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Quality Improvement by Enhancement Techniques (QIET) on Low Quality Fingerprint Image

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Abstract- ***Fingerprints are mostly used in the form of biometric identification. A fingerprint Image may not always be in well condition due to noise that corrupts the clarity of ridges structure or basic information, which is required for fingerprint recognition. Here the QIET enhance the global and local features of fingerprints using the spatial and frequency domain technique. This proposed work has been used FFT to clear the shapes of the ridges of fingerprint images using a particular enhancement level according to the quality of images, and CLAHE also an enhancement technique, which makes ridges clear according to clip limit values. Here we use Morphology based technique used to find the Real Minutia points from the fingerprint image, and to remove the false minutia points of a fingerprint image. These set of operation applied on the FVC 2002 database images to improve the quality of fingerprint images. These methods show some improvements in the fingerprint image enhancement process in terms of efficiency or time required.***

Index Terms- **Ridge FFT filter, CLAHE for contrast enhancement, Minutiae extraction, Threshold rule, Remove False Minutiae.**

I. INTRODUCTION

A fingerprint is an impression of the ridges and valleys in the inner surface of a human finger or a thumb. The fingerprint of an individual is unique and remains unchanged over a lifetime. A fingerprint is formed from an impression of the pattern of ridges on a finger [4]. A ridge is defined as a single curved segment, and a valley is the region between two adjacent ridges. The minutiae, which are the local discontinuities in the ridge flow pattern, provide the features that are used for identification. Details such as type, orientation, and location of minutiae are taken into account when performing minutiae extraction [1].

A. Fingerprint Features

Fingerprint features can be classified into three classes [12].

Level 1 Show the global features (ridges flow shape).

Level 2 Features (minutiae point) are discriminative enough for recognition.

Level 3 Features (pores) complement the uniqueness of level 2 features.

a. Global Ridge Pattern

A fingerprint is a pattern of ridges and valleys with a spiral-curve-like line shape. There are two types of ridges flows: the pseudo- parallel ridges flows and high-curvature ridges flows which are located around the core point or delta point.

b. Singular Points

A core is uppermost of the innermost curving ridge, and a delta point is the junction point (Fig 1) [13], where three ridge flows meet. They are usually used for fingerprint registration and classification.

C. Local Ridge Pattern

Local ridge details are the discontinuities of local ridges structure referred to as minutiae (Fig 2) [16]. Sir Francis Galton was the first person who observed the structures and permanence of minutiae. Therefore, minutiae are also called "Galton details". They are used by forensic expert to match two fingerprints.

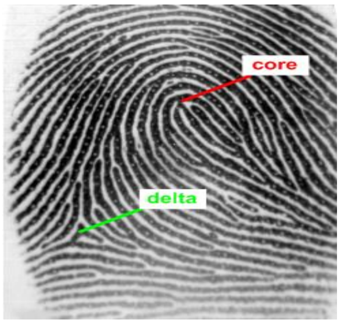

Fig 1: Singular Points Denote Core and Deltas and Ridge Bifurcation

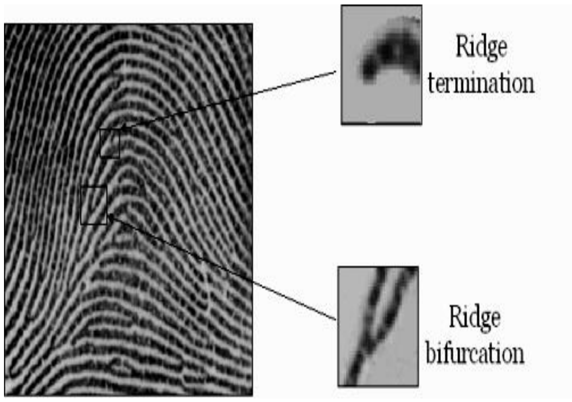

Fig 2: Example of Ridge Termination

II. THE PROPOSED METHOD

This proposed method used to reconstruct the fingerprint's orientation field and breaking ridges in Fingerprint images and also for minutiae extraction.

A. Enhancement Segment

a. Normalization:

In image processing, **normalization** is a process that changes the range of pixel intensity values [19]. In more general fields of data processing, such as digital signal processing, it is referred to as dynamic range expansion [17]. The given following equation is:

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$$S_k = T(r_k) = \sum_{j=1}^{k} P_r(r_j) = \sum_{j=1}^{k} \frac{n_j}{n} \qquad (1)$$

Where S_k is the intensity value in the processed image corresponding to r_k in the input image, and $P_r(r_j)$=1, 2, 3... L is the input fingerprint image intensity level.

b. Ridge Enhancement:

Here we enhance the ridges of a fingerprint image using the Fast Fourier Transform Filter [3].

***Step 1*:** We divide the image into small blocks of 16 by 16 pixels.

Step 2: And apply Fourier transform on each blocks using the equation [10]:

$$p(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp\left\{-j2\pi \times \left(\frac{ux}{M}+\frac{vy}{N}\right)\right\}$$

(2)

For u=0,1,2,3,….,15 and v=0,1,2,3,…...15 in order to Enhance a specific block by its dominant frequencies.

***Step 3*:** We multiply the FFT of the block by its magnitude a set of times. Where the magnitude of the original is:

$$FFT = abs\left(F(u,v)\right) = |F(u,v)| \qquad (3)$$

Step 4: And enhance the blocks according to:

$$g(x,y) = F^{-1}\{F(u,v) \times |F(u,v)|^{K}\} \qquad (4)$$

Step 5: Where $F^{-1}F(u,v)$ is done by:

$$f(x,y) = \frac{1}{MN} p(u,v) \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(u,v) \times exp\left\{j2\pi \times \left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \qquad (5)$$

For x = 0, 1, 2, ..., 15 and y = 0, 1, 2, ……, 15. The k in equation (4) is an enhancement factor, where we set k=0.45 to enhance the image. We can use "k" higher to improve the appearance of the ridges and valleys and to filling up small holes in ridges, if we use too high "k" then results may be false joining of ridges.

c. Contrast Enhancement

After Ridge enhancement, apply the CLAHE on fingerprint image. Contrast Limited Adaptive Histogram Equalization is used to enhance the contrast of the small tiles of an image and to combine the neighboring tiles using a bilinear interpolation which will eliminate the artificially induced boundaries [11].

Step 1: Obtain all input Regions, Dynamic range and Clip Limit.

Step 2: Process the input.

Step 3: Process each Contextual Region Producing Gray Level Mapping.

Step 4: Interpolate gray level mapping in order to assemble final image.

B. Minutiae Extraction

This Morphology Technique based on mathematical morphology (Fig 3) [2]. They process the image to reduce the effort in the post processing of the image with morphological operators to remove spurious points etc.

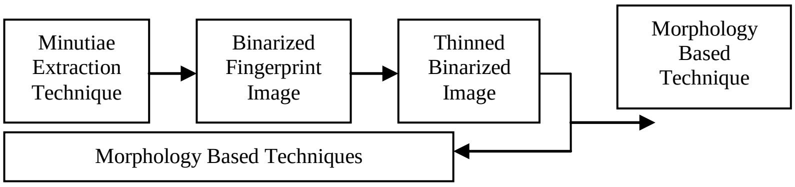

Fig 3: Minutiae Extraction Technique

a. Convert into Binary Image

To convert 8-bit Gray fingerprint image into 1-bit image with 0-value for ridges and 1- value for valleys we use binarization [4]. After converting the image into binary, ridges in the fingerprint are highlighted with black color while valleys are highlighted with white [9]. The Threshold rule is used to convert the gray image into Binary image. If the value of pixel is larger than the threshold value of the current block (16×16) to which the pixel belongs then transform the pixel value to 1.

b. Convert into Thinned Image

Ridge Thinning is used to make the ridges are just one pixel wide [15]. Here we use a one-in-all method to extract thinned ridges from a binary fingerprint images directly [7]. Here we used the built-in Morphological thinning function in MATLAB. The thinned ridge filtered by other Morphological operations to remove some H breaks and spikes.

c. Segmentation Using Direction Block Estimation

Region of Interest (ROI) is useful to be recognized for each fingerprint image [6]. The image area without effective ridges and furrows is first discarded then the bound of the remaining effective area is sketched out. Since the minutiae points in the bound regions are confusing with those spurious minutiae that are generated when the ridges are out of the sensor. To extract the ROI, we use two-step method. The first step is block direction estimation [9] and direction variety check while in second step we use some Morphological methods.

Step 1: Estimate the block direction for each block of the fingerprint image with WxW (W is 16 pixels by default).The algorithm is:

a) Firstly we calculate the gradient values along x-direction (g_x) and y-direction (g_y) for each pixel of the block. And two Sobel filters are used to fulfill the task.

b) For each block, to get the Least Square approximation of the block direction.

$$tg2ß = 2 \Sigma \Sigma (g_x * g_y)/\Sigma \Sigma (g_x^2 - g_y^2) \qquad (6)$$

For all the pixels in each block. Here we use the gradient values along x-direction and y-direction as cosine value and sine value. So the tangent value of the block direction is estimated by using this formula.

$$tg2\theta = 2\sin\theta \cos\theta \,/\, (\cos 2\theta - \sin 2\theta) \qquad (7)$$

Step 2: After finished the step 1 estimation of each block direction:

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a) Those blocks without significant information on ridges and furrows are discarded based on the following formulas

$$E = \{2\sum\sum(g_x * g_y) + \sum\sum(g_x^2 - g_y^2:)\}/W * W * \sum\sum(g_x^2 + g_y^2) \quad (8)$$

For each block, if blocks certainty level E is below the threshold, then the block is regarded as a background block.

b) ROI extraction is done by Two Morphological operations called "OPEN" and "CLOSE". The "OPEN" operation can expand images and the "CLOSE" operation can shrink images and eliminate small cavities. The bound is the subtraction of the closed area from the opened area. Then the algorithm throws away those leftmost, rightmost, uppermost and bottommost blocks out of the bound.

d. Minutiae Points Extraction

Here firstly we divide the image into 3x3 size window, then to find the Minutiae point we check for these conditions.

a) If the central pixel is 1 and has exactly 3 one-value neighbors, then the central pixel is a ridge branch.

b) If the central pixel is 1 and has only 1 one-value neighbor, then the central pixel is a ridge ending.

c) Here is also a special case that a genuine branch, triple counted. Suppose both the uppermost pixel with value 1 and the rightmost pixel with value 1 have another neighbor outside the 3x3 window, so the two pixels will be marked as branches too.

The average inter-ridge width D is also estimated at this stage. The average inter-ridge width refers to the average distance between two neighboring ridges. The method to calculate the D is:

Step 1: Scan complete row of the thinned ridge image and after this sum up all pixel of the row whose value is one.

Step 2: Then divide the row length with the above summation to get an inter-ridge width D.

Together with the minutia marking, all thinned ridges in the fingerprint image are labeled with a unique ID for further operation.

e. False Minutia Point Removal

The false ridge breaks due to insufficient amount of ink and ridge cross-connections due to over inking are not totally eliminated which later lead to spurious minutia. Some mechanisms of removing false minutia are essential to keep the fingerprint Verification system effective. Procedures to remove the false minutia points are:

a) If the distance between one bifurcation and one termination is less than D and the two minutiae are in the same ridge. Remove both of them.

b) If the distance between two bifurcations is less than D and they are in the same ridge, remove the two bifurcations.

c) If two terminations are within a distance D and their directions are coincident with a small angle variation. Then the two terminations are regarded as false minutia derived from a broken ridge and are removed.

d) If two terminations are located in a short ridge with length less than D, remove the two terminations.

Removing false minutia has advantage to reduce the computation complexity. It surpasses the way adopted that does not utilize the relations among the false minutia types.

f. Minutia Matching

Here we use two set of minutia of two fingerprint images. And try to match the real minutiae between original and enhanced image. And minutia match algorithm determines whether the two minutia sets are from the same finger or not. Here we match only the Real Minutia points of the two images. Alignment base algorithm is used to match the two fingerprint image. This algorithm has two stages.

Stage 1: The ridge associated with each minutia is represented as a series of x-coordinates $(x_1, x_2, \dots\dots, x_n)$of the points on the ridge. A point is sampled per ridge length L starting from the minutia point, where the L is the average inter-ridge length. And n is set to 10 unless the total ridge length is less than$10 * L$. So the similarity of correlating the two ridges is derived from:

$$S = \sum_{i=0}^{m} x_i X_i \Big/ \left[\sum_{i=0}^{m} x_i^2 X_i^2\right]^{0.5} \quad (9)$$

Where $(x_i \sim x_n)$ and $(X_i \sim X_N)$ are the set of real minutia for each fingerprint image respectively. And m is minimal one of the n and N value. If the similarity score is larger than 0.8, then go to step 2, otherwise continue to match the next pair of ridges.

Stage 2: For each fingerprint, translate and rotate all other minutia with respect to the reference minutia according to the following formula:

$$\begin{pmatrix} x_i\_new \\ y_i\_new \\ \theta_i\_new \end{pmatrix} = TM * \begin{bmatrix} (x_i - x) \\ (y_i - y) \\ (\theta_i - \theta) \end{bmatrix} \quad (10)$$

Where (x, y, θ) is the parameters of the reference minutia, and Transform Matrix (TM) is:

$$TM = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (11)$$

Here we use the rotation angle calculated earlier by densely tracing a short ridge start from the minutia with length D. Here we elastically match minutia which is achieved by placing a bounding box around each template minutia.

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III. PROPOSED ARCHIETECTURE

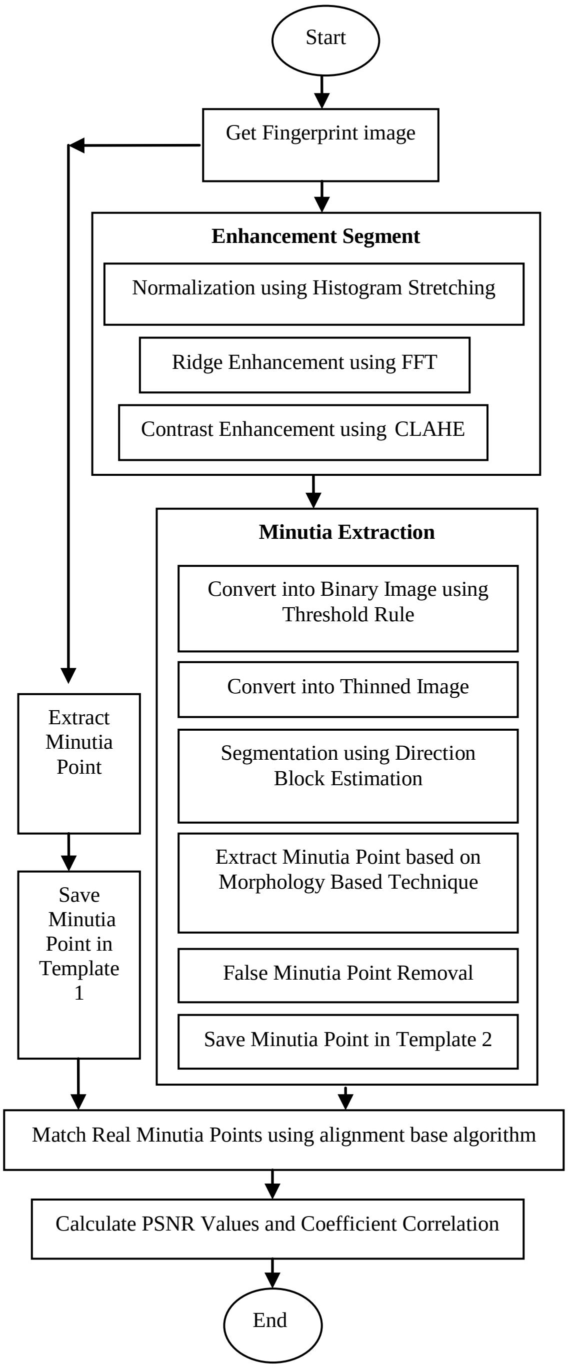

Fig 4: Proposed Architecture

IV. RESULTS

Following parameters are used for performance analysis of the proposed work discussed:

A. PSNR (Peak Signal-to-noise ratio)

The PSNR computes the peak signal-to-noise ratio and represents a measure of the peak error in decibels, between two images. This ratio is often used as a quality measurement between the original and a compressed or reconstructed image [20]. PSNR is expressed as:

$$PSNR = 10\ log_{10}\left(\frac{R^2}{MSE}\right) \quad (12)$$

MSE in denominator represents which represents the cumulative squared error between the reconstructed and the original image. The lower value of MSE represents the lower error in the reconstruction of the image. The mean-squared error is expressed as:

$$\frac{\left(\frac{Original\ Image - Enhanced\ Image}{Enhanced\ Image}\right)^2}{M * N} \quad (13)$$

Where M, N represent the rows and columns of the image.

B. Correlation Coefficient

Correlation Value computes the comparison of two images for the purposes of image registration, object recognition and disparity measurement [21]. This is observed by using **corrcoef (Original image, Enhanced image)** inbuilt function of MATLAB. These observations derived experimentally by applying various above enhancement techniques on FVC2002 database images on MATLAB 7.12.0.

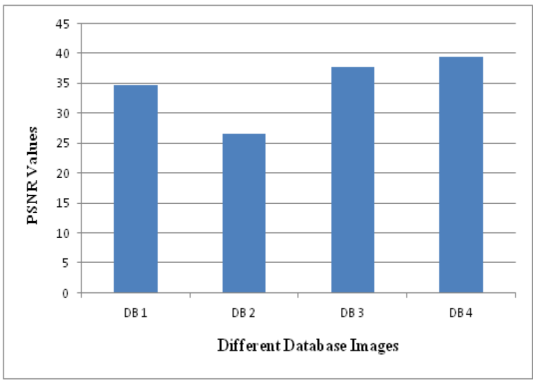

Fig 5: Graph for the PSNR Values on the Different Images of the FVC Database

The further graphs (Fig 5) shows the PSNR LEVEL, Coefficient Correlations (Fig 6) on the images of different type of images of FVC2002 database using the f=0.45 (Where f is the factor which enhance the image).

We can more enhance the images by increase the value of this factor, but value should be in limit otherwise it change the original property of image and after this using the ClipLimit W=0.02 to increase the contrast of image to make the ridges and valleys clear.

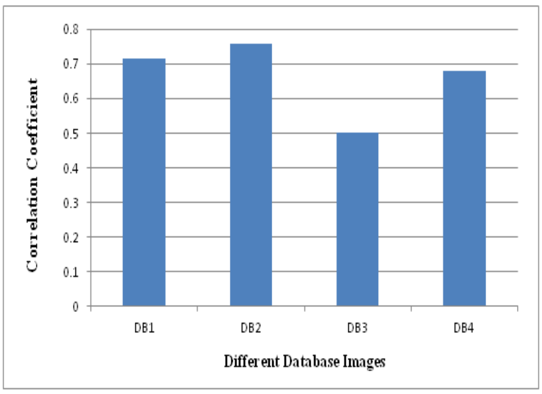

Fig 6: Graph for the Correlation Coefficient on the Different images of the FVC database

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For the above 2 graphs we set the value of k=0.45 and W=0.02(Clip Limit) but for the images of DB3. if we use the K=0.25 and W=0.01 then it increase the value of CC=0.50 to 0.5213, because these DB3 images are of high contrast.

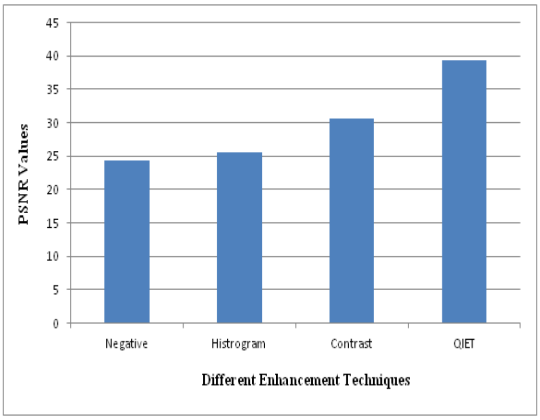

Fig 7: Comparative Graph for the PSNR Values on the Different Enhancement Techniques

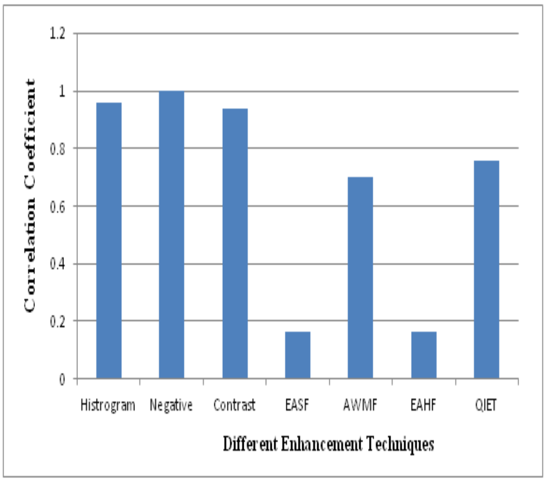

Fig 8: Graph for the Correlation Coefficient on the Different Enhancement Techniques

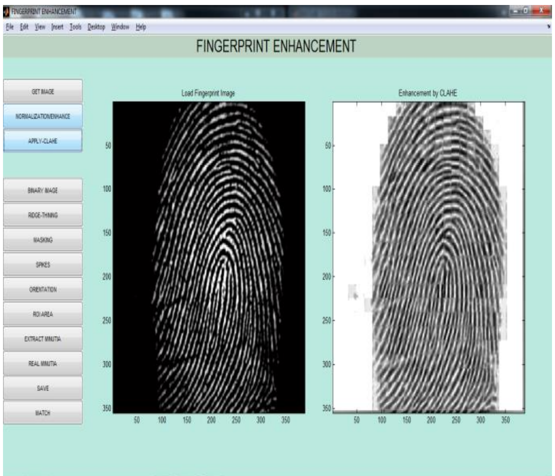

Fig 9: Enhanced Image

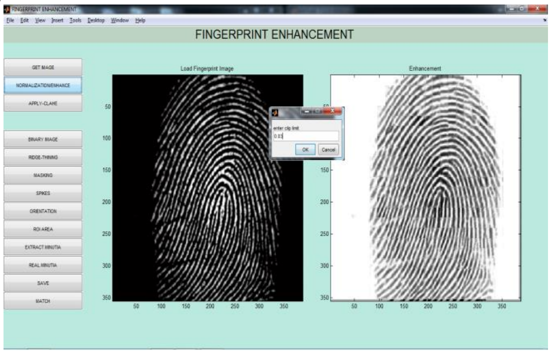

Fig 10: Image After Apply CLAHE

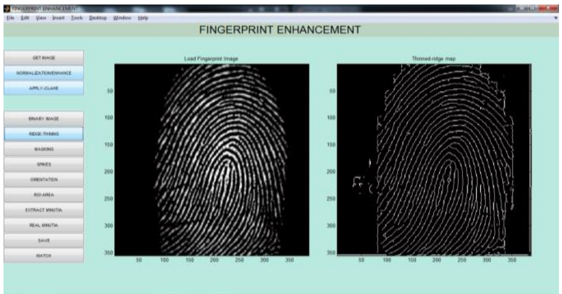

Fig 11: Thinned Image

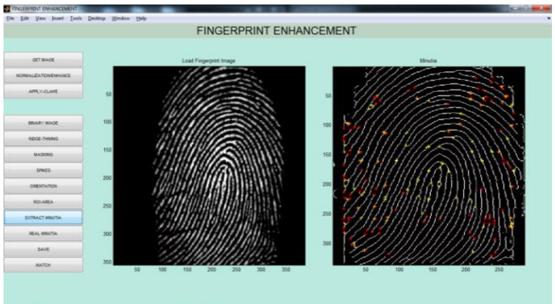

Fig 12: Extract Minutia Point

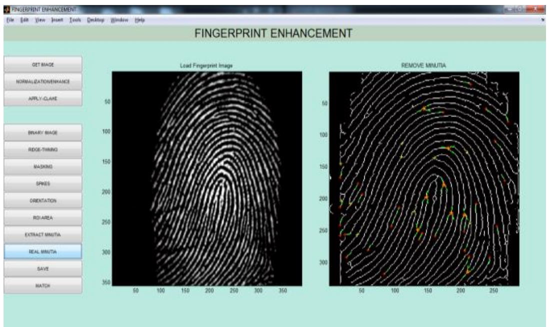

Fig 13: Remove False Minutia Point

V. CONCLUSION

The primary aim of Paper is to implement low quality fingerprint image enhancement by avoiding undesired side effects on originality (Unique Id) of a fingerprint image. It is successfully accomplished and its performance also, measured and analyzed. The proposed work tested on four different database images of FVC 2002 Database, and gives good result in terms of speed and accuracy. In addition, the progressive enhancement strategy helps to achieve flexible compromise among enhancement results. We conclude from the results that CLAHE achieve high enhancement performance in enhancement techniques in less time. FFT also gives the better results to improve the quality of a fingerprint image by selecting a suitable range of enhancement factor on the basis of the quality of the image. For the local feature enhancement, the morphology based techniques gives better results. It is a shape based technique which work on binary images and also reduce the work of post processing. We have thus utilized the best features of proposed algorithms (QIET) to speed up the enhancement and improve the accuracy.

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