Quality of Image Processing Using Various Image Enhancement Methods for MRI Images

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**Abstract.** In the world of health, medical imaging is critical for correctly extracting important data as information which can be used to track the patient’s condition and giving the right treatment decision. The level of diagnostic accuracy can be increased by providing high-quality images. This paper presents image enhancement, by using HE, CLAHE, and Otsu Thresholding. To assess its efficacy, those three algorithms are run on a group of MRI images. Furthermore, various variables, including PSNR, AMBE, and SSIM are used as parameters to demonstrate the greater performance among all algorithms. The purpose of this experiment is to identify which is the best image enhancement method for MRI images. After comparing three distinct methods, CLAHE turned out to be the best enhancement MRI images in this experiment with the lowest AMBE value of 24,8134551 and has the highest similarity index of 0,5360092.

**Keywords:** Image Processing, Image Enhancement, HE, CLAHE, Otsu Thresholding, MRI Image

# INTRODUCTION

Medical Resonance Imaging (MRI) scan is a result image that uses computer-generated radio waves and a magnetic field that shows a detailed illustration of tissues, organs, and internal structures of the human body. The MRI equipment generates a powerful magnetic field, which aligns the atoms of the human body in one direction. After that, the machine emits radio waves that cause the atoms to depart from their initial position. The atoms return to their original position as the radio waves are turned off and then radio signals are received by the computer. The computer converts the signals into MRI images. In recent days, MRI has become a reliable technology used by medical workers to create diagnostics and support decision-making [[1](#_ENREF_1)].

MRI images are usually still affected by artifacts and noise, particularly those that are stored in cloud storage. The other challenges are low contrast between tissues and inter-individual variability and non-uniform distribution of the image intensity. This is clinical because it can have an impact on the accuracy of the medical diagnosis. These shortcomings would also affect the computer-aided design (CAD) tools for data analysis, such as 3-D image reconstruction and the classification of disease. Therefore, image enhancement is a good approach to removing noise and adjusting the quality of MRI images. At the same time, it preserves the details of the image.

Image enhancement is a process of highlighting a specific part of an image to be strengthened or weakened. The objective is to make the visual interpretation of an image easier. An example of image enhancement is noise elimination, level adjustment, and revealing blurred details. The key to comprehending image enhancement is to understand the image histogram. An image is a representation of a histogram. Every pixel in an image has a brightness value from 0 to 255 called intensity shown on the x-axis. Meanwhile, the y-axis denotes the frequency of the brightness value that appears.

There are two main image enhancement methods, the first on spatial domain processing and the second on frequency domain processing. The updated histogram and unsharp mask methods used by the spatial domain method are used to process the pixels in the image. The frequency domain processing method modifies the image into a frequency domain and transforms it using the Fourier transform, discrete wavelet transforms, and discrete cosine transform. The image is then converted into the original image space [[2](#_ENREF_2)].

In this paper, various image enhancement methods in medical images are implemented to process the images. This experiment aims to compare the effectiveness of various image enhancement methods in enhancing the image and allow health workers to see detailed and fewer noise images to make it suitable for medical applications. Medical images, particularly those which are captured and sent via messengers or the internet, can have less quality than the actual ones. This study is divided into five sections: section 1 is an introduction, section 2 discusses earlier papers, and section 3 outlines the approach method in this paper. Section 4 gives the evaluation metrics used to examine the experiment, followed by Section 5 which explains the experimental outcomes and section 6 to concludes the experiment.

# Related Works

In recent years, there have been several studies that have developed image enhancement based on spatial domain and frequency domain processing to increase image quality. In order to raise the quality of image, researchers have proposed numerous approaches to assist the medical environment. For example, in [[3](#_ENREF_3)], different methods using Genetic Algorithm based Adaptive Histogram Equalize (GAAHE) for medical image enhancement is proposed using the exposure threshold and optimal threshold to maintain the brightness and minimize the information loss. Zhao et al [[4](#_ENREF_4)] also introduced a new contrast and details improvement approach based upon luminance-level modulation and gradient modulation (LM&GM) is two-stage techniques that first boosts visual perception by compressing the range of luminance levels in the input using LM operation and utilizes the GM to enhance the images. V. Anoop and P. R. Bipin [[5](#_ENREF_5)] uses a bilateral filter (BF) to remove different noise, including impulse noise and Rician noise on MRI images and applies enhanced grasshopper optimization algorithm (EGOA) to optimize the BF parameters.

# METHODS

There are several image enhancement techniques that could help to make Medical Image look smooth and improve the information perception of the images. Therefore, edge or contrast enhancement enhances an image for human viewer evaluation. Many of the techniques including Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE), and Otsu’s Thresholding.

## HISTOGRAM EQUALIZATION (HE)

Histogram of an image denotes how much intensities each pixel in the image occurred. The value ranges from 0 to 255, where 0 indicates that the color is completely black. Conversely, 255 indicates that the color is completely white. [[6](#_ENREF_6)] In computer vision, a technique called histogram equalization is commonly used to increase an image's contrast by altering its intensities. The histogram's dynamic range is widened by this method. Each sample image is denoted with pixels. Probability mass function (PMF) of each intensity in gray-level value is calculated. [[7](#_ENREF_7)]The PMF is defined as

(1)

After having the PMF of each intensity, the histogram equal level can be calculated. The histogram equal level is defined with .

(2)

denotes the cumulative distribution function (CDF). The CDF are the result of PDF along i and j summed. The value of is rounded to the nearest upper integer. Then, construct the histogram from the values of histogram equal level.

## CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION (CLAHE)

The Adaptive Histogram Equalization (AHE) is different from the original histogram equalization because this technique is using an adaptive method that enhance the contrast locally, meaning that the image is divided into blocks and the histogram for each block are computed. Therefore, AHE resulted in computing many histograms for each segment of the image. In AHE, the technique depends on the neighborhood pixel values because each pixel depends on the histogram of the square surrounding pixels [[8](#_ENREF_8)].

To enhance low contrast medical images, CLAHE, or Contrast Limited Adaptive Histogram Equalization, was originally developed. The scope of Adaptive Histogram Equalization has been expanded (AHE). This technique's enhancement function is created by segmenting the image into smaller areas, applying it to all nearby pixels, and deriving a transformation function. The contrast limiting is where CLAHE differs most from AHE; in order to restrict the amplification, CLAHE tends to clip the histogram at a user-defined number called clip limit. By observing the clipping level, it demonstrates how much the contrast should be improved and how much noise in the histogram should be smoothed. [[9](#_ENREF_9)].

## OTSU THRESHOLDING

Otsu method is a binary thresholding method to differentiate the image into two segments: foreground and background. Otsu thresholding seeks for the threshold value to minimize the within-class variance, which is the weighted sum of variances among the two classes. The method itself is a statistical method, because it depends on the values obtained from the histogram.

Using this technique, the image is divided into two regions, light region and dark region . The set of intensities for and where t is the selected threshold value and l is the highest level of gray. The Otsu thresholding method scans all possible thresholding values to obtain the minimum value for the pixel levels on either side of the threshold. Finding the threshold value with the lowest total foreground and background entropy is the goal. By reducing the weighted group variances, where the weights correspond to the probability of the various groups, the optimal threshold value can be found [[10](#_ENREF_10)]. The following formula is used to determine a threshold t's within-class variance:

(3)

where and respectively represents the sum of background and foreground pixels at threshold t, represents the sum of all pixels in the image, and represents the variance of the color values [[11](#_ENREF_11)].

# Evaluation Metrics

There are many Images Quality Assessment (IQA) techniques to help us to measure the accuracy of image enhancement. Multiple objective image quality metrics are used in MRI, including PSNR, AMBE, and SSIM.

## PEAK SIGNAL-TO-NOISE RATIO (PSNR)

MSE is used to represent noise in the Peak Signal-to-Noise Ratio (PSNR) method, which is the most popular and frequently used IQA technique. The PSNR formula determines the relationship between the greatest amount of image power and the power of picture-corrupting noise. According to [[12](#_ENREF_12)], the PSNR formula is as follows:

(4)

where L denotes the number of maximum intensity levels in the image and the root mean squared error, which is derived the average of the squared pixel intensity differences between the distorted and the reference image. RMSE is defined as follows:

(5)

where is the pixel value in the original image, is the pixel value in the equalized image, and the n denotes the number of the observed images.

## ABSOLUTE MEAN BRIGHTNESS ERROR (AMBE)

The absolute difference between the mean of the original image's pixels and the equalized image's pixels is known as AMBE. The AMBE formula is as shown below:

(6)

AMBE was proposed by Soong-Der Chen and A.R. Ramli. The method is invented to detect distortions-excessive brightness change [[13](#_ENREF_13)].

## STRUCTURAL SIMILARITY INDEX (SSIM)

SSIM is measurement used to identify the similarity between two images. This method compares two images based on the three key features: structure, contrast, luminance. According to the originator, SSIM corresponds well with perceptual image quality and outperforms the prior sophisticated human visual system-based metrics. [[14](#_ENREF_14)]The method calculates the structural similarity index in each two images.

Hence, the value of similarity index is between -1 and +1. The value -1 indicates both images are not similar and the value +1 indicates that both images are similar. The formula for key features is as shown below:

(7)

Where stands for luminance, for contrast, for structure, and is defined as:

(8)

By combining those three key features together, the SSIM formula is obtained:

(9)

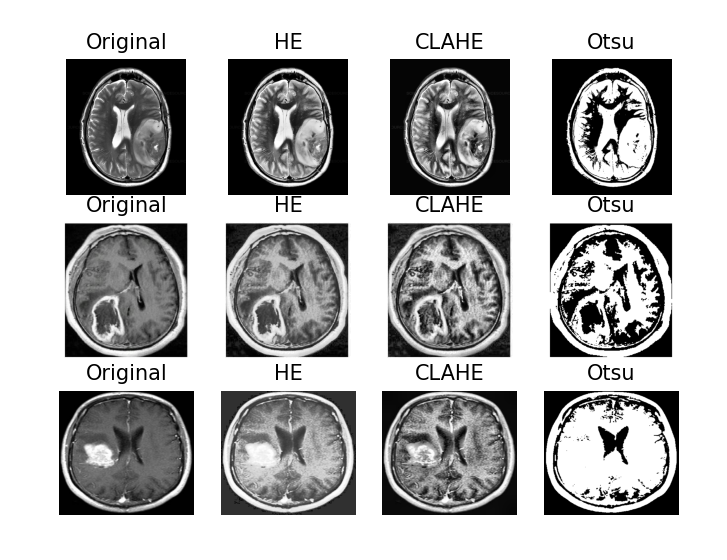
# RESULTS AND DISCUSSION

## DATA SET

In order to obtain the experimental result of the several histogram equalization techniques, 78 MRI images are used. All the images are obtained from the Brain MRI Images for Brain Tumor Detection. Brain MRI Images for Brain Tumor Detection dataset is available in the Kaggle website.

## QUANTITATIVE ANALYSIS

In this section, the result of image enhancement using HE, CLAHE, and Otsu’s Thresholding will be evaluated using the evaluation metrics defined.



**FIGURE 1.** Results of enhanced image using various image enhancement techniques.

As seen in FIGURE 1, there are three images out of 78 images in the MRI images data set that are being shown as a sample. The initial row displays the original picture. The image is displayed in the second row following the application of histogram equalization. Followed by the third and fourth row where the CLAHE and the Otsu Threshold are performed to the original image.

Furthermore, to see the performance of the image enhancement methods in a numerical approach, several evaluation metrics such as PSNR, AMBE, and SSIM are performed to evaluate the proposed work. The results are shown in TABLE I for the Histogram Equalization, TABLE II for the CLAHE, Table III for the Otsu Threshold, and the last TABLE IV for the average Quality Assessment from each table.

**TABLE I**. Performance analysis based on the Histogram Equalization

|  |  |  |  |
| --- | --- | --- | --- |
| TEST | Quality Assessment Techniques | | |
| **PSNR** | **AMBE** | **SSIM** |
| 1 | 27,807514 | 51,736239 | 0,592593 |
| 2 | 28,241274 | 20,720794 | 0,791975 |
| 3 | 28,072617 | 76,12058 | 0,431916 |
| 4 | 28,177545 | 68,748998 | 0,386631 |
| 5 | 27,742827 | 54,240653 | 0,563814 |
| 6 | 28,703655 | 20,26401 | 0,830086 |
| 7 | 28,405866 | 32,594941 | 0,723888 |
| 8 | 32,041932 | 6,442376 | 0,968242 |
| 9 | 28,173114 | 44,050731 | 0,649285 |
| 10 | 28,617289 | 54,260139 | 0,546805 |

**TABLE I** presents the performance analysis results for Histogram Equalization. The test quality assessment range for PSNR is nearly 27,742827 to 32,041932, for AMBE is approximately 6,442376 to 76,12058, and for SSIM is around 0.386631 to 0.968242.

**TABLE II**. Performance analysis based on the CLAHE

|  |  |  |  |
| --- | --- | --- | --- |
| TEST | Quality Assessment Techniques | | |
| **PSNR** | **AMBE** | **SSIM** |
| 1 | 27,77195 | 25,39554 | 0,531576 |
| 2 | 28,7044 | 6,260623 | 0,767581 |
| 3 | 27,767328 | 33,731427 | 0,515743 |
| 4 | 27,60777 | 28,686101 | 0,491434 |
| 5 | 27,795984 | 26,975798 | 0,552335 |
| 6 | 28,227072 | 11,158253 | 0,672614 |
| 7 | 28,072367 | 23,784254 | 0,599607 |
| 8 | 29,508348 | 0,315705 | 0,618924 |
| 9 | 27,922856 | 19,095395 | 0,606613 |
| 10 | 28,52846 | 18,261848 | 0,479698 |

**TABLE II** includes the CLAHE performance analysis results. The test performance assessment area for PSNR is at about 27,60777 to 29,508348, for AMBE is around 0,315705 to 33,731427, and for SSIM is between 0,479698 to 0.767581.

**Table III**. Performance analysis based on the Otsu Thresholding

|  |  |  |  |
| --- | --- | --- | --- |
| TEST | Quality Assessment Techniques | | |
| **PSNR** | **AMBE** | **SSIM** |
| 1 | 29,278255 | 53,89735 | 0,36774 |
| 2 | 27,897864 | 39,714707 | 0,32241 |
| 3 | 29,182599 | 98,569286 | 0,32524 |
| 4 | 29,659136 | 77,77501 | 0,50674 |
| 5 | 27,51071 | 78,087204 | 0,23491 |
| 6 | 28,24933 | 47,114824 | 0,36825 |
| 7 | 27,709617 | 33,858048 | 0,11915 |
| 8 | 30,296452 | 34,701388 | 0,63269 |
| 9 | 28,744326 | 80,677846 | 0,38574 |
| 10 | 30,339743 | 56,146381 | 0,44988 |

**Table III** provides the performance analysis results for Otsu Thresholding. The test quality evaluation range for PSNR is about 27,51071 to 30,339743, for AMBE is estimated 33,858048 to 98,569286, and for SSIM is somewhere around 0,11915 to 0,63269.

**TABLE IV**. Average performance analysis based on the HE, CLAHE, and Otsu Thresholding

|  |  |  |  |
| --- | --- | --- | --- |
| Method | Average Quality Assessment Techniques | | |
| **PSNR** | **AMBE** | **SSIM** |
| HE | 28,9603833 | 60,5022434 | 0,5359646 |
| CLAHE | 28,5046158 | **24,8134551** | **0,5360092** |
| OTSU | **29,6498784** | 53,8778261 | 0,4083313 |

By observing the average result performance based on **TABLE IV**, the result shows that CLAHE has the closest similarity value based on the SSIM indicator with 0,5360092 and has the least average AMBE with 24,8134551. Meanwhile the Otsu Threshold has the best average PSNR value with 29,6498784.

# CONCLUSIONS

This work suggested several pictures enhancing techniques, including Otsu's Thresholding, Contrast Limited Adaptive Histogram Equalization (CLAHE), and Histogram Equalization (HE). Each approach is assessed using image quality measurements, including PSNR, AMBE, and SSIM. The result from these experiments shows that the Otsu threshold is the most effective method to provide the best quality MRI images. Based on the evaluation metrics, CLAHE has the best result from SSIM value with 0,5360092 and least AMBE value with 24,8134551. Furthermore, the images produced by CLAHE enhancement have more detail than the original pictures MRI image, which can aid medical analysts in their analysis. Future research should build on the conclusions of this study by adopting new algorithms or acquiring further data.

# Author’s Contribution

The study was conceived and designed by Bryan Felix. The experiments are performed by Bryan Felix and Jeremy Christiandi. The writing is guided by Alexander A S Gunawan. All authors read and approved the manuscript.

# Availability Data and Materials

This study utilized public data from the Kaggle website titled "Brain MRI Images for Brain Tumor Detection” available at https://www.kaggle.com/datasets/navoneel/brain-mri-images-for-brain-tumor-detection.

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