Contrast Fingerprint Enhancement Based on Histogram Equalization Followed By Bit Reduction of Vector Quantization

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Summary
Fingerprint minutiae are presently used in fingerprint image enhancement. The extraction of fingerprint minutiae is heavily affected by the quality of fingerprint images. This leads to the incorporation of fingerprint enhancement module in fingerprint recognition systems to make the system robust with respect to the quality of input fingerprint images. Histogram equalization (HE) is widely used for contrast enhancement. However, it leads to change the brightness of an image. Preserving the input brightness of the image is required to avoid annoying artifacts in an output image. The goal of image enhancement technique is to improve the characteristics or quality of an image such that the resulting image is better than the original image which is the objective in this paper. A low bit rate image coding scheme based on vector quantization is proposed. The block prediction coding techniques are employed to cut down the required bit rate of vector quantization. In block prediction coding neighboring encoded blocks are taken to compress the current block. So we investigated the performance of four steps procedure for fingerprint compression and enhancement using contrast limited adaptive histogram equalization with clip limit (CLAHE), Wiener filtering, image binarization, thinning and Vector Quantization (VQ). In conclusion, the paper is shown some improvement in the minutiae detection process in terms of efficiency and time required. Input here the part of summary.

Key words:
image enhancement, vector quantization, histogram equalization, business intelligence and fingerprint.

1. Introduction

Image enhancement means "making an image more vivid for human vision". Fingerprint recognition has been used in identifying individuals for a long time and it was being the most popular method in biometric authentication at present. Consequently, no single standard method of enhancement can be said to be "the best". Besides that, the nature of each image in term of distribution of pixel values range will change from one area to another. Minutiae, typically including termination and bifurcation, are characteristics features of fingerprints that determine their uniqueness. In fingerprint recognition system, valid minutiae can be hidden and spurious minutiae can be produced due to the low quality of fingerprint image. So, fingerprint enhancement is often required to enhance the quality of fingerprint image. [1-4]

Contrast of an image is determined by its dynamic range, which is defined as a ratio between the brightest and the darkest pixel intensities. Contrast enhancement techniques had various application areas for enhancing visual quality of low contrast images [5, 6]. The HE was being very popular technique for enhancing the contrast of an image. Theoretically, it can be shown that the mean brightness of the histogram equalization image is always the middle gray level regardless of the input mean [7]. Fingerprints are becoming big business. The Federal Bureau of Investigation (FBI) started collecting fingerprints in the form of inked impressions on paper cards back in 1924 and recently they have about 220 million cards, produces another bit-stream with lower bit rate that may meet the new bandwidth constraints.[8]

However, the main problem is the size in bits. When a typical fingerprint card is scanned at 500 dpi, with eight bits/pixel, it results in about 10 mb of data. Thus, the total size of the digitized collection would be more than 2000 terabytes; such amount of data is absolutely huge even by year 2008 standards. Therefore quantization is a key technology for reducing the bit rate of compressed data.

The proposed scheme constructed an optimal quantization codebook in an iterative manner for a given original quantization codebook that was constructed based on the quantization codebook of the transmitter. Algorithm implemented in fingerprint compression means using VQ codebook that had been computed from several previous training images. [9]

The analytics such as the analysis in this research are seen as a part of BI (Business intelligence), but the term analytics becomes a way to distinguish various BI applications such as operations analytics, finance analytics, IT analytics, …, etc. So, BI involves a process of gathering, problem solving, reasoning, and learning to enable the successful functioning of the business system through effective decision making. Briefly, BI is a superset of tools and analytics, where it is a goal, not the means as stated by Herschel (2010) (18).

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However, IT articles about BI would talk about technology's ability to contribute to successful business results not simply about components and their capabilities. The structure of the paper is arranged as follows: section 1 included the introduction and section 2 included the methodology of the proposed scheme. The results are explained with many details in Section 3. Conclusions are shown in Section 4.

2. Methodology

Image Enhancement

Image enhancement operation improves the quality of an image and it can be used to improve an image contrast and brightness characteristics, reduce its noise content, and/or sharpen its details. Image enhancement techniques may be grouped as either subjective enhancement or objective enhancement. Subjective enhancement technique may be repeatedly applied in various forms until the observer feels that the image yields the details necessary for particular application. Objective image enhancement corrects an image for known degradations. Here distortions are known and enhancement is not applied arbitrarily. This enhancement is not repeatedly applied but applied once based on the measurements taken from the system.
Image enhancement fall into two broad categories: Spatial domain technique and Frequency domain technique. Spatial domain refers to the image plane itself, where approaches in this category are based on direct manipulation of pixels in an image. Also, spatial domain refers to the aggregate of pixels composing an image. They operate directly on these pixels. Frequency domain processing techniques are based on modifying the Fourier transform of an image. Spatial domain processes, which are used in this paper, will be denoted by the expression.

$$G(x, y) = T(f(x, y))$$

where f(x, y) is the input image, G(x, y) is the processed image and T is an operator on f

Histogram Equalization

Histogram equalization is a general process used to enhance the contrast of images by transforming its intensity values [10]. As a secondary result, it can amplify the noise producing worse results than the original image for certain fingerprints. Therefore, instead of using the histogram equalization which affects the whole image, CLAHE is applied to enhance the contrast of small tiles and to combine the neighboring tiles in an image by using bilinear interpolation, which eliminates the artificially induced boundaries. In addition, the 'Clip Limit' factor is applied to avoid over-saturation of the image specifically in homogeneous areas that present high peaks in the histogram of certain image tiles due to many pixels falling inside the same gray level range[10]. Additionally, a combination of filters in both domains, spatial and Fourier are used to obtain a proper enhanced image.

Wiener filtering noise reduction

We proposed to use a pixel-wise adaptive Wiener method for noise reduction. The filter is based on local statistics estimated from a local neighborhood of size 3x3 of each pixel, which is given by[4][17]:

$$w(n_1, n_2) = \mu + \frac{\sigma^2 - v^2}{\sigma^2}\left(I(n_1, n_2) - \mu\right)$$

where v^2 is noise variance, μ and σ^2 are local mean and variance, where we represented the gray level intensity in (n1, n2) $\in \eta$.

Binarization

The operation that converts a grayscale image into a binary image is known as binarization by computing the mean value of each 32-by-32 input block matrix and transferring the pixel value to 1 if larger than the mean or to 0 if smaller. We carried out the binarization process using the following an adaptive threshold [17].

$$I_{new}(n_1, n_2) = \begin{cases} 1 \text{ if } I_{old}(n_1, n_2) \geq Local\ Mean \\ 0\ otherwise \end{cases}$$

Thinning

During this stage, the characterization of each feature is carried out by determining the value of each pixel. Some techniques exist based on thinning the pixel neighborhood having a maximum value initially (16) and filtered in the final step in order to eliminate the false lonely points and breaks; an algorithm is presented which eliminates the false information by slide neighborhood processing in a first step followed by thinning without any additional filtering. Then, the fingerprint image is separated from the background and local minutiae is located on the binary thinned image.[17]

Vector Quantization

The VQ is a commonly used scheme for grayscale image compression by many authors. Basically, VQ has the advantages of requiring a low bit rate and having a simple image decoding structure. The VQ is often used for image and speech compression. It is especially suitable for the multimedia applications that having a limited computation power. Also VQ was used for data hiding and data mining.

The basic concept of VQ, also called codewords, is to generate a set of representative vectors, to form the codebook. These codewords in the codebook are then used for image encoding and image decoding. In other words, VQ consists of three main procedures: codebook generation, image encoding, and image decoding [11-13]. The goal of codebook generation procedure is to produce a set of representative codewords. In current literature, the Linde-Buzo-Gray (LBG) algorithm [11] is the commonly used algorithm to design the VQ codebooks. It is a clustering-based algorithm that is proofed to be sub-optimal. The performance of the LBG algorithm is highly affected by the codebook initialization. Once a codebook is designed, the image encoding/decoding procedures of VQ can then be triggered. In the image encoding procedure, each grayscale image to be compressed is first divided into a set of nonoverlapped image blocks of the size n * n pixels. Each image block can be viewed as a k-dimensional vector where k = n*n. Then, each image block is processed in the left-to-right and top-to-bottom order.

Given one image block x and a codebook of N codewords, the closest codeword in the codebook is to be determined. Generally, the squared Euclidean distance (SED) is taken to measure the degree of similarity between two given vectors. To find out the closest codeword for x, the SED between each codeword and x is calculated. A total of N SEDs are calculated and the codeword corresponding to the least SED is selected. Finally, the index of the searched codeword is recorded and taken as the compressed code of x. After each image block is sequentially compressed, the compressed codes of one given image are the indices of the codewords in the codebook. In the image decoding procedure, the same codebook used in the image encoding procedure is required. To recover each compressed block x, the index of x is first extracted. Then, the corresponding codeword in the codebook is taken to rebuild the compressed block. By successively processing each extracted index, the whole compressed image of VQ can then be reconstructed. VQ has the advantage of requiring a low bit rate for image compression. The bit rate of VQ is 0.5 bpp when the codebook size and the vector dimensions are 256 and 16, respectively. Another advantage of VQ is that it has a low-complexity image decoding procedure. By simply referencing the appropriate table, the image decoding procedure is executed. It is especially suitable for some multimedia applications that have limited computational power for image decoding. Generally, the reconstructed image quality of VQ highly depends on the codebook used. If a representative set of codewords is designed, a good reconstructed image quality of the compressed image is achieved. In the LBG algorithm, the codebook initialization plays an important role in the resultant codebook. Several initialization techniques have been proposed to solve this problem as used in many articles. [14-16]

The Proposed Scheme

Using the proposed scheme we can summarize the fingerprint image enhancement and compression processes and its results as shown in the following Figure 1:

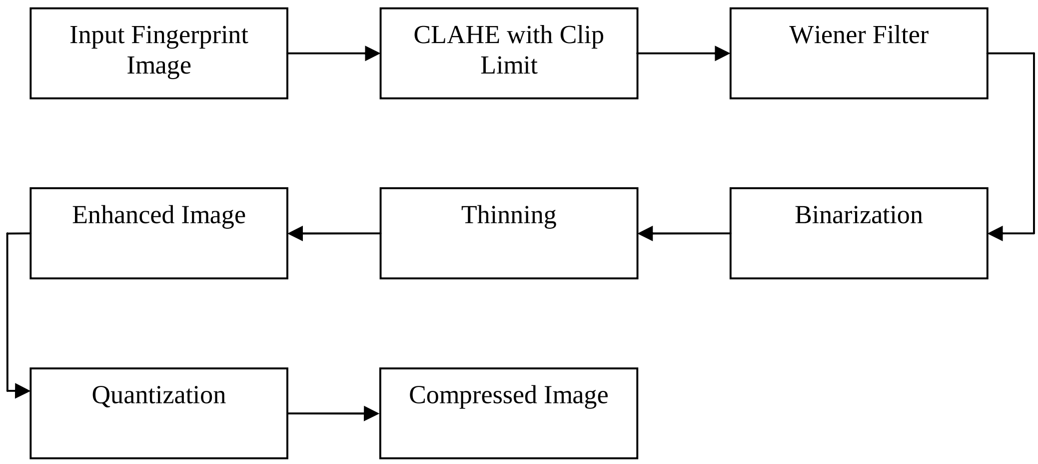

Figure 1: Shows the proposed algorithm

Step 1: At this step of the fingerprint image enhancement process, histogram equalization is applied to enhance the image’s contrast by transforming the intensity values of the image (the values in the color map of an indexed image), which are given by the following equation: [17]

$$s_k = T(r_k) = \sum_{j=1}^{k} p_r(r_j) = \sum_{j=1}^{k} \frac{n_j}{n}$$

where sk is the intensity value in the processed image corresponding to rk in the input image, pr(rj)=1, 2, 3... L is the input fingerprint image intensity level , n is the total number of pixels in the image, nj is the number of pixels that have gray level rk and L is the total number of possible gray levels in the image. In other words, the values in a normalized histogram approximate the probability of occurrence of each intensity level in the image.

The differences between the histogram of the normal fingerprint before and after histogram equalization (implemented in the MATLAB Image processing toolbox by function “histeq”) are depicted, as shown in Figures 2 and 3, and Figures 4 and 5.

Figure 2: Original fingerprint

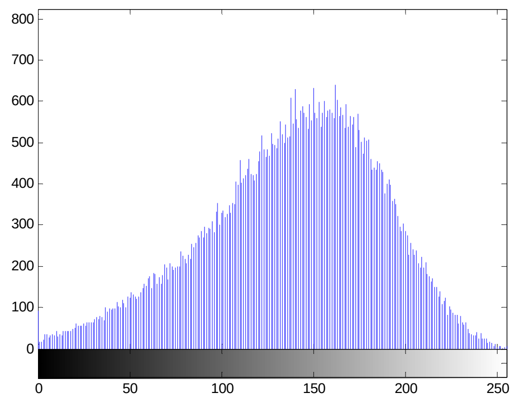

Figure 3: Histogram of original fingerprint image

Figure 4: After Histogram equalization

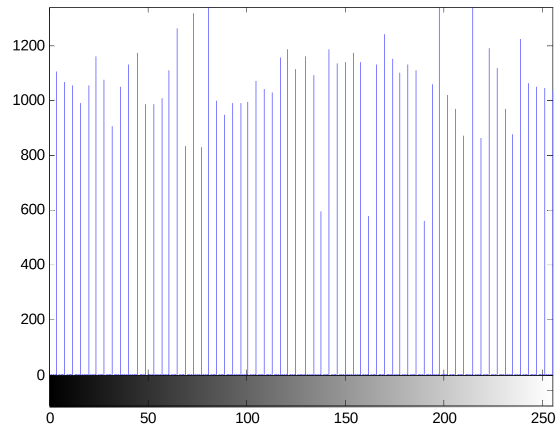

Figure 5: Histogram of image After Histogram equalization

However, by enhancing the contrast of an image through a transformation of its intensity values, the histogram equalization can amplify the noise and produce worse results than the original image for some fingerprints, due to many pixels falling inside the same gray level range. Therefore, instead of applying the histogram equalization, which works on the whole image, CLAHE 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.

In addition, 'Clip Limit' factor (implemented in the MATLAB Image Processing Toolbox by the function adapthisteq (f,”clipLimit”) is applied to avoid the over-saturation of the image, specifically in homogeneous areas which display a high peak in the histogram of the particular image tile. The images in Figures (6-9) are the histogram-equalized results of same fingerprint image and improvements in average intensity and contrast are obvious. In addition, the spread of the histogram over the entire intensity is increasing the contrast and the average intensity level in the histogram of the equalized image is higher (lighter) than the original.

Figure 6: Image After CLAHE

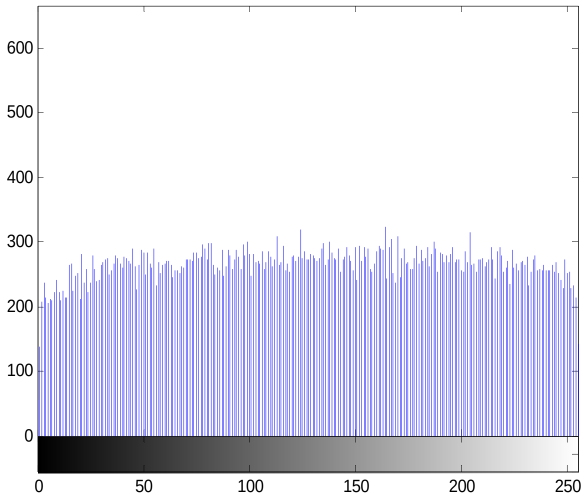

Figure 7: Histogram After CLAHE

Figure 8: Image After CLAHE with Clip Limit

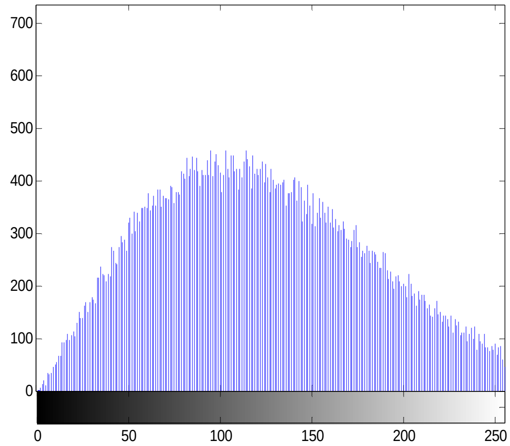

Figure 9: Histogram After CLAHE with Clip Limit

Step-2: The result step2 of the wiener filtering is shown in Figure 10.

Figure 10: Image After Wiener Filter result using local neighborhood of 3x3 pixels

Step-3:This step includes the result of the Binarization as shown in Figure 11.

Figure 11: Image After Binarization

Step-4 The result of the Thinning is shown in Figure 12.

Figure 12: Image After Thinning

Step-5 To encode one grayscale image with the proposed scheme, the image is first partitioned into a set of non-overlapped image blocks of n * n pixels. Each image block can be viewed as a k-dimensional vector where k =n * n. Suppose the VQ codebook Y = {y1, y2, , yN} of N codewords was previously generated by using the LBG algorithm. Before the encoding procedure is executed, the codeword reordering process is performed. In the codeword reordering process, the codewords in Y are sorted by their sum values in ascending order. By doing so, we hope that close codewords are located in the neighboring areas. But, it is not guaranteed that two codewords having the closest sum values are definitely similar. For most smooth codewords, the claim might be true. For complex codewords, it is possible that two codewords having close sum values but a large difference in variance values are found.

In the traditional VQ scheme, image blocks are encoded in the order of left-to-right and top-to-bottom. The same order is employed in the proposed image encoding procedure. To simplify the encoding procedure, each image block x that is either in the first column or the first block row of the image is compressed by the traditional VQ scheme. This is because these image blocks do not have enough neighbors for the block prediction technique.

For each remaining image block x to be processed, we first checked whether the block prediction technique can be employed. A predefined threshold is used to control the degree of similarity for two given image blocks. Two adjacent encoded neighbors of x as shown in Figure 13 are examined to find whether a suitable one exists to represent it. Let L and U denote the two encoded blocks in the codebook respectively.

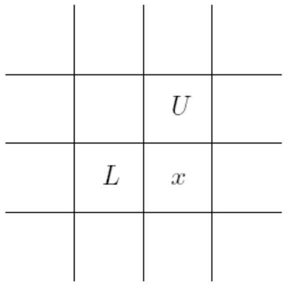

Figure 13: Explains Position diagram of the two adjacent neighbors for the currently encoded block x.

If L is not equal U, two SED values are calculated. They can be computed as follows.

$$d(x, L) = \sum_{i=1}^{k} (x_i, L_i)^2$$

$$d(x, U) = \sum_{i=1}^{k} (x_i, U_i)^2$$

The smaller SED value among them is selected and stored in dmin. If dmin is less than or equals , the block prediction technique is employed to encode x. Otherwise, the relative addressing technique is employed to process the index. If the encoded neighbors of x are the same, only one SED value is computed.

It can be seen that the PSNR obtained by the proposed algorithm is higher than that of wavelet transform. Hence, a better image reconstruction is possible with less number of bits. The experimental results reveal the fact that VQ is suitable for low bit rate image coding. The proposed scheme yields encoding outputs of good quality as shown in figure 14 and 15.

Figure 14: Original Image

Figure 15: After Enhancement and compression PSNR = 28.87 dB

4. Conclusion

We have introduced a new fingerprint enhancement algorithm. This algorithm, unlike other algorithms, concentrates a large amount of effort to allowing superior performances. Experimental results show that this algorithm is applied to avoid specific shortfalls. This improvement, in turn, results in an improvement in the quality of input fingerprint images. The procedure follows first the application of CLAHE with Clip Limit in order to enhance the contrast of small tiles, to eliminate the artificially induced boundaries and to avoid over-saturation of the image specifically in homogeneous areas. In addition, the wiener filtering is used to obtain a proper enhanced image.

The another phase of this new enhancement methodology is the application of the slide neighborhood processing to obtain a thinned fingerprint image without any intermediate filtering and substantial reduction of the computational complexity. The analysis of its possible advantages is carried out through a simulated investigation. This module checks the quality of the input fingerprint image objectively. The enhancement module is applied to the input fingerprint image if and only if the quality of the input fingerprint image is poor and the true ridge/valley structures are recoverable. We are currently designing such a module.

A low bit rate image compression scheme based on VQ is proposed. By exploiting the high correlation among neighboring blocks, the block prediction technique refers two neighboring encoded blocks. The encoding rules for the block prediction technique make use of block similarity to cut down the bit rates of VQ. By using the codeword reordering process, the codewords in the codebook are reorganized so that similar codewords are arranged in the neighborhood. According to the results, it is shown that the proposed scheme achieves good image quality while keeping a low bit rate.

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