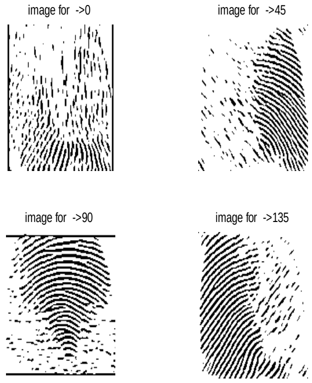
$g_{even}(x,y,f, \theta_k, \partial_x\text{-}\partial_y)$=

$$\exp\left[\frac{-1}{2}\left(\frac{x_{\theta_k}^2}{\delta_x^2}+\frac{y_{\theta_x}^2}{\delta_y^2}\right)\right]\times \exp(2\pi\ j\ f\ x_{\theta_t})\cos$$

godd $(x,y, f, \theta_k, \partial_x\text{-}\partial_y)$=

$$\exp\left[\frac{-1}{2}\left(\frac{x_{\theta_k}^2}{\delta_x^2}+\frac{y_{\theta_k}^2}{\delta_y^2}\right)\right]\times (2\pi\ j\ f\ x_{\theta_k})\sin$$

A fingerprint image can be decomposed into four component images using four different values of $\theta_k=0^0, 45^0, 90^0, 135^0$, (with respect to the *x* -axis)



Fif.3, 2-D Gabor filter response with orientations of

$\theta_k = 0^{0.}$, $45^{0.}$,$90^{\ 0.}$*and* $135^{\ 0.}$

A fingerprint image *I* (*x*, *y*) is normalized and convolved with each of the four Gabor filters to produce four component images. Convolution with an oriented filter accentuates ridges parallel to the *x* -axis, and it smoothes ridges that are not parallel to the *x* -axis. Filters tuned to other directions work in a similar way as shown in Fig 4. According to the experimental results, the four component images capture most of the ridge directionality information present in a fingerprint image and thus form a valid representation. It is illustrated by reconstructing a fingerprint image by adding together all the four filtered images. The reconstructed image is similar to the original image but the ridges have been enhanced..

3.1. Finger code generation:

To generate the Gabor filter-based finger code from the fingerprint image following steps are performed sequentially:

1. Find the core point of each fingerprint image.
2. Crop the fingerprint image into 128x128 pixels using its core point as the center.
3. Divide the cropped image into a set of 8x8 non overlapping blocks and sample the fingerprint image by set of Gabor filters to give $F_{i\theta k}(x,y)$ the filtered image in$\theta_k = 0^0$ directions.
4. Now, $\forall \in \{1,2,3 \ldots 256\}$ and $\theta_k=0^0, 45^0, 90^0, 135^0$, the feature values are the average absolute deviation from the mean defined as

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$F_{i\theta}k=1\ 1/n_i\Sigma\ |\ F_{i\theta}k(x,y)-p_{i\theta}\ |$

Where ni = 64 , is the number of pixels in the block of 8x8, is the mean of pixel values in that block .Thus, the average absolute deviation of each 8x8 block of the four filtered images defines the components of the finger

IV. EUCLIDEAN DISTANCE MATCHING

Once the average absolute deviation is found out for the enquired image it is found out for the enquired image it is compared with average absolute deviation of the stored database by Euclidean Distance method, and the distance having minimum value will be considered as best match.

In mathematics the Euclidean distance or Euclidean matrix is the ordinary distance between two point's hat one should measure with a ruler, and is given by the Pythagorean formula. By using this formula as Euclidean space become a metric space.

The Euclidean distance between points p&q is the length of line segment In Cartesian co-ordinates if p=(p1,p2,----pn) and q=(q1,q2,-----qn)are two points in Euclidean space then the distance from p to q is given by

$$\sqrt{(p_1-q_1)^2+(p_2+q_2)^2+\ldots(p_n-q_n)^2}$$

Advantages:

1) The fingerprint matching is based on the distance between the two corresponding finger codes and hence is extremely fast.

2) Good verification accuracy with less computation time for verification is achieved by the method.

3) The system is less complex.

V. RESULTS

5.1Database

The evaluation and testing of the proposed approach has been done on four diverse fingerprint databases taken from **FVC2002**. Each database consists of 80 finger print. Images taken from 10 different persons i.e.8 fingerprints of 10 different fingers (excluding both thumbs)of each person. From those first three fingerprints of each person are processed as trainee fingerprints and their average absolute deviations are stored as reference .i.e. in each database thirty images of ten persons are stored in trainee form and remaining fifty fingerprints are treated as enquiry images .Also the database of 32 inked fingerprint images from 4 persons (8 images per person) are captured and their digital format with the scanner at 200 dpi and 256 gray level resolution are captured. The 5 fingerprints of each person i.e. total 20 images are taken as trainee images and 12 images as enquiry images for recognition.

Database taken from FVC

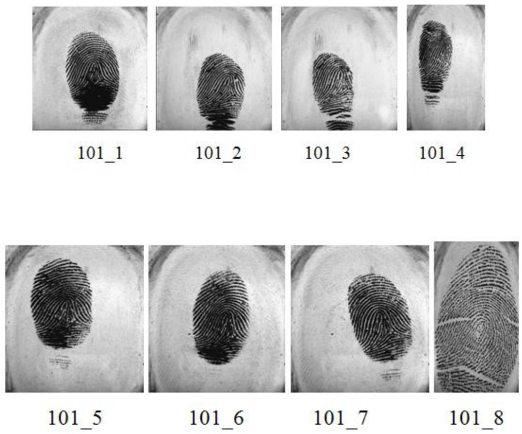

Fig.4 , Database from FVC

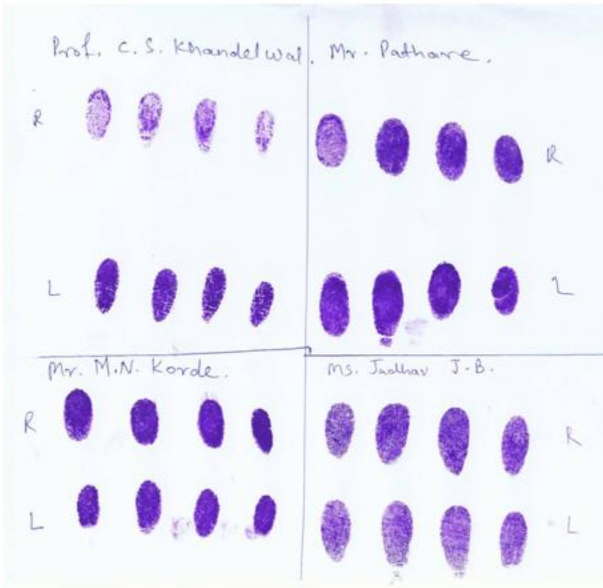

Fig.5, Database taken in inked fingerprints, scanned by scanner

5.2 Result

When any fingerprint is given for recognition it is tallied by the stored database (trainee images) and the minimum value between the enrollment image and trainee is searched and the person with whom it matches by minimum distance it is assigned to that person and match is found.

The accuracy for databases taken from FVC and by inked fingerprints taken by scanner are as given below respectively

DB_1 = 58%

DB_2 = 70%

DB_3 = 68.5%

DB_4 = 78.5%

Inked fingerprint database-93%

Average time for matching the features is 1.25 second i.e system is fast enough

The FAR is 0.1679

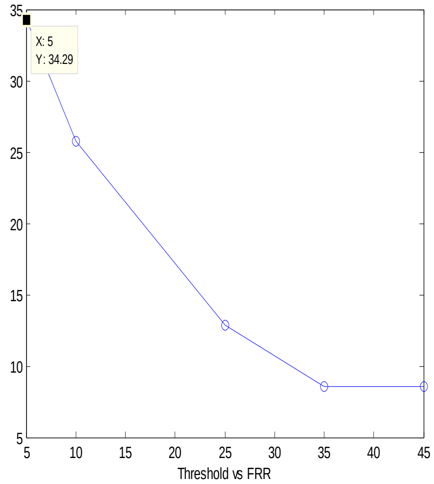

Fig 6 : Graph of threshold verses FRR

VI. Conclusion

The fixed length square finger code of size16x16x4 generated using a set of Gabor filters contains local information. The filter frequency *f* and the values ofδ x and δy that determine the bandwidth of the Gabor filter should be selected properly. If *f* is too large, spurious ridges may be created in the filtered image, whereas if *f* is too small, nearby ridges may be merged into one. Similarly, if the values of δx and δy are too large, the filter is more robust to noise, but is more likely to smooth the image to the extent that the ridge and furrow details in the fingerprint are lost. On the other hand, if they are too small, the filter is not effective in removing noise. Since, the fingerprint matching is based on the Euclidean distance between the two corresponding finger codes, it is extremely fast. This reveals that by setting the parameters to appropriate values, the method is more efficient and suitable than conventional methods for a small-scale fingerprint verification system.

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