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Designing of Fingerprint Enhancement Based on Curved Region Based Ridge Frequency Estimation

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***Abstract*— Fingerprint enhancement algorithm is used to improve the clarity of ridges and valleys of input fingerprint images. These kind of algorithm make them more suitable for the minutiae extraction algorithm. The ultimate criterion for evaluating such an enhancement algorithm is the total amount of "quality" improvement when the algorithm is applied to the noisy input fingerprint images. There are various biometric features for personal identification but Fingerprints are today the most widely used biometric features for the same. Many automatic systems are there for fingerprint enhancement which is based on ridges and valleys. Automatic fingerprint recognition system is totally based on Fingerprint enhancement. It is necessary to choose the suitable enhancement technique for fingerprint, in order to reduce the post-processing part of the fingerprint recognition system. Different Fingerprint Enhancement techniques have been implemented in the past. These different methods are used by which the image quality is enhanced and Fingerprint Matching techniques are applied. These algorithms contribute to recognize the person and provide authenticity on the basis of physiological or behavioral characteristic possessed by the user. There is a need to develop a system that can be used for fingerprint verification through extracting and matching minutiae in an efficient manner. To achieve good minutiae, initially, extraction is done in fingerprints with varying quality, then preprocessing in form of image enhancement. A fast fingerprint enhancement algorithm, which can adaptively improve the clarity of ridge and valley structures of input fingerprint images based on Curved Region Based Ridge Frequency Estimation, is be implemented. The implementation work is done using MATLAB R2008a, as an implementation platform.**

***Keywords*— Enhancement, Fingerprint, Ridges ,Valleys.**

I. INTRODUCTION

Skin on human fingertips contains ridges and valleys which together forms distinctive patterns. These patterns are fully developed under pregnancy and are permanent throughout whole lifetime. Prints of those patterns are called fingerprints. Injuries like cuts, burns and bruises can temporarily damage quality of fingerprints but when fully healed, patterns will be restored. Through various studies it has been observed that no two persons have the same fingerprints, hence they are unique for every individual [1].

Fig. 1 A fingerprint image obtained by optical sensor

Due to the above mentioned properties, fingerprints are very popular as biometrics measurements. Especially, in law enforcement, where they have been used over a hundred years to help solve crime, unfortunately fingerprint matching is a complex pattern recognition problem. Manual fingerprint matching is not only time consuming but education and training of experts takes a long time. Therefore since 1960s there have been done a lot of effort on development of automatic fingerprint recognition systems. Automation of the fingerprint recognition process turned out to be success in forensic applications.

Achievements made in forensic area expanded the usage of the automatic fingerprint recognition into the civilian applications. Fingerprints have remarkable permanency and individuality over the time. The observations showed that the fingerprints offer more secure and reliable person identification than keys, passwords or id-cards can provide. Examples such as mobile phones and computers equipped with fingerprint sensing devices for fingerprint based password protection are being produced to replace ordinary password protection methods. Those are only a fraction of civilian applications where fingerprints can be used [1].

The method that is selected for fingerprint matching was first discovered by Sir Francis Galton. In 1888 he observed that fingerprints are rich in details also called minutiae in form of discontinuities in ridges. He also noticed that position of those minutiae doesn't change over the time. Therefore minutiae matching are a good way to establish if two fingerprints are from the same person or not.

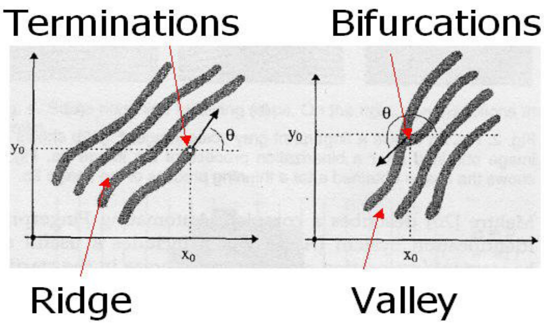

Fig. 2 Minutias. (valley is also referred as furrow, termination is also called ending and bifurcation is called branch)

The two most important minutiae are termination and bifurcation, termination, which is the immediate ending of a ridge; the other is called bifurcation, which is the point on the ridge from which two branches derive. The fingerprint recognition problem can be grouped into two sub-domains: one is fingerprint verification and the other is fingerprint identification.

A. *Fingerprint Enhancement Techniques*

A critical step in Automatic Fingerprint matching system is to automatically and reliably extract minutiae from input finger print images. However the performance of the Minutiae extraction algorithm relies heavily on the quality of the input fingerprint image. In order to ensure to extract the true minutiae points it is essential to incorporate the enhancement algorithm.

There are two ways in which author can enhance the input fingerprint image.

1) Binarization Method: The ridge structures in fingerprint image are not always well defined, and therefore, an enhancement algorithm is needed to improve the clarity of the ridge and valley structure. The first method of enhancement algorithm is Binarization-based fingerprint image enhancement. This process is carried out using Local Histogram Equalization, Weiner filtering, and image Binarization. Author use local Histogram equalization for contrast expansion and wiener filtering for noise reduction. The binarization process is applied by adaptive thresholding based on the local intensity mean. Finally Morphological filtering is applied to eliminate artifacts in the noise regions and to fill some gaps in valid ridgelines.

In some Binarization-based approaches the Binarization and thinning process are preceded by a smoothing operation, based on convolution with a Gaussian mask, in order to regularize the starting image. The main stages in this algorithm include the following:

i)Histogram equalization defines a mapping of gray-levels into gray levels such that the distribution of gray level is uniform. This mapping stretches the contrast (expands the range of gray levels) for gray levels near the histogram maxima. Histogram equalization is done by using a local window of 11X 11 pixels. This results in expanding the contrast locally, and changing the intensity of each pixel according to its local neighbourhood.

ii)Wiener method is used for noise reduction. In this pixels-wise adaptive Wiener Filtering is carried out. The filter is based on local statistics estimated from a local neighborhood η of size 3X3 of each pixel.

iii)The operation that converts a grayscale image into a binary image is known as Binarization. Binarization process is carried out using an adaptive thresholding. Each pixel is assigned a new value (0 or 1) according to the intensity mean in local neighborhood. Thinned (one pixel thickness) ridge lines are obtained using morphological thinning operation.

iv)In the thinned binary image there appears noise like: False fridge line and gaps within a true ridge lines. The false ridgeline connections are almost perpendicular to local ridge direction. Therefore, lines with similar features are automatically removed by the post-processing and binary filtering.

B. *Basic Algorithm*

In this section, the methodology for each stage of the enhancement algorithm, including any modifications that have been made to the original techniques, has been discussed.

1) *Normalization:* The first step in the fingerprint enhancement process is image normalization. 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.

Let I(i,j) represent the grey-level value at pixel (i,j) and N (i,j) represent the normalized grey-level value at pixel (i,j). The normalized image is defined as:

$$G(i,j) = \begin{cases} M_0 + \sqrt{\dfrac{VAR_0(I(i,j) - M)^2}{VAR}} & if\ I(i,j) > M \\ M_0 - \sqrt{\dfrac{VAR_0(I(i,j) - M)^2}{VAR}} & otherwise \end{cases}$$

Where M and V are the estimated mean and variance of I (i, j), respectively, and M0 and V0 are the desired mean and variance values, respectively. Normalization does not change the ridge structures in a fingerprint; it is performed to standardize the dynamic levels of variation in grey-level values, which facilitates the processing of subsequent image enhancement stages.

2) Orientation estimation:

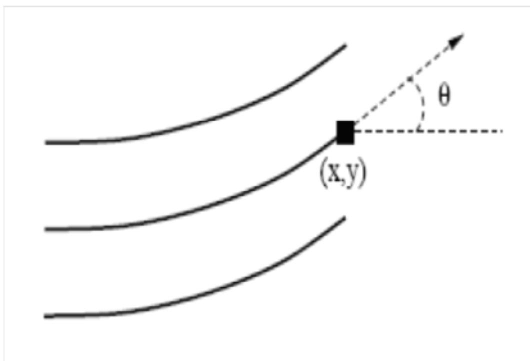

Fig. 3 The orientation of a ridge pixel in a fingerprint.

The orientation field of a fingerprint image defines the local orientation of the ridges contained in the fingerprint (see Figure 3). The orientation estimation is a fundamental step in the enhancement process as the subsequent Gabor filtering stage relies on the local orientation in order to effectively enhance the fingerprint image. The least mean square estimation method employed by Hong et al. [6] is used to compute the orientation image. However, instead of estimating the orientation block-wise, pixel-wise scheme, which produces a finer and more accurate estimation of the orientation field, is chosen in proposed method.

The steps for calculating the orientation at pixel(i, j) are as follows:

i) Firstly, a block of size W x W is centered at pixel (i, j) in the normalized fingerprint image.

ii) For each pixel in the block, compute the gradients ∂x(i, j) and ∂y(i, j), which are the gradient magnitudes in the x and y directions, respectively. The horizontal Sobel operator is used to compute ∂x(i, j) :

$$\begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix}$$

The vertical Sobel operator is used to compute ∂y(i, j) :

$$\begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix}$$

The local orientation at pixel (i, j) can then be estimated using the following:

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

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

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

Where θ(i, j) is the least square estimate of the local orientation at the block centered at pixel(i, j).

iii) Smooth the orientation field in a local neighbourhood using a Gaussian filter. The orientation image is firstly converted into a continuous vector field, which is defined as:

$$\emptyset_x(i,j) = \cos\big(2\theta(i,j)\big)$$

$$\emptyset_y(i,j) = \sin\big(2\theta(i,j)\big)$$

iv) Where φx and φy are the x and y components of the vector field, respectively. After the vector field has been computed, Gaussian smoothing is then performed as follows:

$$\emptyset'_x(i,j) = \sum_{u=-w_\emptyset/2}^{w_\emptyset/2} \sum_{v=-w_\emptyset/2}^{w_\emptyset/2} W(u,v)\emptyset_x(i-uw, j-vw)$$

$$\emptyset'_y(i,j) = \sum_{u=-w_\emptyset/2}^{w_\emptyset/2} \sum_{v=-w_\emptyset/2}^{w_\emptyset/2} W(u,v)\emptyset_y(i-uw, j-vw)$$

v) The final smoothed orientation field O at pixel (i,j) is defined as:

$$O(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{\emptyset'_y(i,j)}{\emptyset'_x(i,j)}\right)$$

3) *Ridge frequency estimation:* In addition to the orientation image, another important parameter that is used in the construction of the Gabor filter is the local ridge frequency. The frequency image represents the local frequency of the ridges in a fingerprint. The first step in the frequency estimation stage is to divide the image into blocks of size W x W. The next step is to project the grey-level values of all the pixels located inside each block along a direction orthogonal to the local ridge orientation. This projection forms an almost sinusoidal-shape wave with the local minimum points corresponding to the ridges in the fingerprint. An example of a projected waveform is shown in Figure 4.

The original frequency estimation stage used by Hong et al. [6] is modified by including an additional projection smoothing step prior to computing the ridge spacing. This involves smoothing the projected waveform using a Gaussian low pass filter of size w x w to reduce the effect of noise in the projection. The ridge spacing S is then computed by counting the median number of pixels between consecutive minima points in the projected waveform. Hence, the ridge frequency F for a block centered at pixel is defined as:

$$F(i,j) = 1/\,S(i,j)$$

Given that the fingerprint is scanned at a fixed resolution, then ideally the ridge frequency values should lie within a certain range. However, there are cases where a valid frequency value cannot be reliably obtained from the projection. Examples are when no consecutive peaks can be detected from the projection, and also when minutiae points appear in the block. For the blocks where minutiae points appear, the projected waveform does not produce a well-defined sinusoidal shape wave, which can lead to an inaccurate estimation of the ridge frequency. Thus, the out of range frequency values are interpolated using values from neighboring blocks that have a well-defined frequency.

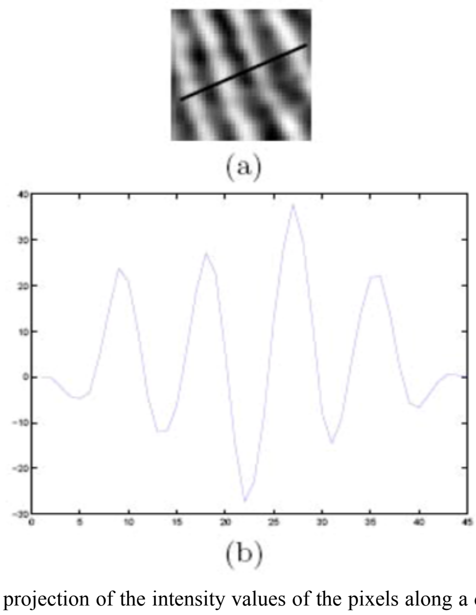

Fig 4: The projection of the intensity values of the pixels along a direction orthogonal to the local ridge orientation. (a) A 32 x 32 block from a fingerprint image. (b) The projected waveform of the block

II. PAGE LAYOUT

A) Pre-processing

Reading of input finger print image and conversion in to gray scale image.

B) Normalization

1) Initialization of input parameter for normalization of gray image
2) Required mean
3) Variance value
4) Normalization of gray-scale image using above mentioned parameters so that it could have zero mean and one standard deviation.
5) Calculation of image gradients.

C) Orientation Estimation

Estimate the local ridge orientation at each point by finding the principal axis of variation in the image gradients.

Estimation of Ridge frequency

1) Initialization of parameters for estimation of ridge frequency.
2) Size of window
3) Size of block
4) Minimum and maximum wavelength
5) Consideration of blocks in the normalized image and determining a ridge count within each block.
6) Getting of median ridge frequency.

D) Final Filtration

1) Initialization of two input parameters, so as to use them in designing of filter to enhance the ridge image.
2) bandwidth control
3) orientation control,
4) Application of ridge filter with the help of above mentioned parameters and median frequency.

E) Post processing

Binarization of new enhanced ridge image.

Display binary normalized image for where the values are one.

III. EXPERIMENTAL RESULTS

Fingerprint enhancement improves the ridge and valley structure of input fingerprint image. These improvements can be analyzed subjectively by a visual inspection of a number of typical enhancement results. Examples of the enhancement results are shown in Figures below. From these figures, it can be seen that proposed enhancement algorithm does improve the clarity of the ridge and valley structures of input fingerprint images. An image left.jpeg has been taken for implementation purpose shown in fig. 5. After that, normalized image is calculated shown in fig 6. After that, filtered and enhanced image is shown in fig.7 followed by binary masked normalized image shown in fig.8.

Fig 5: Input finger print image

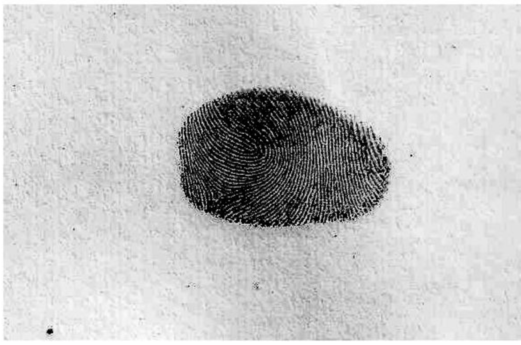

Fig 6: normalized image

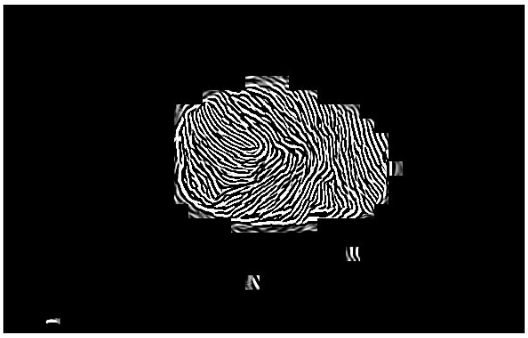

Fig 7: snap-shot of enhanced normalized ridge image

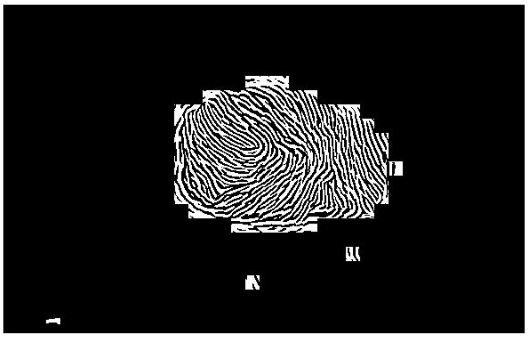

Fig 8: binary masked enhanced image

IV. CONCLUSIONS

Experimental results show that our enhancement algorithm is capable of improving the ridge and valley structure. The algorithm also identifies the unrecoverable corrupted regions in the fingerprint and removes them from further processing. This work has described a method for RF estimation using curved regions and image enhancement by filters. For low-quality fingerprint images, in comparison with existing enhancement methods, improvements of the performance have been shown. The experimental results show that the proposed scheme is able to handle various input contexts and achieves the best performance in combination with existing verification algorithms. It is noted that the operation has been performed on MATLAB platform in our simulation. The future works related to this paper are as follows. Pixel processing could be used instead of block processing to reduce the computation complexity, and try to improve the speed of the proposed method.

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