A Study of Image Enhancement for Iris Recognition

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***Abstract*—Iris recognition is one of the most prevalent methods for personal identification in the modern day. Low quality iris images that are blurry, of low resolution, and poor illumination poses a big challenge for iris recognition as the iris recognition efficiency is entirely dependent on whether the image supplied is of good quality. Therefore, several enhancement techniques have been proposed and used for image processing to increase the quality of iris images. Although there is no best approach for all types of image enhancement, histogram equalization (HE) is a commonly used approach as it is a simple yet effective method. In this paper, several enhancement techniques based on histogram equalization approaches, such as histogram equalization (HE), brightness preserving bi-histogram equalization (BBHE), dynamic histogram equalization (DHE), adaptive histogram equalization (AHE), contrast limited adaptive histogram equalization (CLAHE), dualistic sub-image histogram equalization (DSIHE), and multi-scale adaptive histogram equalization (MAHE), have been explored. A comparison is conducted based on the image quality of all image enhancement techniques proposed in this paper.**

***Index Terms*—biometric approach, histogram equalization, Iris recognition, Iris enhancement**

I. Introduction

The sequential steps for digital image processing include image acquisition, enhancement, segmentation, feature extraction, representation and recognition [1], [2]. Image quality is an important factor in performance of an iris recognition system therefore; image enhancement is a crucial step as there is a growing demand for iris recognition of images obtained in a non-cooperative environment such as surveillance videos of people in moving conditions. Digital image processing plays a vital role in the modern day. Image enhancement can be described as a process of transforming the intensity of an input image into a new image such that it is suitable for both subjective and objective point of view. Subjective can be defined as based on human perspective, whereas objective can be measured in several criteria such as peak signal to noise ratio (PSNR), absolute mean brightness error (AMBR), and contrast [2]. To test the image quality of an enhanced image with digital image processing system, parameters in other sequential steps should be fixed i.e.segmentation, feature extraction, representation, and recognition. In this paper, several enhancement techniques have been studied with an iris recognition system. A very common enhancement technique is histogram equalization (HE) which enhances overall contrast of an image by transforming an original image into a uniform histogram [3]. Hence, this technique is a powerful global enhancement but may reduce the local details within an image. Researchers have proposed several enhancement techniques based on the improvement of traditional histogram equalization, brightness preserving bi-histogram equalization (BBHE), dynamic histogram equalization (DHE), adaptive histogram equalization (AHE), contrast limited adaptive histogram equalization (CLAHE), dualistic sub-image histogram equalization (DSIHE), multi-scale adaptive histogram equalization (MAHE), brightness preserved dynamic histogram equalization (BPDHE), multilevel component based histogram equalization, and weighted mean-separated sub-histogram equalization (WMSHE). More survey details of contrast enhancement techniques based on histogram equalization techniques can be found in [4]. The iris images used in this experiment come from CASIA database [5]. The detail of iris recognition algorithm that has been used in this paper is adopted from [6]. This research introduces image enhancement techniques and discusses the implementation algorithm. Further, the experiment setup, results and future research have been discussed.

II. Image Enhancement

A. Image Enhancement

Image enhancement is a technique in image processing that uses in preparing an image for a particular application. The outputs of the process usually bring out details information that is suitable for a specific application. There is no general best theory for image enhancement. An enhancement technique that gives a

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high performance in one application might not be useful in another application. Generally, there are two approaches in image enhancement: spatial domain method and frequency domain method. In this paper, we have studied only an image enhancement in a spatial domain. Let r be an input image and s be a processed image, a spatial domain process will be expressed as

$$s = T[r] \quad (1)$$

where $T[\,]$ represents a transformation function of r.

B. Histogram Equalization (HE)

A histogram equalization technique is a cumulative distribution transformation function. It is a process of transforming an original image into equally likely intensity image. The transformed image tends to have a higher contrast than an original image. Let $p_r(r_k)$ be a probability of occurrence of gray level image, r_k , which can be given by

$$p_r(r_k) = \frac{n_k}{n}, \quad \text{k=0, 1, 2, …, L-1} \quad (2)$$

where L is a number of gray level. The transformation function of histogram equalization can be written as

$$S(k) = \sum_{j=0}^{k} p_r(r_j) \quad (3)$$

C. Brightness Preserving Bi-Histogram Equalization (BBHE)

A brightness preserving bi-histogram equalization is done by dividing the histogram image into two parts, separating by mean brightness value μ. Therefore, each part represents its own histogram. The traditional histogram equalization has been calculated in each part [7].

D. Dynamic Histogram Equalization(DHE)

The histogram equalization discussed in section 2 (B) is a global enhancement. The output is processed by a transformation function based on the probability of occurrence of an entire intensity image. A local enhancement of histogram equalization can also be done. A dynamic histogram equalization which is a local enhancement technique is done by dividing an image into a small block, and then calculating histogram equalization in each block [8].

E. Adaptive Histogram Equalization (AHE)

Adaptive histogram equalization is an extension technique of the traditional histogram equalization. It has been used to improve contrast images and it is suitable for improving the local contrast in more detail with over amplified noise. A given pixel is enhanced based on the histogram equalization of small neighboring area. Noise amplification and boundary artifacts can be created in using adaptive histogram equalization [8].

F. Contrast Limited Adaptive Histogram Equalization (CLAHE)

The difference between AHE and CLAHE is its contrast limitation. A contrast limited adaptive histogram equalization (CLAHE) has been developed to avoid the noise amplification. It is a generalization of adaptive histogram equalization. The undesired noise amplification can be reduced [9] and the boundary effect can also be reduced by background subtraction [10]. The advantage of CLAHE is that the resulted image will not discard the histogram that exceeds the clip limit but it creates an equal density in all histogram bins.

G. Dualistic Sub-Image Histogram Equalization (DSIHE)

Instead of decomposing the histogram image into two parts and then calculate histogram equalization separately as in BBHE, a dualistic sub-image histogram equalization decomposes the histogram image base on maximizing the Shonon's entropy. The image is then decomposed into two equal areas that have the same amount of pixels. Then, the histogram equalization has been calculated separately [11].

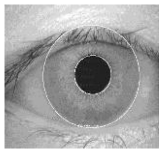
H. Multi-scale Adaptive Histogram Equalization (MAHE)

A multi-scale adaptive histogram equalization decomposes a signal into two different spatial-frequency components. Jin *et. al*. has proposed a multi-scale adaptive histogram equalization using wavelets. A selective wavelet band has been chosen and histogram equalization has been applied. The details can be found in [12]

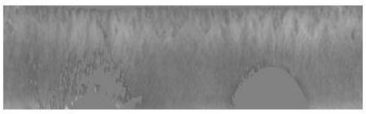
III. Implementation

A. Preprocessing

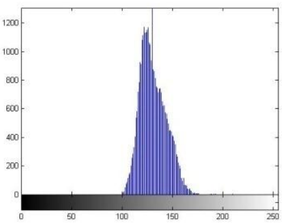
Given an iris image, the Canny edge detection algorithm is applied to generate a gradient image. "A circular Hough transform has been applied to detect the radius and center coordinates of the iris regions" [3]. Daugman rubber sheet model is used to "converts a cartesian coordinate system into a polar coordinate system" [8]. An example of preprocessing process has been shown in Fig. 1.



(a)



(b)



(c)

Figure 1. (a) iris regions (b) Daugman's rubber sheet model (c) histogram of original iris image.

B. Image Enhancement

Several image enhancement techniques described in Section 2 have been used in this paper. Fig. 2 shows the example of the resulted images using several histogram equalization techniques from Section 2 (B-H). Fig. 3 shows the histogram of each techniques.

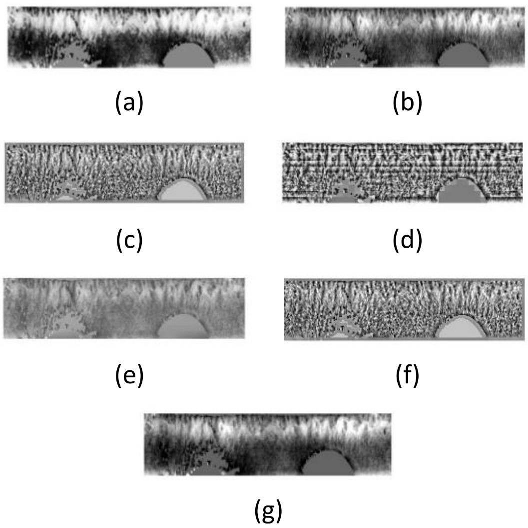


Figure 2. Several Iris enhancement methods (a) HE (b) BBHE (c) DHE (d) AHE (e) CLAHE (f) DSHE (g) MAHE

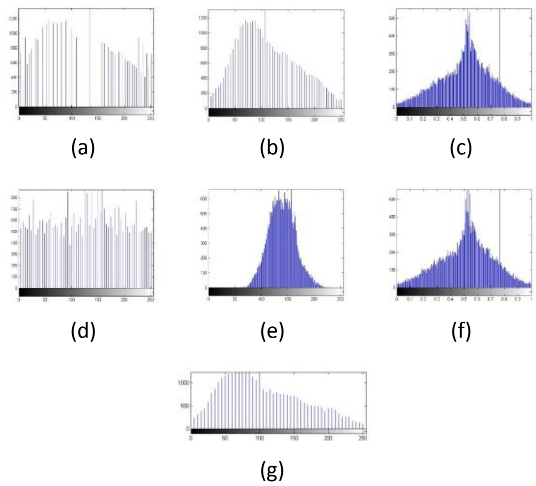


Figure 3. The histogram of the enhanced images (a) HE (b) BBHE (c) DHE (d) AHE (e) CLAHE (f) DSHE (g) MAHE

C. High-Low Pass Filters

A high-low pass can be effectively used for feature extraction [5]. Let $G(x,y)$ is a 2-dimension filter, A, B, and C is a constant where A ≥ B, σy1 > σy2 and m is an arbitrary odd number, a high-low pass filters are defined as

$$G(x,y) = \frac{C}{\sqrt{2\pi\sigma_x^2}} exp\left(-x^2/2\sigma_x^2\right)\left[\frac{A}{\sqrt{2\pi\sigma_{y1}^2}} exp\left(-y^2/2\sigma_{y1}^2\right) - \frac{B}{\sqrt{2\pi\sigma_{y2}^2}} exp\left(-y^2/2\sigma_{y2}^2\right)\right] \quad (4)$$

$$\sigma_i = \frac{1}{2\pi\alpha_i}, \frac{-m+1}{2} \le x \le \frac{m-1}{2}, \frac{-m+1}{2} \le y \le \frac{m-1}{2} \quad (5)$$

The filter can be rotated in order to obtain several directional filters. Fig. 4 shows the example of four directional high-low pass filters.

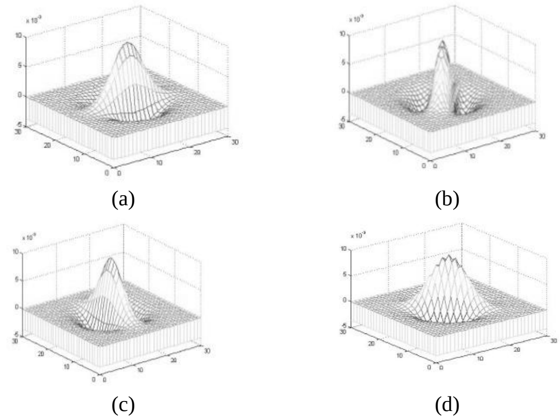


Figure 4. Four directional hi-low pass filters with (a) 0 degree (b) 90 degree (c) 180 degree and (d) 270 degree.

D. A Box-counting Fractal Dimension

A box-counting fractal dimension is a statistic quantity used because of ease in implementation. "The number of boxes covering the interested area is a power law function of the box size" [5] and is indicated as

$$D = \frac{\log(n)}{\log(1/s)} \quad (6)$$

where n is self similar object to cover the original object, s is a scaling number used to partition the original object, and D is a fractal box-counting. The details of using a box-counting fractal dimension for iris recognition can be found in [8].

E. Sum Absolute Difference (SAD)

Two images are said to be identical if the overall distance between two corresponding points are less than a certain threshold. Many distance measurements can be used for texture matching. In this paper, Sum Absolute Difference has been used. "Let D_u be a feature from an input image, D_d be a feature from an image in a database, and n is a number of feature used, sum absolute difference can be calculated from" [5]

$$SAD = \sum_{i=1}^{n} \left|D_{u_i} - D_{d_i}\right| \quad (7)$$

IV. Experimental Setup

Each iris image has been processed as described in Section 3. A gradient image of an iris image has been created using Canny edge detection algorithm. A circular Hough transform has been applied to detect the radius and center coordinates of the iris regions, a polar coordinate image has been created using Daugman rubber sheet model. The iris image has been resized to 150x400 pixels. Several techniques in histogram equalization, i.e. histogram equalization, dynamic histogram equalization, adaptive histogram equalization, contrast limited adaptive histogram equalization, dualistic sub-image histogram equalization, and multi-scale adaptive histogram equalization, have been processed. The four directional high-low pass filters have been convolved with every enhanced image. A box-counting fractal dimension has been created and used as iris feature. Sum absolute difference is calculated for matching score. The performance of matching accuracy are compared.

V. RESULTS

In this experiment, 400 iris images were arbitrarily selected from CASIA [4] and used as the database for this research. The other 700 iris images have been selected as a tested database, 600 images come from the person who has been enrolled in a database and the other 100 images are not a person in the database. All iris images are processed as described in Section 2, Section 3, and Section 4 of this paper. A box-counting fractal dimension with Sum absolute difference (SAD) is used to calculate a distance for iris matching. The performance of each histogram equalization technique has been show in Table I.

TABLE I. THE PERFORMANCE OF EACH HISTOGRAM EQUALIZATION TECHNIQUES IN OUR EXPERIMENTS

Enhancement techniques	Matching accuracy (%)	False acceptance rate (%)
HE	90.71	0.06
BBHE	89.7	0.03
DHE	90.0	0.04
AHE	85.7	0.06
CLAHE	93.0	0.02
DSHE	90.71	0.04
MAHE	92.8	0.02

VI. CONCLUSIONS AND FUTURE WORK

From our experiments, many image enhancement techniques have been implemented and compared. The comparison results using iris recognition system have been shown that CLAHE give the highest performance in iris recognition at 93% matching accuracy with FAR at 0.02%, followed by MAHE at 92.8% matching accuracy with FAR at 0.02%. Thus, CLAHE and MAHE ensure consistency in iris enhancement. AHE give the lowest matching accuracy at 85.5% with 0.06% FAR. Some enhancement techniques that give low performance might come from the size of small neighboring block and other constant. Thus, some constant in each enhancement techniques which are implemented should be adjusted in order to get an optimization performance of each technique. Other enhancement techniques should be considered and compared in the future.

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