Fingerprint Feature Extraction

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Abstract
Fingerprint recognition is a method of biometric authentication that uses pattern recognition techniques based on high-resolution fingerprints images of the individual. Fingerprints have been used in forensic as well as commercial applications for identification as well as verification. The fingerprint surface is made up of a system of ridges and valleys. The steps for Fingerprint recognition include image acquisition, preprocessing, feature extraction and matching In the present work, a new fingerprint feature detection algorithm has been proposed. It has been found that presence of noise in fingerprint images leads to spurious minutiae. To overcome this problem, feature extraction has been done which efficiently determine the minutiae points in fingerprint .The proposed method can be used in matching the template for finding bifurcation and termination. The new smoothing algorithm is proposed for the detection of the features of fingerprints. A method has been introduced for finding ridges in the fingerprint image with the help of eight different masks. It is a process of making a binary image of ridges from the grayscale fingerprint image. The experimental results showed the accuracy of the algorithm in terms of genuine acceptance rate ,false rejection rate, false acceptance rate.

I. Introduction
Biometrics recognition refers to the use of distinctive anatomical and behavioral characteristics or identifiers such as Fingerprints, Face, Iris, Voice, Hand geometry etc. for automatically recognizing a person. Fingerprint recognition is one of the most mature biometric technologies and is suitable for a large number of recognition applications. Live scan fingerprint scanners can easily capture high quality fingerprint images. In the present research we are concentrating into two types of minutiae for feature detection i.e. termination and bifurcation.

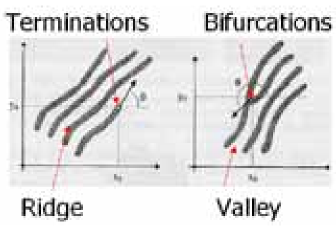

Fig. 1.Minutiae (valley is also referred as furrow, Termination is also called Ending and Bifurcation is also called Branch)

II. Problem formulation
One of the main problems in extracting structural features is due to the presence of noise in the fingerprint image. Commonly used methods for taking fingerprint impressions involve applying a uniform layer of ink on the finger and rolling the finger on paper These cause the following types of problems.

1. Over inked areas of the finger create smudgy areas in the image.
2. Breaks in ridges are created by under inked areas
3. The skin being elastic in nature can change the positional characteristics of the fingerprint features depending upon the pressure being applied on the fingers.

Thus a substantial amount of research reported in the literature on fingerprint identification is devoted to image enhancement techniques.This work proposes a reliable method for feature extraction from fingerprint images. The matching stage uses the position and orientation of minutia features. As a result, the reliability of feature extraction is crucial in the performance of fingerprint matching.

III. Proposed Solution
The proposed approach for feature extraction can be described as follows. A fingerprint image should be viewed as a flow pattern with a definite texture. An orientation field for the flow texture is computed. The input image is divided into equal sized blocks. Each block is processed independently. The gray level projection along a line perpendicular to the local orientation field provides the maximum variance. Locate the ridges using the peaks and the variance in this projection. The ridges are thinned and the resulting skeleton image is enhanced using an adaptive morphological filter. The feature extraction stage applies a set operations on to the thinned and enhanced ridge image. The post processing stage deletes noisy feature points. The overall process can be divided into following operations.

- Load the image.
- Normalization and segmentation.
- Orientation estimation.
- Ridge segmentation and smoothing.
- Thinning.
- Minutiae post processing.
- Region of interest.
- output image.

A. Normalization and segmentation:
Normalization is used to standardize the intensity values in an image by adjusting the range of grey-level values so that it lies within a desired range of values. Normalization is pixel-wise operation. It does not change the clarity of the ridge and furrow structures. The main purpose of normalization is to reduce the variation in gray level values along ridges and furrows, which facilitates the subsequent processing steps. Hence, a method based on variance threshold can be used to perform the segmentation. [3].Initially, the image is divided into blocks and the grey-scale variance is calculated for each block in the image. If the variance is less than the global threshold, then the block is assigned to be a background region; otherwise, it is assigned to be part of the foreground. The result is as shown in Fig.1. The grey-level variance for a block of size N × N. We assume that all the images are scanned at a resolution of 500 dots per inch (dpi), which the resolution is recommended by FBI(Federal Bureau of Investigation) . The mean and variance of a gray-level fingerprint image I are:

$$M(I) = 1/N^2 \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} (I(i,j)) \qquad [1]$$

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$$VAR(I) = 1/N^2 \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} (I(i,j)-M(I))^2 \quad [2]$$

where VAR (I) is the variance for block I, I(i; j) is the greylevel value at pixel (i; j), and M(I) is the mean grey-level value for the block I. The main purpose of normalization is to reduce the variation in gray level values along ridges and furrows, which facilitates the subsequent processing steps.

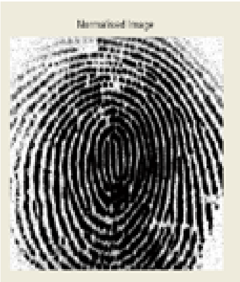

Fig. 2 : Normalized Image

B. Orientation estimation:

The orientation image represents an intrinsic property of the fingerprint images and defines invariant coordinates for ridges and furrows in a local neighborhood. The orientation field of a fingerprint image represents the directionality of ridges in the fingerprint image. The block orientation could be determined from the pixel gradient orientations based on, say, averaging, voting, or optimization [5]. The main steps for the calculation of orient direction from the normalized image.

- Divide the image into 8x8 sized blocks.
- Compute the image gradients $\delta x(i,j)$ and $\delta y(i,j)$ at each pixels.
- Calculate the local orientations at each pixel by finding principle axis of variation in image gradients.
- Smooth the orientation field using Gaussian low-pass filter. The orientation image need to be converted to continuous vector field by:

$$\Phi x(i,j) = \cos(2\theta(i,j))$$

$$\Phi y(i,j) = \sin(2\theta(i,j))$$

Where Φx and Φy are the x,y components of vector field.

All possible directions should get converted into eight directions in the range of 90 degrees to -67.5 degrees. We round the value of the obtained direction to the nearest values of the desired range.We are considering only this range of values for the orientation field calculation. With this, a fairly smooth orientation field estimate can be obtained.

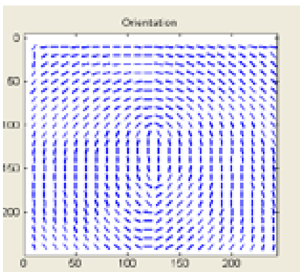

Fig. 3: Orientation Field.

C. Ridge Segmentation and smoothing:

Once we have calculated the orientation field of the given fingerprint image. Now we will round the frequency obtained to reduce the number of distinct frequencies [6]. Then the next step is to generate the filters corresponding to these frequencies. The reference-filters [7] to be used correspond to the range of quantized directions. This basic idea is that when we move one pixel along the X axis, the number of pixels to be moved along Y axis is x.tan (θ). The reference filter will be placed on each block according to the direction orthogonal to the dominant direction of the block. Here the reference filter size is equal to the block size. In each mesh-grid, the decimal numbers are arranged along a line with an angle equal to the dominant direction of the block on which it is to be placed. The pixels along each line of the reference filter are examined. The pixel with minimum value is converted to one, while the others are converted to zero. This process is called linearization of the fingerprint image. After the linearization only those pixels correspond to the ridges will remain.Once the ridges are located, directional smoothing is applied to smooth the ridges. The same reference filters used for ridge segmentation can be used for directional smoothing. Here for each and every block, a reference filter gets selected according to the dominant direction of the block. Each pixel on every line is checked. If the count of `1's is more than 25% of the total number of pixels in the line , then the ridge point is retained by making all the pixel values of the line 1s. If the count of 1's is less than 25% of the total number of pixels in the line, all the pixel values are made 0s.

1. Proposed Algorithm.

In the proposed algorithm of the finger print feature extraction the following steps are used:

- Firstly, Angular Increment is used to divide 180 degree into equal fractions
- Get the size of image
- Find the valid frequency in the image matrix (with the condition that frequency should be greater than zero value).
- Generate the array of distinct frequencies of matrix pixels
- Round the array to reduce the number of distinct frequencies.
- Generate a table, given the frequency value multiplied by 100 to obtain an integer index.
- Generate filters corresponding to these distinct frequencies and orientations in 'angleInc' increments.
- Generate oriented versions of filters.
- Create a function which will provide angles +ve anticlockwise, by giving the minus sign.
- Then convert the orientation matrix from radians to index value.
- Finally, Find the frequency corresponding to frequency index value i.e. freq(r,c)

The efficiency of the algorithm has been calculated in terms of the genuine acceptance rate, false acceptance rate and false rejection rate.

2. Implementation & Results

In the implementation we used Angular Increment (AngInc) equal to 6 (Which will divide 180 degree into equal fractions). Thereafter the second and third step is implemented in MATLAB 7.4. The 'Sub2Ind' function is used to generate the array of distinct frequencies of matrix pixels and the array is rounded to the nearest 0.02 to reduce the number of distinct frequencies.Thereafter, a table consisting of given the frequency value multiplied by 100 to obtain an integer index is generated and filters corresponding to these distinct frequencies and orientations in 'angleInc' increments are generated. Generate oriented versions of filters using 'imrotate' function. Then, convert the orientation matrix from radians to index value and the frequency corresponding to frequency index value i.e. freq(r,c) is computed.

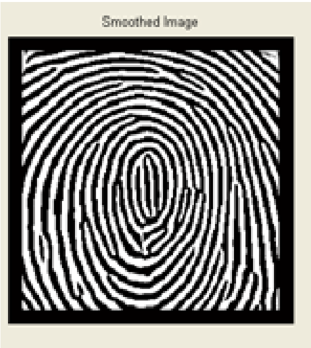

Fig. 4. Smoothed Image

D. Thinning

The final step in pre-processing is thinning before the extraction of minutiae. Thinning is a morphological operation that successively erodes away the foreground pixels until they are one pixel wide. A standard thinning algorithm is used, which performs the thinning operation using two sub iterations. The application of the thinning algorithm to a fingerprint image preserves the connectivity of the ridge structures while forming a skelectonized version of the binary image. This skeleton image is then used in the subsequent extraction of minutiae. After thinning there will be some spikes present in the binary image. These spikes are removed using directional smoothing.

Fig. 5 : Thinned Image

E. Minutiae Extraction Phase

The minutiae are extracted by scanning the local neighborhood of each ridge pixel in the image using a 3x3 window. The most commonly employed method of minutiae extraction is the Crossing Number concept. The CN value is then computed, which is defined as half the sum of the differences between pairs of adjacent pixels in the eight neighborhoods. Using the properties of the CN, the ridge pixel can then be classified as a ridge ending, bifurcation or non-minutiae point.[4]. For example, a ridge pixel with a CN of one corresponds to a ridge ending, and a CN of three corresponds to a bifurcation.

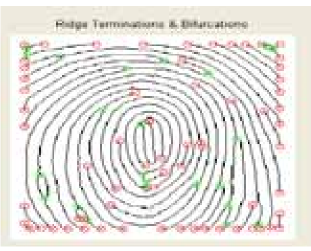

Fig. 6 : Bifurcation and termination.

F. Post processing phase:

This is required in order to remove the spurious minutiae. False minutiae may be introduced into the image due to factors such as noisy images, and image artifacts created by the thinning process. Hence, after the minutiae are extracted, it is necessary to employ a post processing stage[9] in order to validate the minutiae. A method known as distance computation that is based on certain heuristic rules is used to eliminate minutiae within certain threshold distance from each minutia to minimize the number of false minutiae. Furthermore, a boundary effect treatment is applied where the minutiae below a boundary distance of 8 from the boundary of the foreground region are deleted.

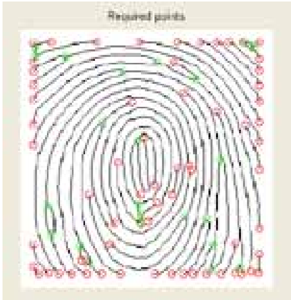

Fig.7 : Required Points

G. Region of Interest:

Two Morphological operations called 'OPEN' and 'ERODE' are adopted. The 'OPEN' operation can expand images and remove peaks introduced by background noise. The 'ERODE' removes pixels on object boundaries. An essential part of the erosion operation is the structuring element used to probe the input image. Two-dimensional, or flat, structuring elements consist of a matrix of 0's and 1's, typically much smaller than the image being processed. The center pixel of the structuring element, called the origin, identifies the pixel of interest, the pixel being processed. The pixels in the structuring element containing 1's define the neighborhood of the structuring element. These pixels are also considered in erosion processing.

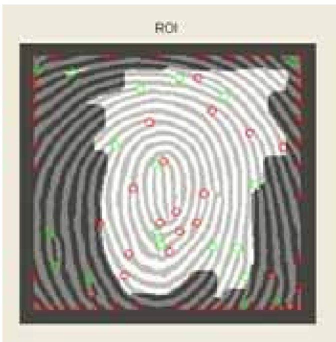

Fig. 8 : Region of Interest

H. Output Image:

After the ROI operation the output image is obtained. For the final post processing phase, we suppress the minutiae external to this ROI which are extreme minutiae. By doing so, we can get efficient number of termination and bifurcation for the fingerprint image. This step involves the extraction of fingerprint image features by discarding the false minutiae. After doing so this algorithm will provide the robustness for the fingerprint feature extraction algorithm.

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I. saving the Minutiae points.

The final step is to save the details of minutiae points. A text file is generated for the saving of calculated minutiae points and angle of the minutiae points. The crossing number concept is used for the calculation of bifurcation and the termination points in the fingerprint image. Then the second step is to calculate the angle of the minutiae points. The angle of the minutiae point is calculated corresponding to the neighboring pixels. The calculated minutiae point and the bifurcation points are then saved in the '*.txt' file.

Fig. 9 : Output image

IV. Experimental results

This feature extraction algorithm mentioned in paper has been tested on 102 images. Each image is of 500dpi (standard specified by the FBI).The parameters such as number of directions in the orientation field were determined by running the algorithm on set of test images. The performance of algorithm has been evaluated in terms of genuine acceptance rate(GAR),False acceptance rate(FAR) and false rejection rate(FRR).This has been shown in table 1.

Table 1: Genuine Acceptance Rate(GAR),False Acceptance Rate(FAR) And False Rejection Rate(FRR).

Common Minutiae(%)	Genuine acceptance rate(%)	False rejection rate(%)	False acceptance rate(%)
25	91.82	8.18	0
20	92.25	7.75	0
15	95.23	4.77	0

The performance evaluation has again been tested again in the terms of GAR ,FRR and FAR for various values of pixel distance.

Table 2: Performance Evaluation Again In The Terms of GAR, FRR And FAR For Various Values Of Pixel Distance.

Pixel Distance	GAR	FRR	FAR
7	97.2	2.8	0
8	98.1	1.9	0

V. Conclusion and future scope

This paper has combined many methods to build a minutia extractor. The combination of multiple methods comes from a wide investigation into research papers. Also some novel changes like orientation by changing the filter size and use of Morphological operations in region of interest. A New method for ridge smoothing has been developed.The investigation into filters whose primary focus is to do the enhancement. These approaches are less effective in enhancing areas containing minutiae points which are the areas of interest A further study into the statistical theory of fingerprint can be done. This can help us to better understand the statistical uniqueness of the fingerprint minutiae. The more refinement in the minutiae calculation can be done by improving the parameters in the algorithm which will help in the more accurate matching of the fingerprint images in the forensic applications.

The wall time for the execution of each step on Intel centrino duo PC:

Process	Time
Normalization	0.10 secs
Orientation	0.15 secs
Smoothening	0.17 secs
Thinning	0.05 secs
Minutiae calculation	0.08 secs
False minutiae removal	0.06 secs
Region of interest calculation	0.04 secs
Output image	0.05 secs.

References

[1] C. Mares ,M. Sepasian, W. Balachandran," Image Enhancement for Fingerprint Minutiae-Based Algorithms Using CLAHE, Standard Deviation Analysis and Sliding Neighborhood", Proceedings of The World Congress on Engineering and Computer Science 2008, pp1199-1203.

[2] Chikkerur,"online fingerprint verification system", Digital Electronics Letters Vol 3, No. 27, 2005, pp.:296 – 298.

[3] D. Suter, A. Bab-Hadiashar , "Fingerprint Segmentation using the Phase of Multiscale Gabor Wavelets", Proceedings of the Fifth Asian Conference on Computer Vision, 2002, pp.27-32.

[4] Espinosa Duro , V. "Minutiae Detection Algorithm for Fingerprint Recognition", Polytechnic University of Catalonia, Electronic and Automatic Department, IEEE 2001, pp. 264-266.

[5] Hastings, Robert,"Ridge Enhancement in Fingerprint Images Using Oriented Diffusion", Digital Image Computing Techniques and Applications, 9th Biennial Conference of the Australian Pattern Recognition Society on Vol 3, No.5,2007, pp.245 – 252.

[6] Hong. L., Jain Anil,Yifei wan, "Fingerprint image enhancement:algorithm and performance" ,IEEE tansactions on pattern analysis and machine intelligence, Vol. 20 no.8, 1998, pp.777-789.

[7] Hong-cai Zhang., Miao-li,"A Gabor filter based fingerprint enhancement algorithm in wavelet domain" . IEEE Conference 2005, pp 1205-1214.

[8] Jain Anil, Maltoni David, Maio Dario, "The Handbook of fingerprint recognisation" Fourth Edition, CRC Press. Security Technical Report, Vol. 3, No. 1, 2006.

[9] Lu, H., Jiang, X, Yau Wei-Yun, "Effective and Efficient Fingerprint Image Post processing", 7th International Conference on Control, Automation, Robotics and Vision (ICARCV), Vol. 2, 2002, pp. 985-989.

[10] Paul, A.M.; Lourde, R.M,"A Study on Image Enhancement Techniques for Fingerprint Identification", Video and Signal Based Surveillance, 2006. AVSS apos;06.IEEEInternational Conference,Vol.5 , No.456, 2006, pp.16 – 20.

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