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.

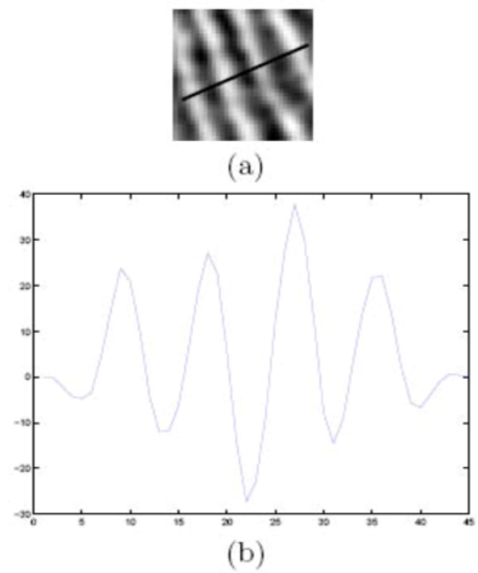


Fig 4: The projection of the intensity values of the pixels along a direction orthogonal to the local ridge orientation. (a) A 32 x 32 block from a fingerprint image. (b) The projected waveform of the block

## 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

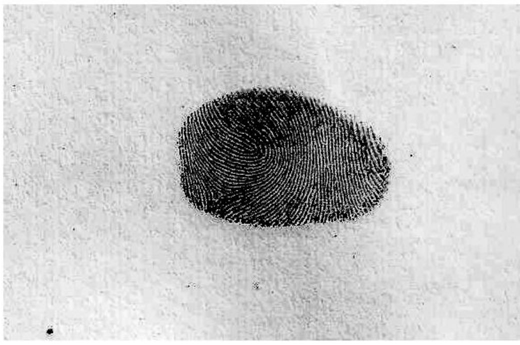

Fig 6: normalized image

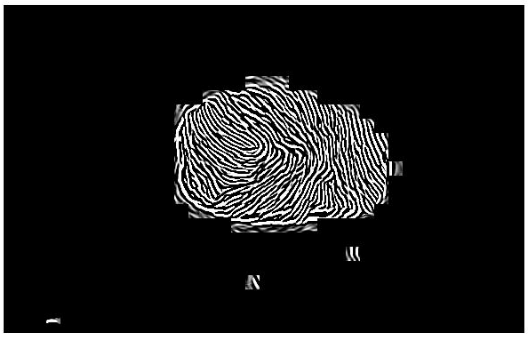

Fig 7: snap-shot of enhanced normalized ridge image

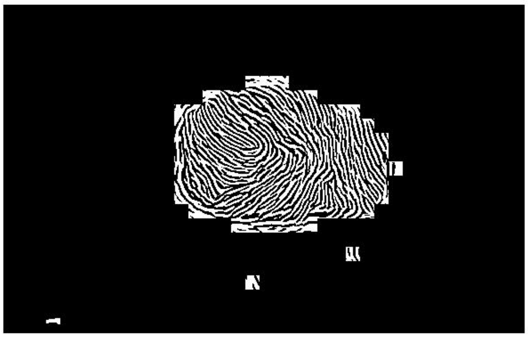

Fig 8: binary masked enhanced image

## 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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