A Comparative Analysis of Fingerprint Enhancement Technique through Absolute Mean Brightness Error and Entropy

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Abstract: - An enhancement algorithm is applied on the input fingerprint image to improve the image quality and to repair broken ridges. There are various enhancement schemes used for enhancing an image which includes gray scales manipulation, Histogram Equalization, Fast Fourier Transformed enhancement and Gabor Filter. There are several factors that affect the quality of the acquired fingerprint image via presence of scars, variations of the pressure between the finger, worn artifacts and acquisition sensor etc. This paper shows the work performed on the new database of fingerprint image acquired with a 500dpi optical sensor. Three different enhancement algorithms are applied on the input image and the qualities of the reconstructed image are compared using Absolute mean brightness error, peak – signal to noise ratio and Entropy.

Keywords: - Fingerprint image, HE, FFT Enhancement, Gabor filter, AMBE, PSNR.

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I. Introduction

A fingerprint refers to the flow of ridge patterns in the tip of the finger. The ridge flow exhibits anomalies in local regions of the fingertip and it is the position and orientation of these anomalies that are used to represent and match fingerprints.

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. A ridge is defined as a single curved segment, and a valley is the region between two adjacent ridges.

In this example, the black pixels correspond to the ridges, and the white pixels correspond to the valleys. 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.

Figure1.1-Illustrates an example of a ridge ending and a bifurcation.

II. Fingerprint Representation

The uniqueness of a fingerprint is determined by the topographic relief of its ridge structure and the presence of certain ridge anomalies termed as minutiae points. Typically, the global configuration defined by the ridge structure is used to determine the class of the fingerprint, while the distribution of minutiae points is used to match and establish the similarity between two fingerprints.[3] Automatic fingerprint identification systems, that match a query print against a large database of prints, rely on the pattern of ridges in the query image to narrow their search in the database (fingerprint indexing), and on the minutiae points to determine an exact match (fingerprint matching). The ridge flow pattern itself is rarely used for matching fingerprints.

III. Fingerprint Image Enhancement:

1. Histogram Equalization

Histogram equalization is a common technique for enhancing the appearance of images. Suppose we have an image, which is predominant dark. Then its histogram would be skewed towards the lower end of the gray scale and all the image details are compressed towards the lower end of the gray scale of the histogram. If we could stretch out the gray levels at the dark end to produce a more uniformly distributed histogram then the image would become much clear.

Histogram equalization involves finding a gray scale transformation function that creates an output image with a uniform histogram.[3]
It is necessary to find a transformation function T that maps gray values r in the input image X to gray values s= T(r) in the transformed image X^1.
It is assumed that:-
T is a single valued & monotonically increasing.
$0 \leq T\ (R) \leq 1\ for\ 0 \leq R \leq 1$
The inverse transformation from s to r is given as
$r = T^{-1}(s)$. (1.1)
The histogram of a digital image with gray levels in the range [0, L-1] can be represented by the discrete function:
$P\ (r_k) = \frac{n_k}{n}$ (1.2)
Where r_k is the k^{th} gray level, n_k is the number of pixels in the image with that gray level, n is the total number of pixels in the mage, and k=0,1,2,…L-1.
The image histogram gives an estimate of the probability of occurrence of a gray level r_k.
A plot of this function for all values of k also provides a global description of the appearance of an image.

2. Fingerprint Enhancement by Fourier Transform
We divide the image into small processing blocks (32 by 32 pixels) and perform the Fourier transform according to: $F(u, v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) * \exp\left\{-j2\pi * \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\}$ …(1.3)
for u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31.
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 the magnitude of the original
FFT = abs(F(u,v)) = |F(u,v)| (1.4)
We get the enhanced block according to
$g(x, y)=F^{-1}\{F(u, v)*|F(u, v|^k\}$ (1.5)
where F-1
(F(u,v)) is done by:
$F(x,y) = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} F(u,v) * \exp\left\{j2\pi * \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\}$ …(1.6)
for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.
The k in formula (2) is an experimentally determined constant, which we choose k=0.45 to calculate. The enhanced image after FFT has the improvements to connect some falsely broken points on ridges and to remove some false connections between ridges.[1]

3. Gabor-filter Based Enhancement
Hong et, al. used Gabor filter for fingerprint enhancement, which has both frequency-selective and orientation- selective properties. Gabor-filtering an image consist three parameters:
Frequency *f* of the sinusoidal wave determined by the local ridge frequency, the filter orientation O, determined by the local ridge orientation. The standard deviations of the Gaussian envelope-$\sigma_{x,}$ $\sigma_{y.}$
Gabor filter defined as the real part of the Gabor function given by a cosine wave modulated by a Gaussian.
$H(x, y{:}\emptyset, f) = e^{-1/2\left[\frac{x\emptyset 2}{\sigma x^2}+\frac{y\emptyset 2}{\sigma y2}\right]\cos(2\pi f x\emptyset)}$
$x_\Phi = x \cos\Phi + y \sin\Phi$ …(1.7)
$y_\Phi = -x \sin\Phi + y \cos\Phi$ …(1.8)
Here, Φ is the orientation of the Gabor filter, *f* is the frequency of a sinusoidal plane wave, $\sigma_{x,}$ σ_y the standard deviations of the Gaussian envelope along x and y axes, respectively, and x_Φ and y_Φ the x and y axes of the filter coordinate frame. [2]

Performance Matrices

1. **AMBE (Absolute Mean Brightness Error)**

AMBE is defined as-
AMBE (x, y) = $|X_m - Y_m|$ …(1.9)
Where X_m is mean intensity of input image X= {x (i, j)} and Y_m is mean intensity of output image y= {y (i, j)}.
Lower AMBE implies better brightness preservation.[5]

2. **PSNR (Peak Signal –to-noise Ratio)**

PSNR is defined as-Assume that N is the total number of pixels in the input image, MSE (Mean Squared Error) is calculated as-
$MSE = \frac{\sum i \sum j |x(i,j) - y(i,j)|}{N}$
The PSNR is calculated as-
$PSNR = 10\log_{10} \frac{(L-1)^2}{MSE}$ …(1.0)
Where, L is the number of discrete gray level.
Note that the greater the PSNR, the better the output image quality.

3. **Entropy**

For a given PDF P, Entropy Ent[P] is computed as-
$Ent\ [P] = \sum_{K=0}^{L-1} P(k) \log_2 P(k)$ …(1.1)
In general, the Entropy is a useful tool to measure the richness of the details in the output image, there are two goals: Brightness preserving and contrast enhancement. So AMBE is used is assess the degree of brightness preservation while both PSNR and Entropy are

employed to quantitatively assess the degree of contrast enhancement.

Experiment Results:-

Enhancement result for the ‘Sample1’ Image

Fig. (a) Original Image
(b) HE Image

(c) BBHE Image
(d) BPDHE Image

(e) FFT Image
(f) Gabor Image

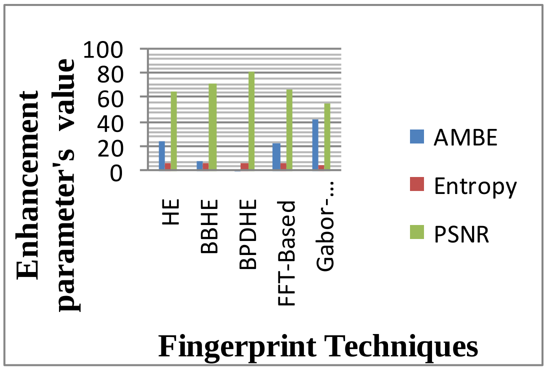
Table 1.1

ENHANCEMENT PARAMETERS FOR SAMPLE1 IMAGE

Metrics	**HE Based**			**FFT Based**	**Gabor Based**
	HE	**BBHE**	**BPDHE**		
AMBE	25.1813	7.4634	0.0732	22.7649	42.4644
Entropy	7.2538	7.2429	7.2360	7.0227	4.4569
PSNR	66.3132	71.8634	81.8251	67.3909	54.9645

The performance of the Fingerprint enhancement method is evaluated by comparing with different techniques on the basis of various performance metrics which are AMBE, PSNR, and Entropy. From this table, it is clear that, in terms of preserving the brightness of the output image and the contrast enhancement, BPDHE is better as the value of AMBE the smallest for this technique, which is desirable for any technique to be the best for image enhancement.

Any enhancement technique having high PSNR and high Entropy is considered to the best one. Thus, in terms of PSNR, we observed that the image produced by the BPDHE algorithm produce the best value. After that BBHE shows the better output as it is cleared from the formula.



From the graph showing in Fig., it is clear that BPDHE technique is giving the least value for AMBE as compared to all other techniques, which is desirable for any technique to preserve the mean brightness of the output image. Hence, in terms of AMBE, BPDHE is best for Fingerprint image enhancement. Similarly BPDHE also has the highest PSNR value as compared to other enhancement technique, but in terms of Entropy, the performance of Gabor based filter is not satisfactory.

Conclusion:

There are various techniques for Fingerprint image enhancement such as HE based, Fourier transform based and Gabor filter based for enhancing the gray scale Fingerprint image enhancement. After implementing some Fingerprint techniques, it is concluded that the enhancement of any image is application dependent. From the tables and graphs it is shown in. It is concluded that among the three methods for Fingerprint image enhancement, the HE based technique perform very well in terms of AMBE, Entropy and PSNR since its AMBE has the least value and its Average Entropy and PSNR has the highest value. After HE based technique the performance of Fourier transform is good. The visual quality of the images using Gabor filter is not satisfactory.

Future Work

In this paper, performance of Fingerprint is evaluated for gray scale fingerprint images. In future, one may address the impact of image enhancement algorithm with the spurious minutia removal algorithm and matching algorithm. New parameters may also be considered for the evaluation of performance by BPDHE technique

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