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Fingerprint Feature Extraction

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Abstract*—-Matching is the basic mechanism of operation which is used in most of the Fingerprint Recognition Systems. But the process used to deal with the poor quality fingerprint impression in this technology is still associated with a lot of problems. For a better extraction of minutiae points, the quality of fingerprint image must be good. So, for better and reliable extraction of minutiae points, image enhancement techniques are employed prior to minutiae extraction for obtaining a more reliable estimate of minutiae points. This paper will focus on presenting a whole process used for extraction of fingerprint features for minutiae matching.

Index Terms— Fingerprint, Minutiae , Fingerprint Recognition, Image Enhancement, Minutiae Extraction.

I. INTRODUCTION

Biometric Recognition is the method of identification of a person on the basis of distinctive physiological traits such as fingerprints, face, retina, iris etc or behavioral traits such as gait and signature characteristics. Every person has unique physiological and behavioral characteristics, so biometrics is more reliable in verifying identity than token-based or knowledge based techniques. Among all the biometrics, fingerprint recognition is the most reliable and promising person identification technology. The uniqueness of fingerprint has been studied and the probability of two fingerprints being alike is 1 in 1.9 x $10^{15.}$ In biometric process of finger scanning, a point where ridge ends abruptly is called ridge ending and a point where ridge forks into branches is called ridge bifurcation. These are usually called minutiae and are prominent structures used in fingerprint identification system.

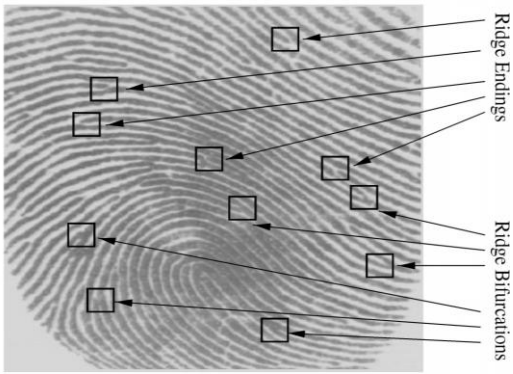

Fig 1: Ridge Ending and Ridge Bifurcation

Categorization of fingerprints can be done on the basis of their global pattern of ridges and valleys. According to Henry Classification there are eight categories, examples of which are shown in the Fig (2) below:

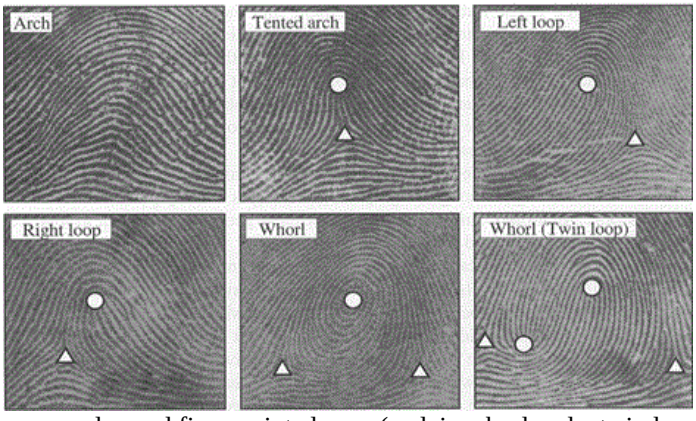

Fig 2: The five commonly used fingerprint classes (a plain whorl and a twin loop , respectively)

II. PROPOSED METHODOLY

The proposed system firstly acquires the fingerprint image. The fingerprint image should be viewed as a flow pattern with definite texture. The input image is divided into equal size blocks and then each block is processed independently. Maximum variance is provided by the grey level projection along a line perpendicular to the local orientation field. Using the peaks and variance locate the ridges in this projection. These ridges are then thinned and the resulting skeleton image is enhanced using a filter. The overall process can be divided into following operations-

- Load the image
- Normalization and Segmentation
- Orientation Estimation
- Ridge segmentation and smoothing
- Binarization
- Thinning
- Feature Extraction

III. LOAD THE IMAGE

Image acquisition is the first step in this approach. A fingerprint image may be classified as offline or live-scan on the basis of mode of acquisition. An offline image is typically obtained by smearing ink on the fingertip and creating an inked impression of the fingertip on the paper .The live scan image of a fingerprint is acquired by the help of a sensor which will sense the tip of the finger directly and digitize the fingerprint on contact [3].

Fig 3: Input Image

IV. SEGMENTATION AND NORMALIZATION

The process of separation of foreground region in the fingerprint image from the background regions is called Segmentation. The clear fingerprint area which contains the ridges and valleys and which is the area of interest is called the foreground region of fingerprint image. Region outside the borders of the fingerprint area, which does not contain any valid information is called background region. The background as a noisy region is also a causing factor for the extraction of false minutiae in the system. The variance value of foreground regions of fingerprint image is high while that of background region is low.

The image is divided into blocks. The gray scale variance is calculated for each block. If the variance is less than the global threshold, then block is assigned to the background region else it is assigned to the foreground region.

For a block of size WxW ,let the variance be V(k),then

$$V(k) = 1/W^2 \sum_{i=0}^{W-1} \sum_{j=0}^{W-1} (I(i,j) - M(k))^2$$

Where I(i,j) is the gray scale value at pixel (i,j) and M(k) is the mean gray value.

Normalization is performed on the segmented fingerprint image ridge structure so as to standardise the intensity values in an image by adjusting the gray level value range, so that it lies in a desired range of values. Let the grey level value at a pixel (i,j) be represented by I(i,j) and the normalized value by represented by N(i,j)**.** Then the normalized image is given by

$$N(i,j) = \begin{cases} M_0 + \dfrac{\sqrt{V_0 (I(i,j) - M)^2}}{V} \\ M_0 - \dfrac{\sqrt{V_0 (I(i,j) - M)^2}}{V} \end{cases}$$

Where M and N are the estimated mean and variance for a pixel I(i,j) and M_o and N_o are the desired mean and variance. Normalization is done to improve the contrast between ridges and valleys. Here the shape of original histogram is not altered. It standardizes the dynamic level of variation in the grey level values.

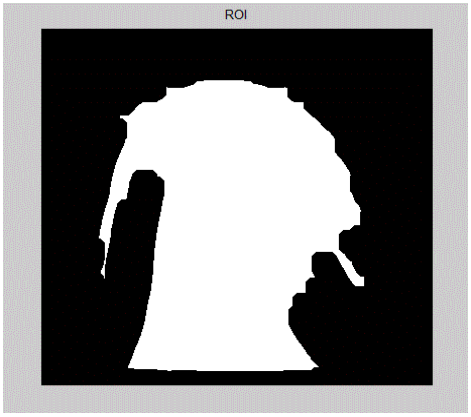

Fig 4 : Region of interest

Fig 5: Normalized Image

V. ORIENTATION ESTIMATION

The orientation image depicts the intrinsic property of fingerprint images and defines invariant coordinates for ridges and valleys in a local neighborhood. It is a matrix of direction vectors. The main steps for calculation of orient direction from normalized image are:

- Divide the image into WxW size blocks.
- Gradients in horizontal and vertical directions are found.
- By finding principal axis of variation in image gradients , compute the local orientation at each pixel using the following equations-

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

$$V_y(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} \left(\partial^2{}_x(u,v)\partial^2{}_y(u,v)\right),$$

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

Where $\theta(i,j)$ is the least square estimate of the local ridge orientation at a block centered at pixel(i,j).

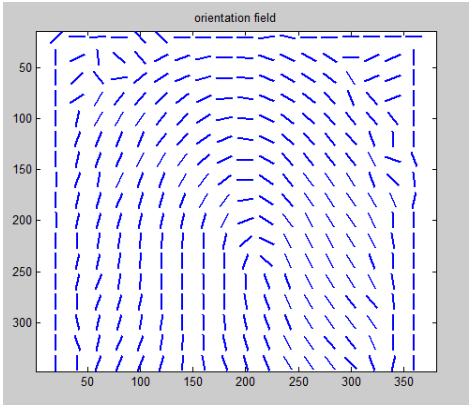

Fig 6: Direction Map

VI. RIDGE FREQUENCY ESTIMATION

The local ridge frequency f_{xy} at a point(x,y) is number of ridges per unit length along a hypothetical segment. Let G be the normalized image and O be the orientation image, then the steps involved in local ridge frequency estimation are as follows:

- Divide G into blocks of size WxW.
- For all the pixels located inside each block project the grey level values along a direction orthogonal to the local ridge orientation.
- Almost a sinusoidal shape with local minimum points corresponding to ridges is formed in this projection.

Ridge spacing is given by counting the number of pixels between consecutive minima points in the projected waveform. Ridge Spacing is denoted by R(i,j).Then the ridge frequency F(i,j) is given by-

F(i,j)=1/R(i,j)

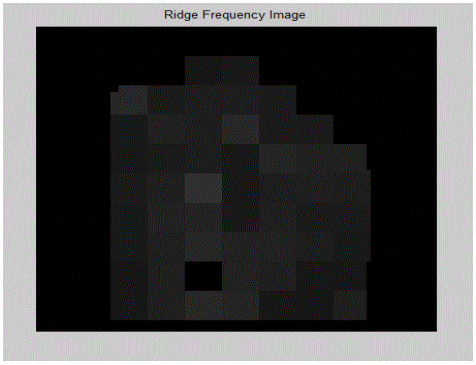

Fig 7 : Ridge Frequency Image

VII. FILTERING

Filtering is done to enhance ridge pattern. Gabor filter is a linear filter used for edge detection. These filters have frequency selective and orientation selective properties which allow the filter to be tuned to maximal response to ridges at a specific orientation and frequency in the fingerprint image.

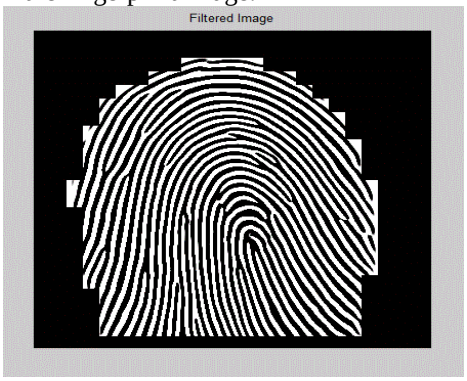

Fig 8 : Filtered Image

VIII. BINARIZATION

Binarization is used to convert grey scale enhanced fingerprint image into binary form, where all black pixels correspond to ridges and all white pixels correspond to valleys [4]. Hence the contrast between the ridges and valleys gets improved. During the binarization process the grey level value of each pixel is analyzed. If the value is greater than the global threshold then the pixel value is set to 1 otherwise it is set to 0.

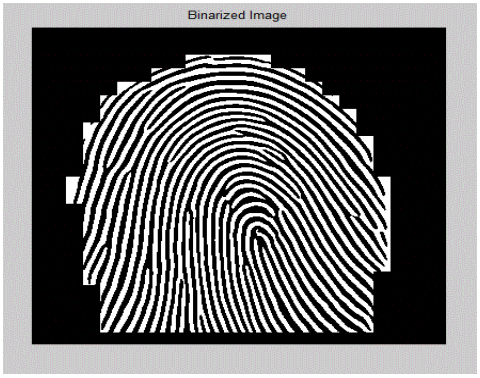

Fig 9 : Binarized Image

IX. THINNING

Thinning is a morphological operation that successively erodes away the foreground pixels until they are one pixel wide .It is performed prior to minutiae marking. It is done by MATLAB's thinning function-

bwmorph(binary_image,'thin',Inf)

The requirements of a good thinning algorithm are-

- The thinned fingerprint image obtained should be of single width.
- Thinning of each ridge must be done to its centre pixel.
- Noise and singular pixels must be removed.

The thinned image is then filtered by removing hbreaks, spikes and isolated points.

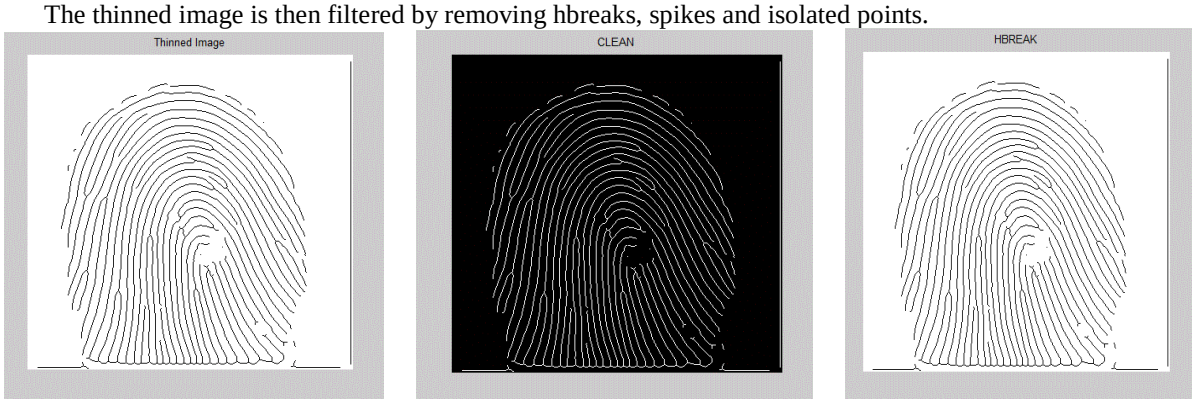

Fig 10: (a)Thinned Image (b) Image after removing isolated pixels (c) Image after removing hbreak

X. FEATURE EXTRACTION

Our next step is to perform minutiae extraction from a perfectly thinned ridge map of a fingerprint image. All we need to do is to count the number of ridge pixels ,every ridge pixel on the thinned image is surrounded by and depending upon the following rule we can assign the minutiae points to those pixels[5].

In a 3x3 window ,if the central pixel is 1 and has exactly 3 one-valued neighbor, then the cental pixel is a ridge branch or bifurcation. i.e. Cn(p)=3 for a pixel P.

In a 3x3 window ,if the central pixel is 1 and has only 1 one-valued neighbor, then the cental pixel is a ridge ending or termination. i.e. Cn(p)=1 for a pixel P.

An exceptional case may arise where a branch may be triple counted. If the value of both uppermost pixel is 1 and the value of lowermost pixel is also 1 and also it has another neighbor outside the 3x3 window dur to some left over spikes , then the two pixels will be marked as branches too. But actually only one branch is located in the small region. Generally this case is very rare.

0	1	0
0	1	0
1	0	1

Bifurcation

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0	0	0
0	1	0
0	0	1

Termination

0	1	0
0	1	1
1	0	0

Triple Counting Branch

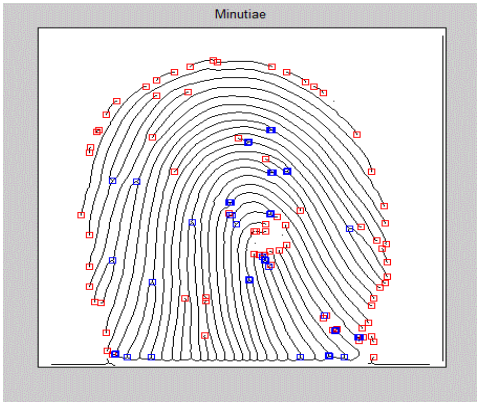

Fig 11: Minutiae

XI. CONCLUSION

The precision of the minutiae extraction algorithm is the most significant contributing factor in reliability of any automatic fingerprint system. There are number of factors which can produce critical damage during correct location of minutiae. The most significant factor which can produce the largest damage in minutiae location process is the poor quality of fingerprint impression. The proposed RE algorithm properly maintains natural shape of gray level ridges and precise locations of minutiae. The proposed algorithm has been used on a variety of fingerprint images with very satisfactory results. By improvement in the hardware which has been used for capturing the fingerprint impression or by using image enhancement process the quality and accuracy of the fingerprint can be improved. Quality of fingerprint image is improved before thinning process so we can get better outcome in the end.

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