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Preprocessing on Digital Image using Histogram Equalization: An Experiment Study on MRI Brain Image

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***Abstract*— In the medical world, MRI is one example for application of digital images. But for some application, for get the desired result, MRI image must be processed first through image processing process. Preprocessing is the first step for digital image processing. Some of preprocessing method that use in this experiment is Histogram Equalization (HE) and Contrast Limited Adaptive Histogram Equalization (CLAHE). To increase the image contrast is the purpose of that method and the result will be analyse for quantitaitve value using RMS Contrast, PSNR and SSIM method.**

***Keywords*— Preprocessing, HE, CLAHE, RMS Contrast, PSNR, SSIM.**

I. Introduction

Utilization of MRI images for patients diagnosis has been no longer a new thing. Sometimes firstly MRI images must processed to obtain better view for analysis or other porpuse.

In the process of digital image processing such as segmentation, clustering, pattern recognition, and others, there are initial step that must be passed first so that the image processing obtain maximum results, it called preprocessing.

Preprocessing is an early stage of digital image processing. The goal is to improve the quality of the processed image. In the case of digital image processing, there are many known preprocessing techniques, one of them is histogram equalization (HE) and its variant Contrast Limited Adaptive Histogram Equalization (CLAHE). The purpose of HE and CLAHE is to improve image contrast.

II. Literature Review

A. Digital Image

Digital image formed by a collection of points called pixels (picture elements). Each pixel is described as a small box and has the coordinates position.

Digital image processing refers to processing digital image using a computer as a tool. According Efford [1], the image processing is a general term of various techniques for manipulating and modifying the image in various ways.

B. MRI

Magnetic Resonance Imaging (MRI) is a medical device in the diagnostic radiology examinations field, which produces crosssectional slice image recording body / organ by using a magnetic field at strength between 0.064 to 1.5 tesla (1 tesla = 1000 Gauss) and resonant vibration of the hydrogen atom core [2].

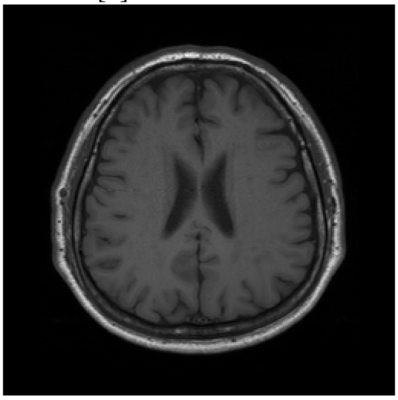


Fig. 1. An MRI Brain Image

Using MRI have several advantages factors, it have an ability to make a coronal slice image (top), sagittal (front), axial (side) and obliquely without manipulating the patient's body position and it is suitable for soft tissue diagnostics.

C. Histogram

Histogram of a digital image with a scale of gray in the range [0, L1] has a discrete function h $(r_k) = n_k$, where r_k is the rate scale of gray and n_k is the number of pixels in the image that has scale levels of gray r_k.

Histogram is the basis of several processing techniques with spatial domain. Settings histogram can be effectively improve quality of the image.

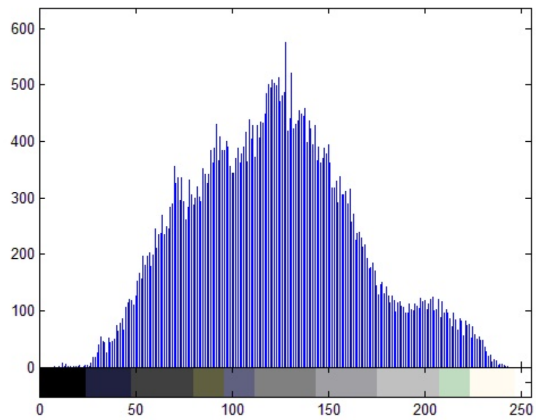


Fig. 2. A histogram of an image

D. Histogram Equalization (HE)

Histogram Equalization (HE) is a very popular technique for improving image contrast [3][4]. Previously, this image contrast enhancement technique has been applied to the image of man and the natural scenery with good results [5]. HE is a process that changing the distribution of gray scale value in an image so that it becomes uniform. The goal is to obtain a uniform spread of the histogram so that each gray scale value has a relatively equal number of pixels. Flattening histogram obtained by changing the gray scale of a pixel (r) with the new one gray scale (s) with a transformation function T [6]. Mathematically can be written by the equation: s = T (r). r can be recovered from s with inverse transformation as in the equation:

$$r = T^{-1}(s) \tag{1}$$

Where 0 <s <1. The equation used to calculate the HE can be written as follows:

$$K_0 = round\left(\frac{C_i(2^k - 1)}{w.h}\right) \tag{2}$$

Where:

C_i = the cumulative distribution of i^{th} grayscale from original image

round = rounding to the nearest value

K_0 = gray level value from histogram equalization

w = width of the image

l = height of the image

This method is also useful for images with both background and foreground are bright or both dark. Particularly, this method provides a better view of the bone structure in the xray image in the biomedical world, producing clear and detail of the images[7].

E. Contrast Limited Adaptive Histogram Equalization (CLAHE)

Unlike the histogram equalization technique that works directly on the image overall, CLAHE work on a part a small part of the image called as *tiles*. Equalization done in each tile, after that adjacent tile combined using bilinear interpolation to remove boundary edge occurs and to avoid the strengthening of noise that may be present in the image, CLAHE use a parameter to limit the image contrast, especially in homogeneous areas.

F. Image Quality Metrics

Image quality metrics have become quite popular in the field of digital image processing. However, so far no one is able to define with good correlation to the imagequality according to general perceptions, One reason is that the image quality is a complex and multidimensional [8]. An approach used to bridge the gap between the perception and calculate is by reducing the complexity of the image quality with breaking the general quality into a quality attribute.

Although in the end, the image quality is determined by the humans perception, various methods have been developed with the aim to measure the quality of it, some methods with the objective quality measurements require a reference image (distorsionfree image) that can be used to compare with the image of the measured quality. Some methods such as PSNR and SSIM requires that dimensional matrix of a reference image and object image must be equal.

G. Peak signal-to-noise ratio (PSNR)

PSNR is a technical term for the ratio between the maximum value of the signal measured and the amount of noise that affects the signals. Because of some signal has a very wide range and dynamic, PSNR is usually measured in decibels (dB). PSNR generally used to determine the quality of the image that has been processed for example compression or noise added.

To determine the PSNR, the first is MSE (Mean Square Error) must be determined. MSE is the average mean squared error value between the initial image (noisefree) and the final image / processed, mathematically formulated as follows:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) \quad K(i,j)]^2 \tag{3}$$

Where:

MSE = Mean Square Error Value

mn = Matrix image

I = the pixel values of the initial image

K = the value of the pixel of the final image

After MSE obtained, the PSNR value can be calculated from the square maximum value divided by MSE. Mathematically PSNR (dB) is formulated as follows:

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right) \tag{4}$$

MAX_I is the maximum value of the pixel image is used (eg 8 bit pixels, $MAX_I = 2^8 - 1 = 255$).

H. SSIM

Structural Similarity Index (SSIM) is a method to determine the quality of a digital image or video, developed at the Laboratory for Image and Video Engineering (LIVE) at the University of Texas, Austin in collaboration with New York University. Developed by Zhou Wang et al in a paper entitled Image quality assessment: From error visibility to structural similarity [9]. SSIM is used to measure the similarity between the two images. SSIM index is a full reference matric, in other words the measurement or prediction based on the image quality of the initial image (the image that has not been compressed / image that is free from noise) as a reference. SSIM made to improve existing methods such as peak signal-to-noise ratio (PSNR) and mean squared error (MSE) which that both methods proved to be inconsistent compare with human visual perception.

SSIM index calculated in some *window* in the image. Measurements between two window x and y with NxN size is:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \tag{5}$$

where:

μ_x = average x

μ_y = average y

σ_x^2 = variance x

σ_y^2 = variance y
σ_{xy} = covariance x dan y
c_1 = $(k_1 L)^2$
c_2 = $(k_2 L)^2$
L = pixel value range $(2^{\#bit\ per\ pixel} - 1)$
k_1 = 0.01
k_2 = 0.03

SSIM index value is a decimal value between -1 and 1. A value of 1 is only obtained in the two datasets are identical. *Window* can be replaced as *pixel by pixel* in the image.

I. RMS Contrast

Root Mean Square (RMS) contrast is defined as the standard deviation of pixel intensity [10].

$$\sqrt{\frac{1}{MN}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}(I_{ij}-\bar{I})^2} \quad (6)$$

Where I_{ij} is the intensity of the element to i and j on 2dimensional image with M x N size. I is intensity average of all pixels values in the image. Image I assumed an intensity image pixel is normalized to the range [0,1].

III. Research Methodology

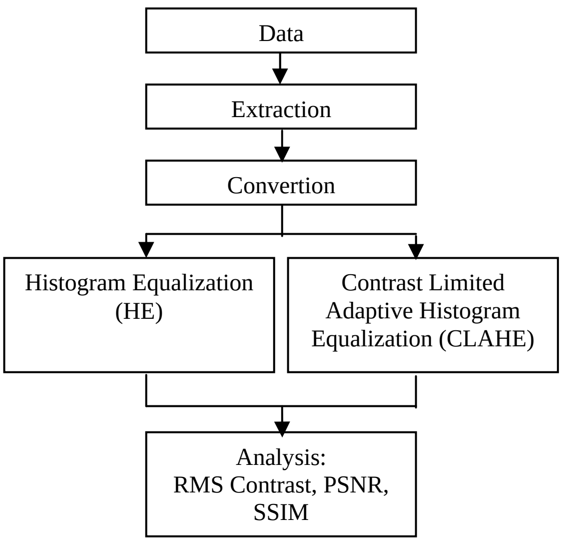
I. Data

The data used in this research is secondary data, image file on the brain MRI scan engine that uses DICOM format (.dcm).

II. Method

Data in the form of MRI image is extracted first, then converted into a format that supported by software. After that, the image preprocessing performed by two techniques, Histogram Equalization (HE) and Contrast Limited Adaptive Histogram Equalization (CLAHE). Furthermore, the quantity measured with RMS Contrast, PSNR and SSIM.

III. Flow Diagram



IV. Experimental Result

A. Data

The data used is a digital file that contains an image of the human brain taken by an MRI machine and stored using DICOM format (.dcm). As for some information about the file can be seen in Table 1.

TABLE I MRI IMAGE FILE INFORMATION

Manufacturer	
InstitutionName	
ReferringPhysicianName	
CodingSchemeDesignator	DCM
PixelPresentation	MONOCHROME
AcquisitionContrast	T1
PatientName	
PatientID	3425
PatientBirthDate	19520918
PatientSex	M
PatientWeight	86
MRAcquisitionType	2D
MagneticFieldStrength	1.5
SpacingBetweenSlices	6
NumberOfFrames	20
Width	256
Height	256
Rows	256
Columns	256
BitsAllocated	16
BitsStored	12

Based on the information in Table I. There is some information, such as MRI machine manufacturers, hospitals or health care facilities where medical action performed, the medical officer or doctor in charge, and information about patients examined, and others others. Saved in the DICOM format that produces an image in monochrome / grayscale type.

MRI machines are used for capturing data using a magnetic field strength at 1.5 Tesla or 1500 Gauss (1 Tesla = 1000 Gauss). Type T1 contrast acquisition produces 2D (two dimensional) MRI images with number of frame is 20 slice, distance between frame2 6 mm. Dimensions area 256 x 256 mm², stored in 256x256 pixel.

B. Extraction

The extraction process is done to extract initial data in the form of a file that contain 20 MRI image data into 20 files eachs containing an MRI image. This is done because the data will be processed individually not as a group.

C. Convertion

Once data is extracted, and then do the conversion is to convert data format from Dicom (.dcm) to Tagged Image File format (.tif). Data format conversion is done because of the software that can not process the Dicom image files directly.

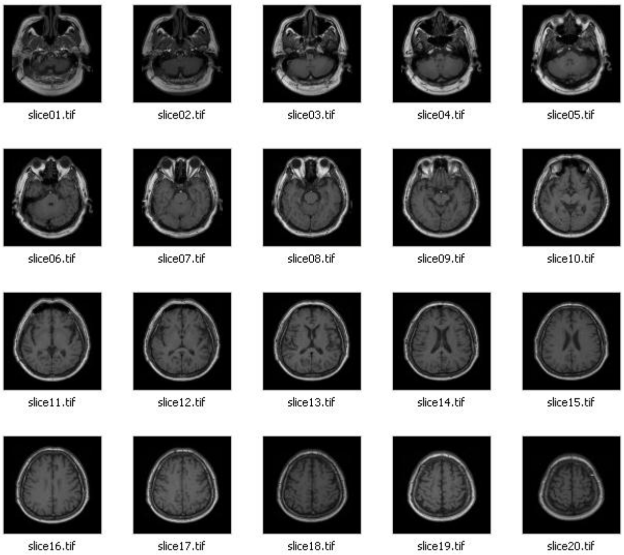


Fig. 3. Extracted and converted MRI Image files

D. *Histogram Equalization*

In this process, eachs image files (20 files) processed using HE technique and CLAHE. One of the example results can be seen in the following figure:

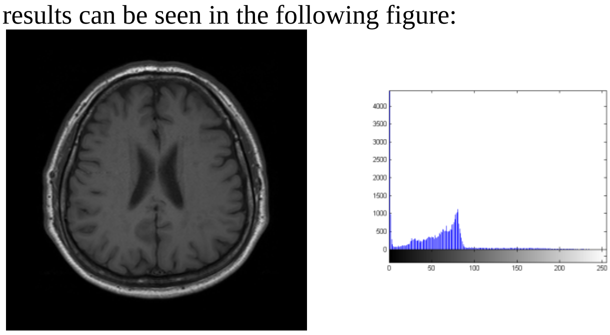


Fig. 4. Original Image an its histogram

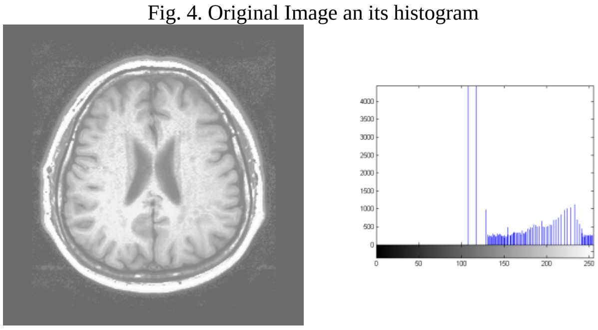


Fig. 5. Histogram Equalization result

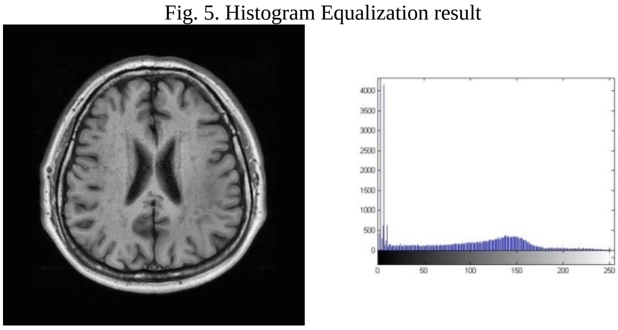


Fig. 6. CLAHE result

From Figures 4, 5 and 6 above, it can be seen that the image with equalization histogram has more spread histogram distribution than the input image, the spread of gray scale value, image becomes more brighter and detail more visible.

E. *RMS Contrast*

Based on the contrast measurement results using RMS contrast method, it appears that by performing histogram equalization can increase the contrast value in the image. The average contrast value of the original image increase from 0.042 into 0.062 (HE) and 0.101 (CLAHE), with a higher increase in using CLAHE. Contrast

measurement results can be seen in table II and graph contrast image in Figure 7.

TABLE II RMS Contrast calculation result

Image No.	**RMS Contrast**		
	input	**HE**	**CLAHE**
Citra 1	0.046	0.083	0.142
Citra 2	0.114	0.144	0.232
Citra 3	0.063	0.071	0.151
Citra 4	0.081	0.098	0.181
Citra 5	0.014	0.015	0.035
Citra 6	0.015	0.018	0.044
Citra 7	0.009	0.013	0.027
Citra 8	0.012	0.020	0.037
Citra 9	0.046	0.095	0.138
Citra 10	0.075	0.124	0.204
Citra 11	0.016	0.015	0.033
Citra 12	0.066	0.102	0.129
Citra 13	0.039	0.034	0.089
Citra 14	0.056	0.113	0.139
Citra 15	0.034	0.070	0.098
Citra 16	0.032	0.050	0.068
Citra 17	0.029	0.041	0.057
Citra 18	0.025	0.047	0.075
Citra 19	0.026	0.026	0.037
Citra 20	0.043	0.055	0.101
Min	**0.009**	**0.013**	**0.027**
Max	**0.114**	**0.144**	**0.232**
Average	**0.042**	**0.062**	**0.101**

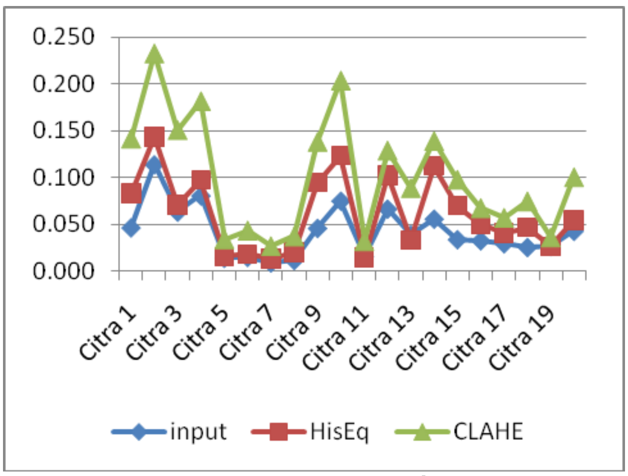


Fig. 7. RMS Contrast Value

F. PSNR and SSIM

PSNR and SSIM value can be seen in Table III.

TABLE III
PSNR and SSIM value

Image No.	PSNR		SSIM	
	HE	CLAHE	HE	CLAHE
Citra 1	7.285	15.644	0.295	0.550
Citra 2	6.742	15.322	0.243	0.522
Citra 3	7.446	16.124	0.303	0.580
Citra 4	7.548	16.309	0.281	0.572
Citra 5	7.623	16.638	0.285	0.580
Citra 6	7.437	16.827	0.283	0.568
Citra 7	7.701	17.149	0.301	0.579
Citra 8	7.865	17.447	0.313	0.588
Citra 9	7.906	17.100	0.322	0.588
Citra 10	7.826	16.496	0.328	0.578
Citra 11	7.624	16.760	0.314	0.568
Citra 12	7.503	16.325	0.309	0.558
Citra 13	7.429	16.252	0.311	0.556
Citra 14	7.164	16.469	0.288	0.543
Citra 15	6.632	16.535	0.269	0.540
Citra 16	7.128	17.174	0.295	0.547
Citra 17	6.959	17.516	0.290	0.541
Citra 18	5.805	16.702	0.216	0.508
Citra 19	6.368	17.505	0.246	0.529
Citra 20	5.183	17.605	0.179	0.498
Average	**7.159**	**16.695**	**0.284**	**0.555**

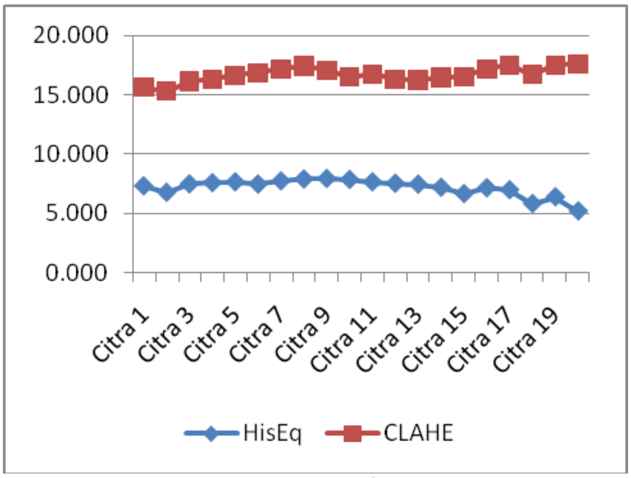


Fig. 8. PSNR value

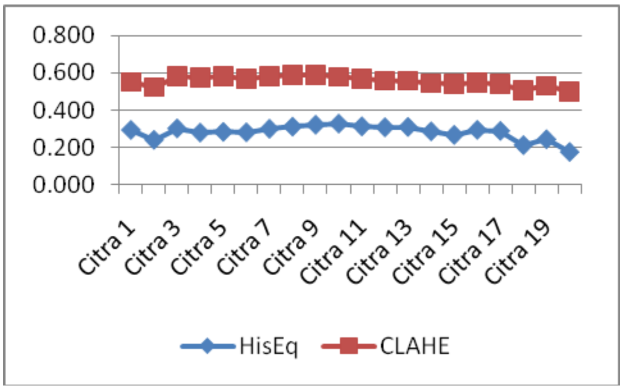


Fig. 9. SSIM value

V. CONCLUSION

From the experiments results that have been done, preprocessing on MRI brain images using HE and CLAHE provide images with higher contrast if contrast calculated using RMS Contrast.

Contrast Limited Adapted Histogram Equalization (CLAHE) method quantitatively produce more higher value than Histogram Equalization (HE), for Contrast, PSNR or SSIM.

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