The Comparison of Iris Detection Using Histogram Equalization and Adaptive Histogram Equalization Methods

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Abstract. This paper presents a comparison between two image improvement techniques, Histogram Equalization (HE) and Adaptive Histogram Equalization (AHE). Canny edge detection is used as a comparison. The HE method is a contrast enhancement method that is designed to be widely applied and has effectiveness in image improvement that will be carried out by segmentation, while AHE is more effective to be applied to images that aim to recognize patterns. Performance measurement using a peak signal to noise ratio (PSNR) produces an average value of 16.76 for the HE method and for the AHE method for 16.95. Before the edge detection process, the image of the iris is done by the compression stage using discrete wavelet transform. Average compression ratio for all tested iris datasets is 1.27.

1. Introduction

In human organ detection, software technology is widely developed through image processing. Several studies of organ detection systems have been developed, such as the detection of ears, face, tongue and iris [1], [2], [3], [4]. Iris is an eye organ that surrounds the pupil with a very unique texture, a different pattern between the left and right eye makes the iris known as the most accurate part for someone's identification. The amount of iris image data requires very large memory, to overcome memory requirements, and to fasten data transfer we are using image compression. Image compression method used in this paper is Discrete Wavelet Transform (DWT). In the DWT algorithm a decomposition process occurs. The decomposed original image is divided into 4 sub-signals, namely the approximate sub-signal that shows the general pixel and 3 sub-signal details showing vertical, horizontal and diagonal detail or image changes. DWT is an efficient technique for image compression and logical ratio compression values. The weakness of the DWT algorithm requires a longer execution time compared to other algorithms [5]. The decomposition process in DWT was tested using 4 levels and resulted in an increase in the PSNR value of 4 dB per level.

The data acquisition process has several obstacles. The iris image taken is blur, camera diffusion, noise, light reflection, and other things that affects the segmentation process [6]. Thus improvement in image quality is needed. The method used in the process of image improvement uses histogram equalization (HE) and adaptive equalization histogram (AHE). In applying the HE method, Red, Green, and Blue components in RGB images can produce dramatic changes in image color balance because the relative distribution of the color channel changes relatively. So it is necessary to convert RGB images into grayscale images.

The darker iris lighting conditions cause the boundary between the pupil and iris hard to differs. This is where HE and AHE take place on the image enhancement before the segmentation process is carried out. HE increases the overall contrast of an image by distributing the intensity value of the image. HE contrast enhancement can change overall brightness which results in low saturation or excessive saturation in certain parts. AHE corrects the weakness of HE by increasing the contrast locally or in certain parts in more detail. AHE contrast enhancement is based on equalization of histograms from smaller areas [7]. This is done to get the iris image with a better balance in contrast.

Edge detection methods are based on edge detection to identify boundaries between regions [8], [9]. The advantages of operator canny is, it uses the probability to find error rates, localization and response,
improve signal to noise ratio, resulting in better detection especially in conditions with a lot of noise. While the disadvantages of canny operators are having more complex computing, false zero crossing, and consuming more time [10].

Based on the literature study above the main problem that arises at the acquisition stage, is image sizes are large enough that compression is required using the DWT method. The decompressed image has a contrast imbalance and image improvement is needed through the HE and AHE methods. Furthermore, the inter-pupillary and iris boundaries are hard to be distinguished, causing difficulty in identifying the edge and the segmentation process required through the canny operator method. The results of the above experiments can be used for normalization, feature extraction and pattern recognition processes.

2. Image Preprocessing: Grayscale
The result of the acquisition process, has an RGB data type that has three channels, namely Red (R), Green (G), and Blue (B). RGB iris image is converted to grayscale image, thresholding is used to separate iris objects from surrounding objects [11]. Grayscale image is an image whose pixel intensity values are based on gray level, it have minimum values and maximum gray level values, these values depend on the number of bits used. If the image uses 8 bits, there are 256 grayscale levels, where 0 is the darkest intensity and 255 is the brightest. Then the conversion process is first made into a grayscale image using the following equation (1):

\[ y = \frac{1}{3} (R + G + B) \]  

Where, y is the intensity value of the image. And R, G, B, each is the value of the Red, Green, and Blue channels.

3. Discrete Wavelet Transform
Image compression is a technique in image processing that aims to reduce file size without losing important information so that image quality can be maintained. This image compression can be done with the Discrete Wavelet Transform (DWT) algorithm. DWT is used to decompose a signal into a wavelet component and wavelet coefficients can be removed to eliminate some of the details. The image is decomposed into 4 sub-bands (Low-Low (LL), Low-High (LH), HL, HH) on 1 DWT domain. LH, HL and HH represent the best scale wavelet coefficients while LL can then be decomposed to get another decomposition level [12]. Functions that can be used on DWT are according to the following equation (2):

\[ f (x) = \frac{1}{\sqrt{M}} \sum_k W_\varphi (J_0, K) \varphi_{J_0,K} (x) + \frac{1}{\sqrt{M}} \sum_{J=J_0}^{J_{max}} \sum_K W_\Psi (J,K) \Psi_{J,K} (x) \]  

Where \( J_0 \) is the initial scale change, \( W_\varphi (J_0, K) \) is an estimate or coefficient of scale and \( W_\Psi_{J,K} \) is a detail or wavelet coefficient.

4. Image Enhancement
4.1 Histogram Equalization
The process of adjusting the intensity value can be done automatically by using histogram equalization. Histogram equalization involves changing the intensity value so that the histogram of the output image corresponds to the specified histogram [13]. Histogram equalization (HE) is an image improvement technique by changing the original image so as to produce a flatter histogram. The basic concept of HE is to remap the value of the intensity of the original image to a new level of intensity through the transformation function. HE can be calculated using equation (3).

\[ S_k = \frac{(n_g-1)}{n} \sum_{j=0}^{k} n_{rj} \]  

Where $S_k$ is the number of gray level levels in the image, $n$ the number of all pixels in the image, $k$ $(0, 1, ..., n_G – 1)$ and $n_{rj}$ are the number of pixels that have a $rj$-gray level.

HE is done by mapping the grayscale image based on the probability distribution of the grayscale input. In this process there is a stretch of the dynamic range of the image histogram and results in a contrast enhancement. HE significantly changes the brightness of the original image which makes some areas of the output image very bright or very dark [14]. HE can be used on grayscale images on matlab by using the histeq function.

4.2 Adaptive Histogram Equalization

Adaptive Histogram Equalization (AHE) increases image contrast by changing the value in the intensity image. AHE operates in a small area in the image. Contrast factor prevents excessive saturation in homogeneous regions which are marked by high peaks in certain image histograms. Adjacent pixels are combined using bilinear interpolation to eliminate artificially induced boundaries. Contrast can be limited to avoiding noise that may exist in the image. Histogram equalization maps input image intensity values so that the resulting image histogram will have an almost uniform distribution. If the variable $r$ represents the gray level of an image to be increased, $T$ is the transformation function and $s$ is the transformed value. Then $s$ can be represented by equation (4) as follows:

$$s = T(r) = \int_0^r P_r(w)dw$$

(4)

If $p_r$ and $p_s$ represent the function of the probability density $r$ and $s$. Then $p_s$ can be obtained by applying equation (5) as follows:

$$p_s(s) = p_r(r) \left| \frac{dr}{ds} \right|$$

(5)

With the $T(r)$ transformation function we can get $p_s$ so that $p_s(s)$ follows an almost uniform distribution that produces an equalized image histogram.

5. PSNR

The quality of a processed image can be measured using the Peak Signal to Noise Ratio (PSNR) with dB units. Basically, PSNR is a simple pixel-based comparison method. PSNR is used to evaluate which coding method produces better results. PSNR can be calculated by equation (6):

$$PSNR = 20 \times \log_{10} \left( \frac{255}{\text{rmse}} \right)$$

(6)

6. The proposed method

There are several methods proposed and in the whole method there are several stages or processes. In general, the process carried out for the first time is the process of data acquisition, data acquisition is the process of collecting and retrieving datasets. The next process is the image compression process using the Discrete Wavelet Transform (DWT) algorithm. This compression process begins with the input image that is going to be compressed. Next, the image is decomposed and compressed. The next stage is to reconstruct the image that has been compressed and finally obtained a decompressed image with a reduced size.

After the compression process is carried out, the image quality improvement process will be carried out. In the image repair process there are several stages, the first step is entering the original image based on RGB, RGB is an image consisting of three colors, namely red, green and blue. Then, the image is converted to grayscale image, grayscale image is an image consisting of gray levels. After being converted to grayscale image, the image quality is improved using two methods. The first method of image improvement uses histogram equalization, the second method uses adaptive equalization histogram. The results of the two improvements to the image will be converted to binary image, binary
image is an image consisting of two colors, black and white. From the entire process of image improvement, the results are obtained for analysis and subsequent processing.

The next process is the edge detection process, the edge detection process is proposed using the canny edge detection method. Some edge detection techniques are Canny, Roberts, Prewitt and Sobel. However, the Canny algorithm has the best performance [15]. The Canny algorithm uses optimal edge detection with criteria finding the most edges and minimizing error rates, marking the edges only once and marking the edges as much as possible to the actual edge to maximize localization. Canny finds the edge by isolating noise from the image before finding the edge of the image without affecting the edge features of the image and finding the critical value for the threshold. Before doing edge detection, the image is converted from grayscale image to binary image, the process has been carried out in the image quality improvement process, this is done to avoid the operator detecting the eyelashes found in the iris. After that, the edge detection process can be done using the canny operator, then the results are obtained in the form of binary images with iris circumference that has been detected.

7. Result and Discuss

Table 1 is the result of image compression using the DWT algorithm using level 1 decomposition:

| No. | Initial Size (kb) | Final Size (kb) | CR  | Percentage |
|-----|-------------------|-----------------|-----|------------|
| 1   | 35.5              | 27.9            | 1.27| 21.41%     |
| 2   | 37                | 29.4            | 1.26| 20.54%     |
| 3   | 35.9              | 28.4            | 1.25| 20.89%     |
| 4   | 25.4              | 19              | 1.33| 25.20%     |
| 5   | 28                | 19              | 1.47| 32.14%     |
| 6   | 36.3              | 28.6            | 1.26| 21.21%     |
| 7   | 20.1              | 16.4            | 1.22| 18.41%     |
| 8   | 29.9              | 24.2            | 1.23| 19.06%     |
| 9   | 24.3              | 20              | 1.21| 21.41%     |
| 10  | 31.8              | 25.1            | 1.26| 20.54%     |
| 11  | 40                | 31.8            | 1.25| 20.89%     |
| 12  | 40.9              | 32.3            | 1.26| 25.20%     |

| Average | 1.27 | 22.24% |

The DWT decomposition level used in compression is level 1. The initial image is inputted and then the decomposition level is selected, i.e. level 1. The image is then compressed and reconstructed to get the final image size. The efficiency of compressed images can be measured using Compression Ratio (CR). CR is obtained through the comparison of the initial image size ($b_{in}$) and the final image size ($b_{out}$). The CR value like 1.27 means that the initial image has 1.27 kb of information carrier for every 1 kb in the decompressed image. In table 1 it can be seen that all initial image datasets were successfully compressed using the DWT algorithm with an average CR of 1.27 and the percentage of compression results of 22.24% of the initial image. This decomposition result shows a high level of success in the application of DWT. The results of the test indicate that the average PSNR value is above 50 dB and the error value is close to 0, so that only 1 decomposition level is chosen. Level 1 computing process is faster than other levels. Therefore, level 1 is chosen as the decomposition level of this image compression and the decomposed image is used for the next stage, namely image improvement.

Table 2 is an example of 4 (four) iris images that present the results of image improvement using the HE method and compared with the AHE method, as well as comparison of the results of edge detection using HE and AHE.
Table 2. The results of image quality improvement and edge detection for HE and AHE

| No. | HE Image | HE Edge Detection | AHE Image | AHE Edge Detection |
|-----|----------|-------------------|-----------|--------------------|
| 1   | ![HE Image](image1.png) | ![HE Edge Detection](image2.png) | ![AHE Image](image3.png) | ![AHE Edge Detection](image4.png) |
| 2   | ![HE Image](image5.png) | ![HE Edge Detection](image6.png) | ![AHE Image](image7.png) | ![AHE Edge Detection](image8.png) |
| 3   | ![HE Image](image9.png) | ![HE Edge Detection](image10.png) | ![AHE Image](image11.png) | ![AHE Edge Detection](image12.png) |
| 4   | ![HE Image](image13.png) | ![HE Edge Detection](image14.png) | ![AHE Image](image15.png) | ![AHE Edge Detection](image16.png) |

Table 2 is the result of the appliance of HE and AHE in attempt to improve image quality and edge detection. In the HE image column displays the image that has been converted from the original image (RGB) to the grayscale image and the image quality improvement process is performed using the histogram equalization method. In the AHE image column displays the image that has been converted from the original image (RGB) to a grayscale image and the image quality improvement process is performed using the adaptive histogram equalization method. The PSNR results using the histogram equalization method and the equalization of the adaptive histogram are presented in table 3.

Table 3. Comparison of PSNR results between the HE and AHE methods

| No. | PSNR |
|-----|------|
|     | Histogram Equalization (dB) | Adaptive Histogram Equalization (dB) |
| 1   | 16.4137 | 18.3682 |
| 2   | 18.5706 | 16.8378 |
| 3   | 17.5973 | 17.3138 |
| 4   | 16.4926 | 18.2768 |
| 5   | 15.8011 | 17.6035 |
| 6   | 19.2336 | 17.1331 |
| 7   | 16.1131 | 15.2023 |
| 8   | 15.9514 | 16.7503 |
| 9   | 16.4380 | 17.9481 |
| 10  | 17.1722 | 16.1297 |
| 11  | 14.4313 | 16.4849 |
| 12  | 16.9324 | 15.3230 |
|     | Average | 16.76 | 16.95 |
8. Conclusion
The results of different experimental comparison can be seen if the AHE method is more suitable for research that requires data with patterns because it produces high contrast. While the HE is more suitable for research that requires image segmentation. Canny edge detection method with HE image quality improvement has a firmer, more organized image and has less noise so that the edge detection of this image will be effectively used for image segmentation, while canny edge detection using the adaptive histogram equalization process displays images with more noise but features the characteristics are more assertive than the results of the canny edge detection using histogram equalization. This results in the adaptive histogram equalization are more preferable in feature extraction and image segmentation. Performance with PSNR results in an average PNSR value for the HE method of 16.76 while the AHE is 16.95.

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