

Contrast Enhancement of Alzheimer's MRI using Histogram Analysis

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Abstract

Contrast enhancement of MRI images frequently needs considerable pre-processing to provide accurate data for disease diagnosis and proper treatment. Enhancing the appearance of medical images becomes a difficult task owing to the uncertainty of the obtained image quality. In this study, Alzheimer's MRI images are subjected to a contrast enhancement algorithm for easy diagnosis. A noise reduction and contrast enhancement technique for MRI images is discussed in this research. Histogram-based algorithms are used to solve the problems of de-noising and enhancing the contrast of images for identification of the infected region. The proposed method is based on contrast-limited adaptive histogram equalization (CLAHE) and the comparison with Histogram Equalization (HE). The suggested enhancement technique's performance can be evaluated using several metrics, including Structure Similarity Index Measure (SSIM), and Peak Signal-to-Noise Ratio (PSNR). Observational studies revealed that the suggested approach is significantly more efficient than the basic enhancement techniques such as HE.

Keywords: Contrast Enhancement, Alzheimer's MRI, Contrast-Limited Adaptive Histogram Equalization, Histogram Equalization, Performance Metrics.

1. Introduction

The majority of diseases that affect the regions of human bodies are generally invisible to human eye. Diagnostics medical images can help with identification by enabling us to view any anomalies within the body (Eg: MRI, CT, PET, etc). Since different modalities generate image files that are noise filled as well as possess low contrast, it is vital to remove the noise and enhance the contrast in medical images to properly extract hidden clinical information. There comes the application of Image enhancement. Image enhancement is the first and most significant phase in image processing to enhance the quality of images and make it easier to diagnose. Medical image processing includes the input medical images, processing, and the resulting outputs. Processing of medical images is done at the initial stage of the procedure to improve the image contrast enhancement. Furthermore, non-contrast MRI scans are more prevalent than contrast MRI scans and are easily accessible for evaluation via open sources ADNI dataset. The lowest contrast is exhibited in the shadow and against a foggy backdrop when the captured images are within a limited range of Light Emitting Diodes. A high contrast has a crucial characteristic for determining if an image is of sufficient quality to suit the needs of the application [1].

The histogram equalization approach is a simplistic yet effective contrast enhancement approach that typically gives high-quality outcomes. Histogram modification approaches attempt to transfer the original image to upgraded results with a more uniform histogram distribution than the original image. HE employs global image enhancement instead of local contrast, ignoring image features at the local level. The CLAHE approach is a kind of local HE. As a result, CLAHE can address the issues of the traditional HE algorithm. The effectiveness of the CLAHE is determined by the number of tiles as well as the clip limit. The provided approaches indicate the need for non-linear brightness modification of the image for contrast enhancement, however, the proposed method reveals more informative images after processing.

2. Related Works

[2] In this study, an image is read from a database that contains a set of cancer MRI images, and the image is then scaled and subjected to CLAHE to get an enhanced image. This method is efficient, fast, and produces excellent outcomes, as subjected in the results.

[3] presented the necessity for nonlinear image brightness modification techniques for contrast enhancement, although additional study is needed for improved images after processing. The suggested HEMIC (histogram equalization with maximum intensity coverage) approach yields a mean value of 2.810 in comparison to the provided image of 17.900. This approach also gives appropriate image contrast and sharpness results.

The STARE dataset is used in [4] to examine image quality improvements utilizing three comparisons. A median filter was used along the contrast stretching approach, HE, and CLAHE. In the research, contrast stretching along with the median filter were utilized in the first comparison. The method of computing the lowest and the maximum values by stretchlim, was used before the grayscale image. MSE and PSNR rates of 9.14 and 42.13 dB were obtained through testing utilizing three unique procedures that are dependent on three different factors.

Selective Apex Adaptive Histogram Equalization (SLAAHE) [5] is a contrast enhancement method that automatically selects the right size of the window for partitioning the low-contrast image into an image grid as well as a clip limit to clip the image's histogram section. The only image visible is the minimum contrast sub-image. The recommended method distinguishes itself by chopping the image histogram. Especially if it is irregularly distributed and increases the overall contrast of the image.

In this study [6], To retain brightness and prevent information loss, a novel subdivision approach for the histogram employs simultaneously the exposure threshold and the ideal threshold. To make the technique more adaptive, the PDF for each sub-histogram is altered to increase image quality.

This study [7], proposes an improved HE technique for non-uniform brightness images called Nonlinear Exposure Intensity-Based Modification Histogram Equalisation (NEIMHE). The proposed approach divides the image into 5 regions as well as modifies its histogram by

calculating CDF. The corrected histograms are then normalized using updated HE that gives improved-intensity and separate intensities connecting directions between underexposed as well as overexposed sub-regions.

3. Methodology

3.1 Histogram Equalization (HE)

It is a basic and most widely utilized method for increasing the contrast of images acquired from the medical field. Equalization is an image enhancement technique that works using image histograms, which are plots of the total amount of pixels allocated to each intensity level to achieve a higher resolution. When the useful data in the image is identified by the closest contrast values, this approach frequently enhances contrast globally. This results in improved contrast over the area of low contrast regions. A histogram simply represents the frequency of occurrence of each grey-level from 0 (black) - 255 (white). The frequency of occurrence across all gray-levels in the image is represented by the histogram, which tells us how the values of individual pixels within an image are distributed. The principle of histogram equalisation depends on the probability distribution of the image's grey-level values

An image i is represented as a discrete function with pixels ranging from 0 to $X-1$. For an 8-bit image, X corresponds to 256.

As a result, the probability of the appearance of grey level g_k

$$P_r(n_k) = n_k/n, \text{ where } k=0,1,2, \dots, X-1$$

g_k = k th grey level of corresponding image

n_k = number of pixels having grey images

n = number of pixels in the image

However, the HE produces artefacts and an overly enhanced image.

3.2 Adaptive Histogram Equalization

Adaptive histogram equalization (AHE) is a contrast enhancement approach that has been shown to be effective as well as broadly applicable. The image is split into small segments called "tiles" in Adaptive Histogram Equalization (AHE) (e.g., 64 tiles (88) is a frequent option). Then, like before, each of these blocks is histogram-equalized. Finally, we use bilinear interpolation to connect each of these components. When an image contains exceptionally dark or brilliant patches, AHE performs better than regular HE. However, because the histogram in such places is extremely concentrated, AHE can overamplify the contrast within near-constant portions of the image. As a result, AHE can cause noise in the near-constant zone to be magnified [8].

Algorithm:

Step 1: Select a grayscale image as input .

Step 2: To prevent border and corner special instances, create an over-sized image along with the values along the boundaries.

Step 3: Initialise every single pixel in the source image to rank 0.

Step 4: Find the rank of each pixels in the original image in its local region (the size of the local area will be provided as input). Pixel rank indicates the number of pixels in the immediate region which are smaller than the centre pixel (the pixel in the source picture on which we are looping).

Step 5: Rank $\times (\text{Max intensity} = 255) / (\text{No. of pixel in localised region})$ produces a new pixel value.

AHE sustains the image's edges and enhances contrast locally. But the major disadvantage is that AHE enhances noise in image areas that are largely homogenous.

3.3 CLAHE

If the pixel values in a block containing noise are more or less consistent, AHE will over-amplify the noise. To overcome this, contrast limiting is used, and the process is known as "Contrast Limited Adaptive Histogram Equalisation"(CLAHE). In a nutshell, CLAHE conducts high-accuracy histogram equalisation in small patches as well as small tiles with contrast limiting. Before implementing histogram equalisation, histogram is clipped at a preset value and distribute it evenly across other regions in CLAHE.

Algorithm:

Step 1: Split the image into blocks or tiles (the number 8 is commonly used).

Step 2: Plot a histogram and decide whether or not to clip.

Step 3: The CDF & transformation function are then computed for each block. The above transformation function is just applicable to the centre pixel of the block.

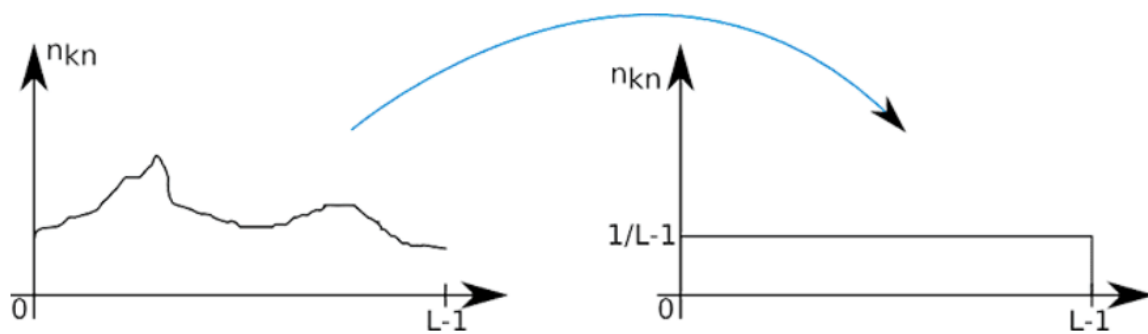


Figure 1. The Histogram Equalization Focus on Results in a Linear CDF for the Output Image. [9]

Step 4: Interpolation is used to alter all of the remaining pixels in relation to the centre pixels.

For a particular intensity, the degree of contrast enhancement is proportional to the slope that defines the CDF function at that intensity level. CLAHE responds to the fluctuating contrast within different sections of this image by locally performing histogram equalization and creating a more visually pleasant outcome than global histogram equalization.

4. Proposed Work

Previous research has found that medical images require enhancement due to the low performance of diagnostic imaging devices. To solve this issue, image enhancement techniques are analyzed. In this proposed work, a comparison is done between Histogram Equalization and CLAHE to justify the performance of contrast enhancement techniques and their importance in analyzing Alzheimer's disease based on its enhanced regions of the hippocampus in MRI images.

Step 1: Load the MRI images from the OASIS dataset (4 classes).

Step 2: Convert the subjected MRI image into a grayscale image.

Step 3: Perform the Histogram Equalization (HE) and CLAHE methods on the MRI to improve contrast.

Step 4: Compute the Histogram of the proposed techniques.

Step 5: The results are compared based on the performance metrics of the subjected images.

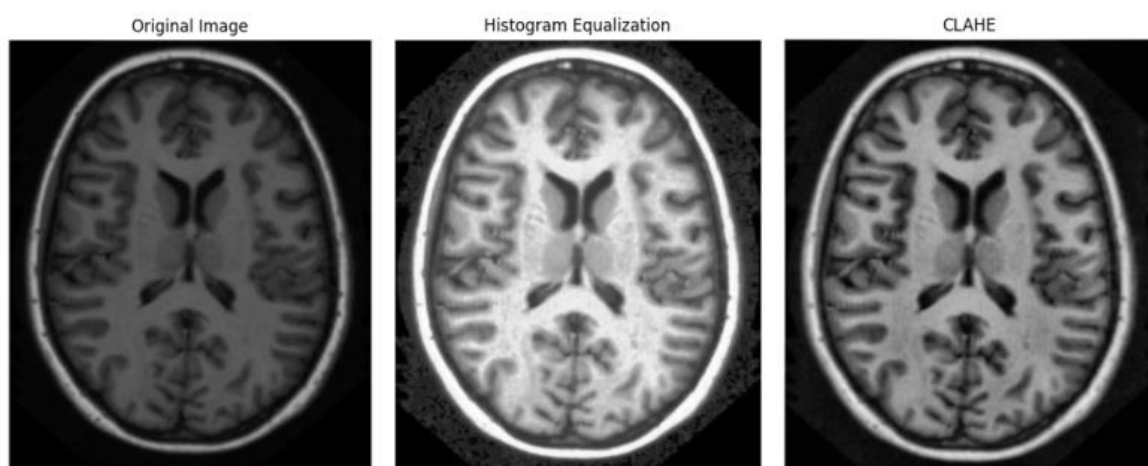
5. Results and Discussion

The performance evaluation of the suggested method is presented in this section by computing the algorithms in the Google Colab platform based on the Python language. As discussed, the above methods are been implemented in the Alzheimer's dataset to determine the efficient method of contrast enhancement.

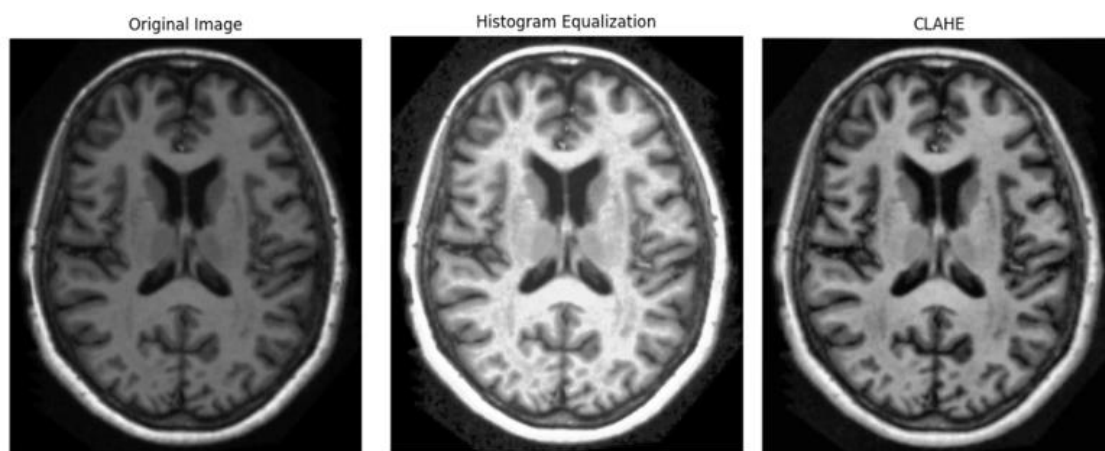
The four different classes of Alzheimer's disease- non-demented, very mild, mild, and moderately demented MRI images are considered. The subjected images are sourced from the OASIS Kaggle dataset, and contrast enhancement techniques are analyzed on the same based on the following performance metrics.

The metrics used to evaluate the performance of each histogram method are: Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR)[10]

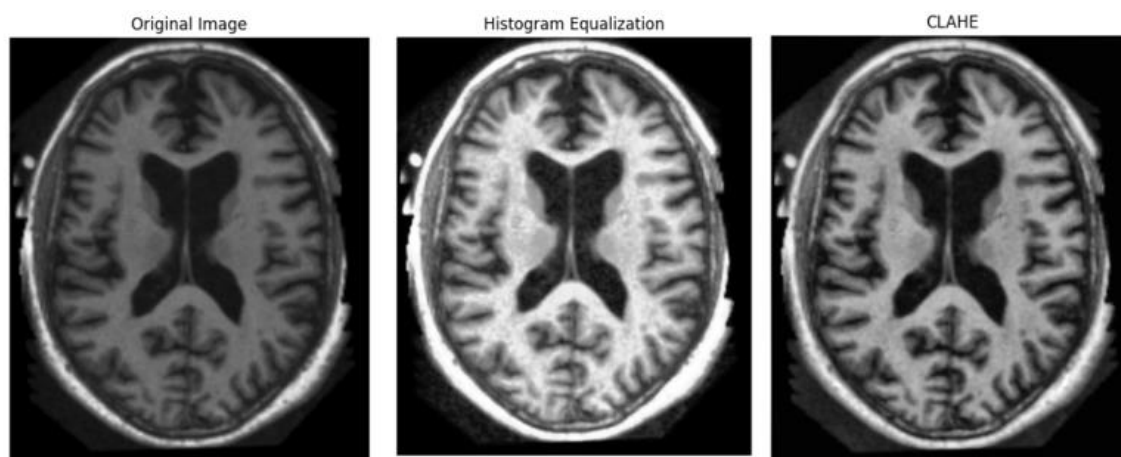
(a)Non-Demented Alzheimer's MRI



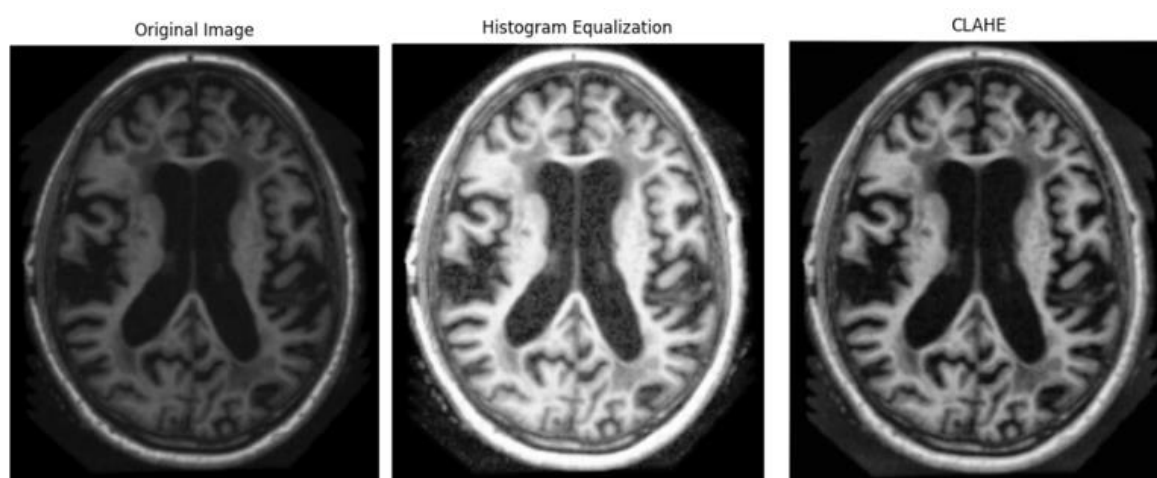
(b) Very Mild Demented Alzheimer's MRI

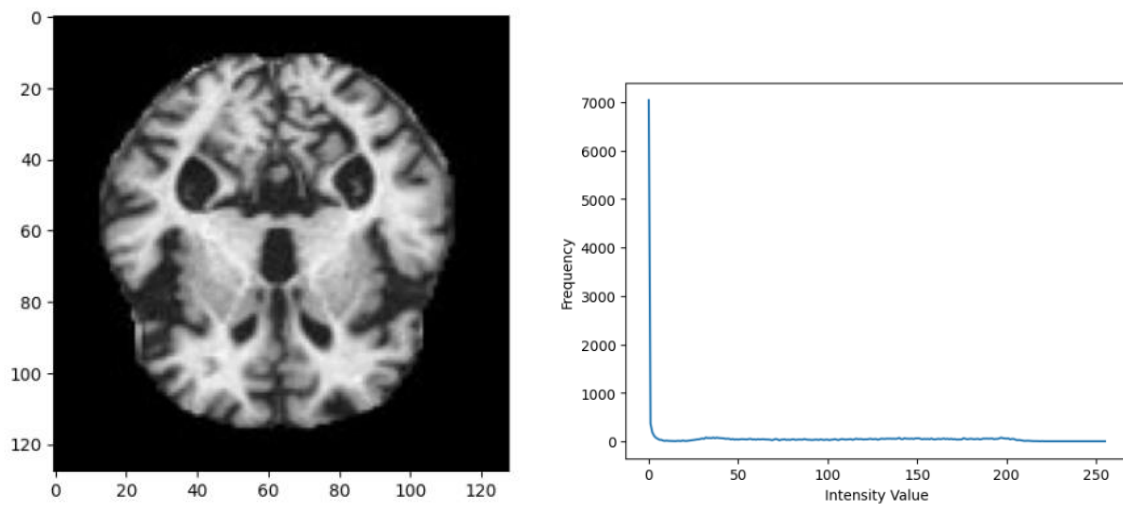
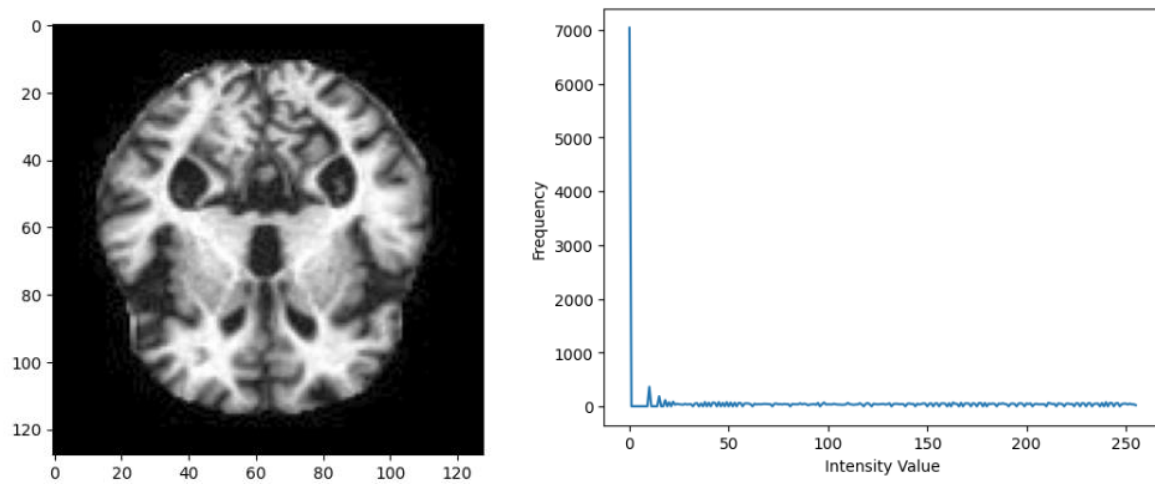


(c) Mild Demented Alzheimer's MRI



(d) Moderate Demented Alzheimer's MRI



(e) Posterior Section and Histogram of the Image of HE and (2) CLAHE**(f) Posterior Section and Histogram of the Image of CLAHE****Figure 2.** Contrast Enhanced MRI Images of Alzheimer's MRI**Table 1.** Comparison of HE and CLAHE Algorithms on Alzheimer's MRI

Classes	PSNR		SSIM	
	HE	CLAHE	HE	CLAHE
Non- demented	11.21	15.32	4518.03	1024.62
Very Mild demented	10.08	14.75	5421.25	2075.51
Mild demented	9.54	12.98	6514.98	1982.37

Moderately Demented	12.07	16.19	5891.05	2134.83
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From the above results in Fig 2, it is analyzed that HE is a localized contrast enhancement method, it globally enhances the contrast of the image in return it also amplifies the noise level where the related regions are overexposed to contrast. CLAHE is more effective since it increases the contrast of an image to an optimal range based on the clip limit. Thus, if compared to the contrast enhancement of MRI in Tables I: PSNR, and MSE values, it is observed that the MSE lowers on increasing PSNR when the CLAHE method is employed.

6. Conclusion

In this research work, a simple histogram equalization is compared with the Contrast Limited Adaptive Histogram Equalization. The comparison is analyzed on Alzheimer's dataset of four different classes and it is analyzed that the CLAHE algorithm performs better when compared to the traditional HE method justifying the performance of metrics such as MSE and PSNR it also prohibits excessive enhancement of contrast. On analyzing the visualization results, CLAHE provides detailed information on the hippocampus's local region, which helps in the diagnosis of Alzheimer's disease.

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