Extracting Minutiae from Fingerprint Images using Image Inversion and Bi-Histogram Equalization

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Abstract: **Finger print patterns contain local discontinuities known as minutiae. Minutiae are mainly terminations and bifurcations. One of the most important steps in automatic fingerprint identification and classification is to extract these minutiae. In this work a novel technique is proposed for fingerprint image enhancement. This technique is carried out using Image Inversion and Bi-histogram Equalization (IIBE), Wiener filtering and Image Binarization. Bi-histogram Equalization (BE) is an extension of histogram equalization, used for contrast enhancement by preserving the brightness of the image. Before going to apply BE over the finger print image, the image is inversed first and then BE is applied. The resultant image is again inversed so as to get the brightness preserved, contrast enhanced original image. Finally the image is given as input to Weiner Filtering and binarization and thinning processes to get the enhanced result. This method shows some improvement in the minutiae detection process in terms of either efficiency or time required.**

Index Terms: **Bi-histogram equalization(BE), Histogram Equalization (HE), Image inversion, Binarization, Thinning, Weiner Filter.**

I. INTRODUCTION

FINGERPRINTS are today the most widely used biometric features for personal identification. Most automatic systems for fingerprint comparison are based on minutiae matching [3]. Minutiae characteristics are local discontinuities in the fingerprint pattern which represent terminations and bifurcations. A ridge termination is defined as the point where a ridge ends abruptly. A ridge bifurcation is defined as the point where a ridge forks or diverges into branch ridges (Fig. 1). Reliable automatic extraction of minutiae is a critical step in fingerprint classification. The ridge structures in fingerprint images are not always well defined, and therefore, an enhancement algorithm, which can improve the clarity of the ridge structures, is necessary [4]. Most of the minutiae detection methods which have been proposed in the literature are based on image binarization, while some others extract the minutiae directly from gray scale images [5]. Concerning these two approaches, this work proposes a method for fingerprint image enhancement. This is carried out using a new technique called Image Inversion and Bi-histogram Equalization (I^1IBE) which is not only used to preserve the brightness of an image resulting high contrast but also to consider some important gray scale values of the image which are not usually considered in normal Histogram equalization. The output of this method is passed to a Wiener filter for noise removal and image binarization. Section II addresses the main steps of binarization approach. Section III gives general idea about HE, BE and application BE over the inversed image and re-inversing the BEed image. Section IV presents the noise removal using Weiner filter and Binarization and thinning operation applied over the IIBEed image. Finally, in Section V some conclusions are drawn.

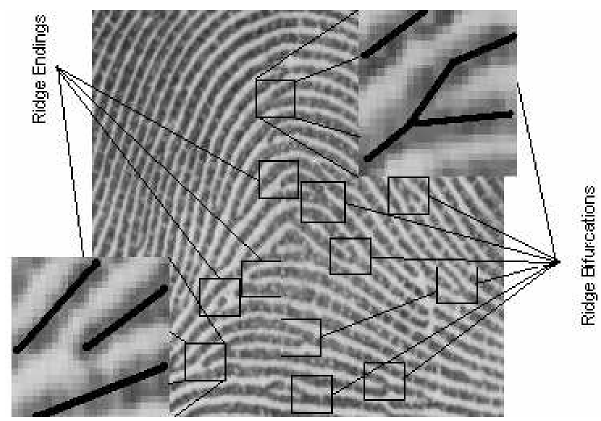

Figure 1. Examples of ridge ending and bifurcation

II. A BINARIZATION - BASED METHOD

In some binarization-based approaches the binarization and thinning process are preceded by a smoothing operation, based on convolution with a Gaussian mask [5], in order to regularize the starting image. We propose an enhancement process, which combines filters and noise reduction techniques for pre and post processing as well. The main stages of our proposed enhancement process conducted on a binary ridge fingerprint images are shown in Fig. 2.

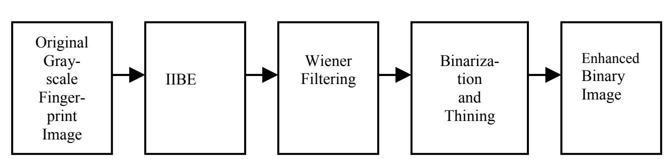

Figure 2. Filtering and binarization-based process

Instead of using a local histogram equalization for contrast expansion, a new technique called IIBE is introduced for preserving brightness as well as contrast and Wiener filter is applied for noise reduction. The binarization process is applied by adaptive thresholding based on the local intensity mean. Thinning is then carried out through the

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algorithm presented in [1], which provides good results on fingerprints. Finally morphological filtering is applied to eliminate artifacts in noisy regions and to fill some gaps in valid ridgelines[2].

III. IIBE

A. Histogram Equalization

Histogram equalization (HE) is a very popular technique for enhancing the contrast of an image. Its basic idea lies on mapping the gray levels based on the probability distribution of the input gray levels. It flattens and stretches the dynamics range of the images histogram and resulting in overall contrast improvement (Fig. 3). HE has been applied in various fields such as medical image processing and radar image processing [7], [9], [10] & [11].

For a given image X, the probability density function $P(X_k)$ is defined as

$$P(X_k) = n^k / n \quad (1)$$

For k=0,1,...,L-1, where n^k represents the number of times that the level X_k appears in the input image X and 'n' is the total number of samples in the input image. Note that $P(X_k)$ is associated with the histogram of the input image which represents the number of pixels that have a specific intensity X_k. Based on the probability density function , the cumulative density function is defined as

$$\sum_{j=0}^{k} P(X_j) \quad (2)$$

Where X_k=X , for k=0,1,…,L-1. Note that $C(x_{L-1}) = 1$ by definition. HE is a scheme that maps the input image into the entire dynamic range, (X_0, X_{L-1}) , by using the cumulative density function as a transform function. Let's define a transform function f(x) based on the cumulative density function as

$$f(x) = X_0 + (X_{L-1} – X_0)\, C(x) \quad (3)$$

Then the output image of the HE, Y= {Y(i, j)}, can be expressed as

$$Y = f(X) \quad (4)$$

$$= \{f(X(i,j) \mid \forall X(i,j) \in X\} \quad (5)$$

The high performance of the HE in enhancing the contrast of an image as a consequence of the dynamic range expansion, Besides, HE also flattens a histogram. HE can introduce a significant change in brightness of an image, which hesitates the direct application of HE scheme.

B. Bi-Histogram Equalization

Brightness preserving Bi-histogram equalization (BHE) has been proposed to overcome the above mentioned problems [8] & [12]. BHE firstly separate the input images histogram into two based on its mean; one having range from minimum gray level to mean and the other ranges from mean to the maximum gray level. Next, it equalizes the two histograms independently. It has been analyzed both mathematically and experimentally. This technique is capable to preserve the original brightness to a certain extends.

Let **Xm** be the mean of the image X and assume that X_m ε $\{X_0, X_1 \ldots X_{L-1}\}$. Based on the mean, the input image is decomposed into two sub-images X_L and X_U as

$$X = X_L \cup X_U \quad (6)$$

Where

$$X_L = \{(X(i,j) \mid X(i,j) \le X_m, \forall X(i,j) \in X\} \quad (7)$$

and

$$X_U = \{(X(i,j) \mid X(i,j) > X_m, \forall X(i,j) \in X\} \quad (8)$$

Note that the sub-image X_L is composed of $\{X_0, X_1 \ldots X_m\}$ and the other image X_U is composed of $\{X_{m+1}, X_{m+2}, \ldots X_{L-1}\}$. Next, define the respective probability density functions of the sub-images X_L and X_U as

$$P_L(X_k) = n^k{}_L / n_L \quad (9)$$

Where k = 0,1…., m, and

$$P_U(X_k) = n^k{}_u / n_u \quad (10)$$

Where k = m+1, m+2, …… ,L-1, in which $n^k{}_L$ and $n^k{}_U$ represent the respective numbers of X_k in $\mathbf{X}_L$ and X_U, and n_L and n_u are the total number of samples in X_L and X_U, respectively.

Note that $n_L = \sum_{k=0}^{m} n^k{}_L$, $n_u = \sum_{k=m+1}^{L-1} n^k{}_u$ $n^k{}_u$ and $n=n_L + n_u$. The respective cumulative density functions for X_L and X_u are then defined as

$$C_L(x) = \sum_{j=0}^{k} P_L(X_j) \quad (11)$$

and

$$C_u(x) = \sum_{j=m+1}^{k} P_u(X_j) \quad (12)$$

where X_k = X Note that $C_L(X_m) = 1$ and $c_u(X_{L-1}) = 1$ by definition.

Similar to the case of HE where a cumulative density function is used as a transform functions, let's define the following transform functions exploiting the cumulative density functions

$$f_L(x) = X_0 + (X_m – X_0)\, C_L(x) \quad (13)$$

and

$$f_u(x) = X_{m+1} + (X_{L+1} - X_{m+1})\, C_U(x) \quad (14)$$

Based on these transform functions, the decomposed sub-images are equalized independently and the composition of the resulting equalized sub-images constitute the output of BBHE.That is, the output image of BBHE, Y, is finally expressed as

$$Y=\{Y(i,j)\} \quad (15)$$

$$= f_L(X_L) \cup f_u(X_u), \quad (16)$$

Where

$$f_L(X_L) = \{f_L(X(i,j) \mid \forall X(i,j) \in X_L\} \quad (17)$$

and

$$f_u(X_u) = \{f_u(X(i,j) \mid \forall X(i,j) \in X_u\} \quad (18)$$

Note that $0<C_L(x), C_U(x)< 1$,it is easy to see that $f_L(X_L)$ equalizes the sub-image X_L over the range (X_o, X_m) whereas $f_U(X_U)$ equalizes the sub-image X_U over the range (X_{m+1}, X_{L-1}). As a consequence ,the input image X is equalized over the entire dynamic range (X_o, X_{L-1}) with the constraint that the sample less than the input mean are mapped to $(X_o, X_m)$and the samples greater than the mean are mapped to (X_{m+1}, X_{L-1}).

C. Analysis on the Brightness Change By the BE

Suppose that X is a continuous random variable, then the output of the HE, Y is also regarded as a random variable. It is well known that the HE produces an image, whose gray levels have a uniform density, i.e.,

$P(x) = 1 |(X_{L-1} + X_o)$ (19)

for $X_o < x < X_{L-1}$.Thus, it is easy to show that the mean brightness of the output image of the HE is the middle grey level since

$$E(Y) = \sum xP(x)dx \quad (20)$$

$$= \sum_{x_0}^{x_{L-1}} \frac{x}{X_L - X_0} dx \quad (21)$$

$$= \frac{X_L + X_0}{2} \quad (22)$$

Where E(Y) denotes statistical expectation . It should be emphasized here that the output mean of the HE has nothing to do with the input message That is , it is always the middle gray level to no matter how much the input image is bright/dark. clearly, this property is not desirable in many applications.

Suppose that X is a random variable, which has symmetric distribution around its mean X_m. When sub-images are equalized independently, the mean brightness of the output of the BHE can be expressed as

$E(Y) = E(Y| X \le X_m)Pr(X \le X_m)+E(Y |X > X_m)Pr(X>X_m)$

$= 1/2\{E(Y |X \le X_m)+E(Y| X > X_m)\}$ (23)

where $Pr(X \le X_m) = Pr(X > X_m)= 1/2$ .Since X is assumed to have a symmetric distribution around X_m. With similar discussion used to obtain (22), it can easily shown that

$E(Y|X \le X_m)=(X_0+X_m)/2$ (24)

and

$E(Y| X > X_m)=(X_{m+1}+X_{L-1})/2$ (25)

Substituting (24) and (25) in (23) results in

$E(Y)= (X_m + X_g) / 2$ (26)

Where

$X_g=(X_0 + X_{L-1}) / 2$ (27)

X_g is the middle gray level, which implies that the mean brightness of the equalized image by BHE locates in the middle of the input mean the middle gray level. Note that the output mean of the BHE is a function of the input mean brightness X_m. This fact clearly indicates that the BHE preserves the brightness compared to HE where output mean is always the middle gray level.

D. Image Inversion and BE

There are still cases that are not handled well by doing BE alone since some important pixels with significant gray level values are not considered during the BE process, resulting the attenuation of those pixels' gray values from the image. To overcome this problem, a novel technique is proposed in this paper called IIBE. In this technique, the finger print image is first inversed and then the BE process is applied. The resultant inversed image is once again inversed to get the contrast enhanced brightness preserved image (Fig. 4).

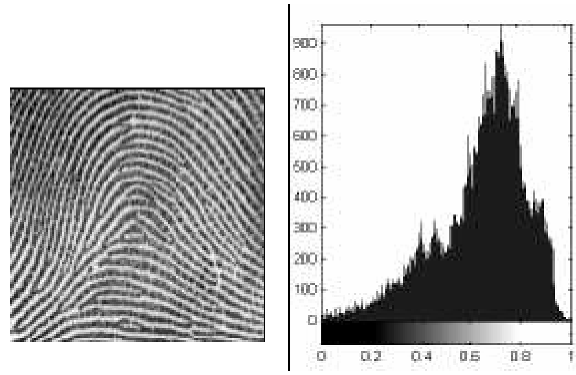

Figure 3. Original Image and its Histogram

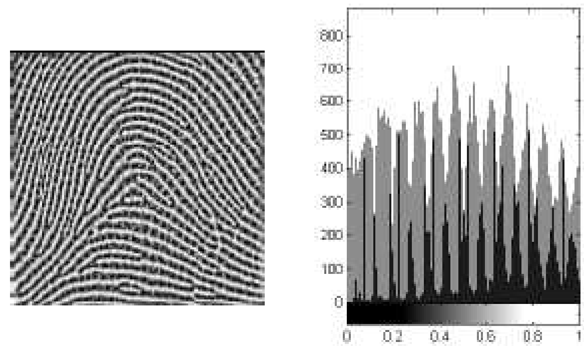

Figure 4. IIBEed Image and its Histogram

IV. WIENER FILTERING, BINARIZATION AND THINNING

We propose to use a pixel-wise adaptive Wiener method for noise reduction. The filter is based on local statistics estimated from a local neighborhood η of size 3x3 of each pixel, and is given by:

$$w(n_1, n_2) = \mu + \frac{\sigma^2 - \vartheta^2}{\sigma^2}(I(n_1, n_2) - \mu) \quad (28)$$

where υ^2 is noise variance, μ and σ^2 are local mean and variance, I represent gray level intensity in $n_1, n_2 \in \eta$. The result of Wiener filter is shown in Fig. 5, left.

The operation that converts a grayscale image into a binary image is known as binarization. We carried out the binarization process using an adaptive thresholding. Each pixel is assigned a new value (1 or 0) according to the intensity mean in a local neighborhood (13x13 pixels), as follow:

$$I_{new}(n_1, n_2) = \begin{cases} 1 \;\; if \; I_{old}\,(n_1, n_2) \ge Local\, Mean \\ 0 \;\; otherwise \end{cases} \quad (29)$$

Thinned (one pixel thickness) ridgelines are obtained using morphological thinning operations (Fig. 5, right).

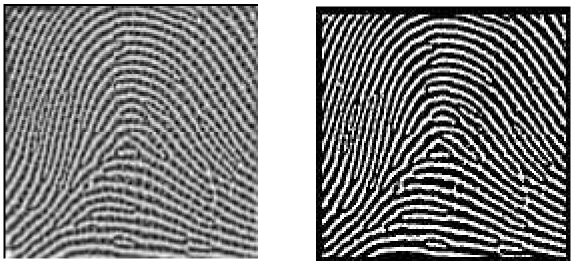

Figure 5. (left) Weiner Filtering Result (right) Thinned Image

V. CONCLUSION

In this paper a novel technique, Image Inversion and Bi-histogram Equalization (IIBE), is introduced for extracting minutiae from finger print images. The major advantage of this method is not only the preservation of brightness and contrast of the image but also the detection of hidden local discontinuities (minutiae). This method has shown improvement in the minutiae detection process in terms of efficiency. For reducing noise, Weiner filter is applied and finally binarization and thinning is also applied over the finger print image to get the resultant image.

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VII. BIOGRAPHIES

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