Comparison of fingerprint enhancement techniques through Mean Square Error and Peak-Signal to Noise Ratio

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***Abstract*— In the fingerprint recognition system the main goal of the fingerprint enhancement algorithm is to reduce the noise present in the image. There are several factors that affect the quality of the acquired fingerprint image viz. presence of scars, variations of the pressure between the finger and acquisition sensor, worn artifacts, and environmental conditions during acquisition process. An input fingerprint image is thereby transformed by the enhancement algorithm to reduce the noise present in the image. This paper shows the work performed on the new database of fingerprint images acquired with a 500dpi optical sensor. Three different enhancement algorithms are applied on the images and the qualities of the reconstructed images are compared using mean-square error and peak-signal to noise ratio.**

Keywords- Histogram equalization, FFT enhancement, Gabor Filter, PSNR, MSE.

I. INTRODUCTION

Fingerprint is a feature pattern of a finger. These feature patterns are developed at the embryonic stage and maintains uniqueness among the population. Fingerprint possesses the ridges and furrows. Fingerprints are distinguished by their minutia and not by the ridges and furrows. Minutia can be categorized as termination (immediate ending of the ridge) and bifurcation (two branches derived from a point) and can be termed as an abnormal point on the ridge.

Fig.1. A fingerprint image acquired by an Nitgen Fingkey Hamster (Optical) Scanner

The verification and identification are the two sub-domains of the fingerprint recognition problem. The major difference between these domains is decided by the number of matches performed in the domain. In the fingerprint verification 1:1 match case has been performed whether in the fingerprint Identification 1: Many match case has been performed.

However, all fingerprint recognition problems, either verification or identification, are ultimately based on a well defined representation of a fingerprint. As long as the representation of fingerprints remains the uniqueness and keeps simple, the fingerprint matching, either for the 1-to-1 verification case or 1-to-M identification case, is straightforward and easy.

There are two different approaches for fingerprint recognition systems depending upon the representation of the images viz. the minutia based approach [2][3] that does the matching by local features and the image based approach, does matching by its global features. The termination and bifurcation are the local features and the global features depend on the whole fingerprint image.

II. BASIC BLOCK DIAGRAM OF THE FINGERPRINT RECOGNITION SYSTEM

A fingerprint recognition system constitutes of fingerprint acquiring device, minutia extractor and minutia matcher as shown in figure 2.

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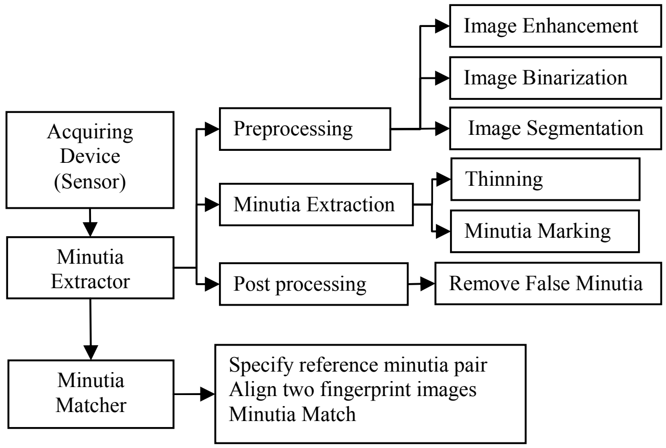


Fig.2. Fingerprint Recognition System

III. FINGERPRINT IMAGE ENHANCEMENT

Fingerprint image enhancement is to make the image clearer for easy further operations. Since the fingerprint images acquired from sensors or other medias are not assured with perfect quality, those enhancement methods, for increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink, are very useful for keep a higher accuracy to fingerprint recognition.

A. Histogram Equalization

Histogram equalization [7] is to expand the pixel value distribution of an image so as to increase the perceptional information. The original histogram of a fingerprint image has the bimodal type, the histogram after the histogram equalization occupies all the range from 0 to 255 and the visualization effect is enhanced. The figure shows the image after histogram equalization.

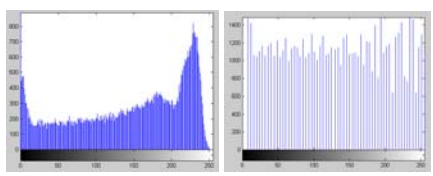


Fig.3. (x) before histogram equalization (y) after histogram equalization.

B. Fourier Transformations

We divide the image into small processing blocks (32x32 pixels) and perform the Fourier Transform according to [7]:

$$G(p_1,q_1)=\sum_{p=0}^{M-1}\sum_{q=0}^{N-1} f(p,q)\times\exp\left\{-2t\pi\times\left(\frac{p_1 p}{M}+\frac{q_1 q}{N}\right)\right\} \quad (1)$$

For p_1=1, 2…32 and q_1=1, 2……32.

In order to enhance a specific block by its dominant frequencies, we multiply the FFT of the block by its magnitude a set of times. Where

$$\text{Magnitude of Original FFT} = \text{abs}(G(p_1,q_1)) = |G(p_1,q_1)|$$

Get the enhanced block according to

$$g(p,q) = G^{-1}\left\{G(p_1,q_1)\times |G(p_1,q_1)|^n\right\} \quad (2)$$

Where $G^{-1}(G(p_1,q_1))$ is done by:

$$f(p,q)=\frac{1}{MN}\sum_{p=0}^{M-1}\sum_{q=0}^{N-1} G(p_1,q_1)\times\exp\left\{t2\pi\times\left(\frac{p_1 p}{M}+\frac{q_1 q}{N}\right)\right\} \quad (3)$$

For p=1, 2, …, 32 and q=1,2,……,32.

The n in formula (2) is an experimentally determined constant, which we choose n=0.50 to calculate. While having a higher "n" improves the appearance of the ridges, filling up small holes in ridges, having too high a "n" can result in false joining of ridges. Thus a termination might become a bifurcation. Figure 4 shows the resultant image after FFT enhancement followed by histogram equalization.

Fig.4. (x) before FFT enhancement (y) after FFT enhancement

C. Enhancement by using Gabor Filter

In this enhancement procedure we follow the technique proposed by Hong et.al.[1] The flowchart is as shown in fig.5

Input Image

1.Normalization →
2. Orientation Image Estimation →
3. Frequency Image Estimation →
4. Region Mask Generation →
5. Filtering

Enhanced Image

Fig.5. Flowchart for fingerprint enhancement algorithm

IV. QUALITY MEASUREMEN T

The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image reconstruction quality. We have used these two metrics to compare the quality of the reconstructed images after applying histogram equalization, FFT enhancement and Hong et.al [1] algorithm.

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. The higher value of the PSNR represents the better the quality of the reconstructed image.

B. MSE: Mean Square Error

The MSE 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.

To compute the PSNR, we first calculate the mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,N} \left[I_1(m,n) - I_2(m,n) \right]^2}{M * N} \quad (4)$$

In equation (4) M and N are the number of rows and columns in the input images, respectively. Then we compute the PSNR using the following equation:

$$PSNR = 10 \log_{10}\left(\frac{R^2}{MSE} \right) \quad (5)$$

V. EXPERIMENTAL RESULTS

We have used the newly acquired fingerprint database. The database contains 66 persons given 10 fingerprints trait per person and each finger having 3 impressions. The whole database contains 66*10*3=1980 fingerprint images. The Graph I and Graph II shows the statistical results of the experiments performed on multiple impressions of the fingerprint trait.

The TABLE I shows the MSE of the three techniques applied on the images.

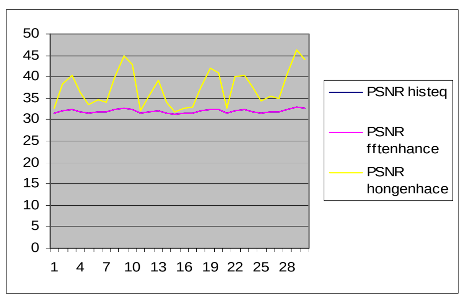
TABLE I. MSE FOR THE THREE TECHNIQUES

MSE		
Histogram Equalization	**FFT Enhance**	**Hong Enhance**
45.7998	45.7998	35.709
41.1262	41.1262	9.5387
38.1678	38.1678	5.857
43.3163	43.3163	15.3173
45.2176	45.2176	29.1327
42.7333	42.7333	22.6052

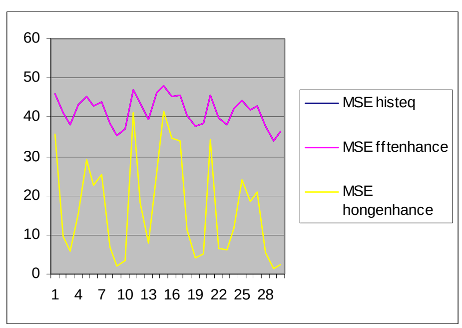
The TABLE II shows the PSNR of the three techniques applied on the images.

TABLE II. PSNR FOR THE THREE TECHNIQUES

PSNR		
Histogram Equalization	**FFT Enhance**	**Hong Enhance**
31.5222	31.5222	32.603
31.9896	31.9896	38.3359
32.3138	32.3138	40.454
31.7643	31.7643	36.279
31.5777	31.5777	33.487
31.8231	31.8231	34.5887



Graph I. The PSNR results of the three techniques.



Graph II. The MSE resultsof the three techniques.

VI. CONCLUSION

Here we focus our work on comparison of the histogram equalization technique, FFT enhancement technique and the algorithm developed by the Hong et.al [1] for fingerprint image enhancement using the peak-signal-to-noise ratio and mean square error. We analyzed that the Hong et.al [1] algorithm gives lowest error rate compared to other two and it gives highest PSNR compared to others. So as to Hong et. al method of enhancement can be used for further work.

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