

Implementation of CLAHE and CLAGAMTWO in Medical Images

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Abstract

In the era of development of medical image processing technology, the quality of radiological images such as X-ray, CT-Scan, and MRI plays an important role in the diagnosis process, detecting diseases early, and evaluating the treatment of various medical conditions. To maximize the potential of images in the diagnostic process, effective pre-processing steps are needed so that anatomical structures are more clearly visible, pathological details are maintained, and noise and artifacts can be reduced. One of the image contrast enhancement techniques is Contrast Limited Adaptive Histogram Equalization (CLAHE) and CLAGAMTWO (Clahe-Gamma-Gamma). CLAHE is superior in ENTROPY of 7.154, while for CLAGAMTWO it is superior in SSIM value of 0.944 and CNR of 1.820. So, in terms of increasing the complexity or diversity of information CLAHE is slightly better than CLAGAMTWO. While for CLAGAMTWO it is better in the level of contrast clarity between dark and bright areas in an image, even though there is noise interference.

Keywords: Medical Image, Image Processing, CLAHE, CLAGAMTWO

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I. INTRODUCTION

In the era of development of medical image processing technology, the quality of radiological images such as X-ray, CT-Scan, and MRI plays an important role in the diagnosis process, detecting diseases early, and evaluating the treatment of various medical conditions. However, medical images often have imperfect qualities, such as low contrast, high noise, uneven lighting, and acquisition artifacts that can interfere with the interpretation of radiologists and computational algorithms such as segmentation, detection, or classification. To maximize the potential of images in the diagnostic process, effective pre-processing steps are needed so that anatomical structures are more clearly visible, pathological details are maintained, and noise and artifacts can be reduced. One of the most important areas in the development of image processing technology is image quality improvement. This effectively provides better visual effects and increases image clarity, which is very useful for further computerization and analysis. [1], [2]. According to [3] image contrast enhancement can improve image contrast which is very good for diagnosis and clinical research.

One of the image contrast enhancement techniques, the Contrast Limited Adaptive Histogram Equalization (CLAHE) method, has been widely proven to improve visibility in various types of medical images. CLAHE is a technique used to enhance image contrast, especially in grayscale images [4]. The study conducted by [5] showed that contrast-enhanced retinal fundus images using the CLAHE technique provided better classification results when used in a CNN model compared to unenhanced images. In addition, research [6] using a kidney CT-scan dataset showed that the use of CLAHE successfully increased the F1-Score by up to 99.56% compared to data where CLAHE was not applied.

CLAHE divides the image into small areas called contextual blocks and then performs local contrast adjustments within each area. Each contextual block is calculated based on its light-dark color distribution and then processed to avoid excessive contrast increases. This process results in a more even color distribution, thereby highlighting previously obscured features [7]. However, the CLAHE method still has several shortcomings, particularly in preserving local and global details simultaneously, as well as in handling very high contrast or uneven lighting. To address these issues, hybrid methods such as CLAGAMTWO, which is CLAHE enhanced with two gamma corrections, have recently been introduced. This method is claimed to provide better image quality improvement results compared to using CLAHE alone. For example, in a study on hip X-ray images, CLAGAMTWO produced an average SSIM value of 0.850 and a CNR of 0.773, while CLAHE only produced an Entropy value of 7.099 [8]. Thus, the development of research on the implementation of CLAGAMTWO in medical imaging deserves attention.

Based on this overview, this study explores and compares the implementation or application of the CLAHE and CLAGAMTWO methods on medical images with the aim of assessing their impact on improving image quality, such as contrast, noise, and detail. Furthermore, this study also considers their implications for computer processes used for diagnostic assistance, such as detection and segmentation. This research is very important because there is a real need to improve the quality of input data in the pre-processing stage of medical images so that subsequent analytical algorithms can run optimally.

II. RELATED WORK

Researchers [9] proposed the use of a combination of CLAHE-HE (Hybrid CLAHE and Histogram Equalization) in brain tumor segmentation research using the U-Net architecture. The dataset used was BRATS-2021 with a resolution of $1,000 \times 1,000$ pixels per image. The methods compared included HE, CLAHE, and CLAHE-HE. The results showed that the CLAHE-HE combination provided a Dice Coefficient value of 0.914 and a Jaccard Index of 0.870, which was better than the single CLAHE method (Dice = 0.893) or HE (Dice = 0.867). The researchers concluded that the use of the hybrid method improved segmentation quality because the global contrast of HE and the local contrast of CLAHE complemented each other in highlighting the boundaries of disease-containing areas.

Research conducted by [10] applied CLAHE to chest X-ray images to help classify patients with Covid-19 and non-Covid. This study investigated the performance differences before and after contrast enhancement using PSNR and MSE metrics. The average PSNR value increased from 28.47 dB to 36.51 dB, while the MSE decreased from 0.0121 to 0.0053. Visually, the results of applying CLAHE improved the clarity of lung boundaries and alveolar structures. This supports the evidence that CLAHE is able to clarify the texture of low-contrast lung tissue, thereby increasing the accuracy of the CNN model by up to 4.5%.

Other researchers [11] introduced a new hybrid method based on Unsharp Masking, Logarithmic Transform, and AHE (called ULAH) to improve the quality of radiological images. They compared this method with CLAHE using 500 abdominal CT images. The results showed that CLAHE remains the best standard with an SSIM value of 0.821 and an Entropy of 7.12, while the ULAH method is only better in the aspect of edge sharpness. However, the ULAH method requires complicated parameter adjustments, making it less efficient for application in clinical automation systems. This study confirms that CLAHE remains a method that balances performance and efficiency.

Researchers [12] conducted a study to evaluate the effectiveness of the CLAHE and AHE methods in improving the quality of non-medical images, specifically night-vision street images. Although this study did not focus on clinical images, the context remains relevant because the low-light conditions in street images are similar to the low-contrast challenges often found in medical images. The results showed that CLAHE provided an improvement in PSNR of 37.2 dB and CNR of 0.791, which is better than AHE which only achieved a PSNR of 34.8 dB. This study supports the argument that the adaptive principle in CLAHE can be applied in various fields, including the medical field, because of its ability to maintain a balance between global and local details.

III. RESEARCH METHODS

In this section, we will explain the methodology that will be used in this research. Figure 1 shows that the research methodology begins with the input of medical images, followed by converting the original image to a grayscale image. The next step is to enhance the image contrast using CLAHE or CLAGAMTWO. The final section will evaluate the results using SSIM (Structured Similarity Index Measure), CNR (Contrast-to-Noise Ratio), and ENTROPY.

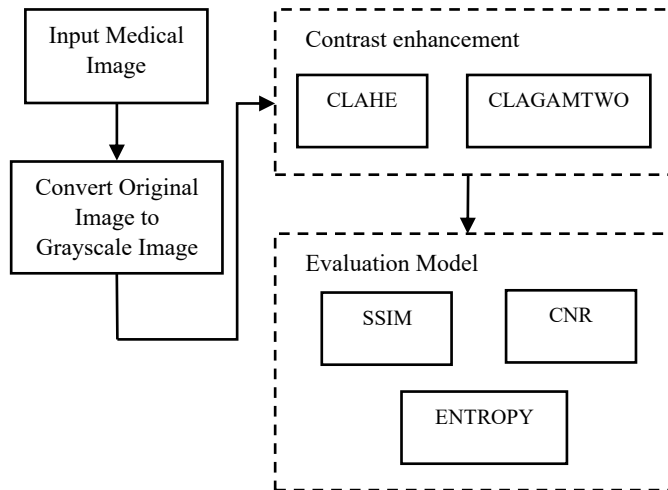


Fig. 1. Research Methodology

SSIM [13] used to evaluate images based on three main components: brightness, contrast, and structure. CNR is a metric used to measure the level of clarity of contrast between dark and light areas in an image, despite the presence of noise. In image processing, CNR helps assess the extent to which a characteristic or detail in an image is clearly visible, without being disturbed by noise. The higher the CNR value, the higher the contrast between the object and the background in the image, making the object easier to see [14].

Meanwhile, ENTROPY is used to measure the level of complexity or diversity of information contained in an image. The higher the ENTROPY value, the higher the level of complexity and diversity of information in the image. Entropy is determined by how the intensity of each pixel is distributed in the image and is used to assess image quality and assist in detecting and classifying patterns in the image [15].

IV. RESULTS AND DISCUSSION

This section displays and analyzes medical images that will be implemented using the two methods mentioned above, namely Contrast Limited Adaptive Histogram Equalization (CLAHE) and CLAGAMTWO. The CLAGAMTWO method itself is carried out by first entering the image into CLAHE and then continuing and correcting it with two gamma corrections.

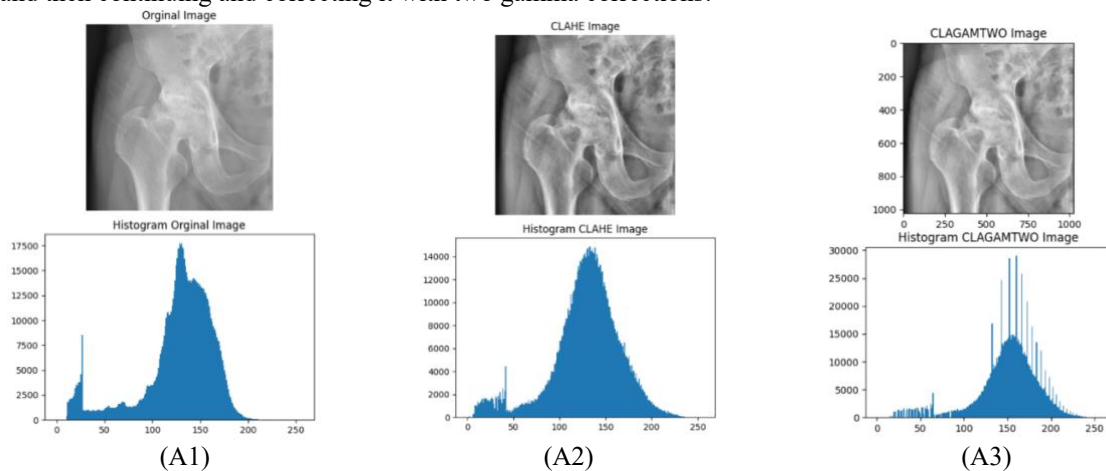


Fig. 2. Implementation of the Hip Image: (A1) Original Image, (A2) CLAHE Image, (A3) CLAGAMTWO Image

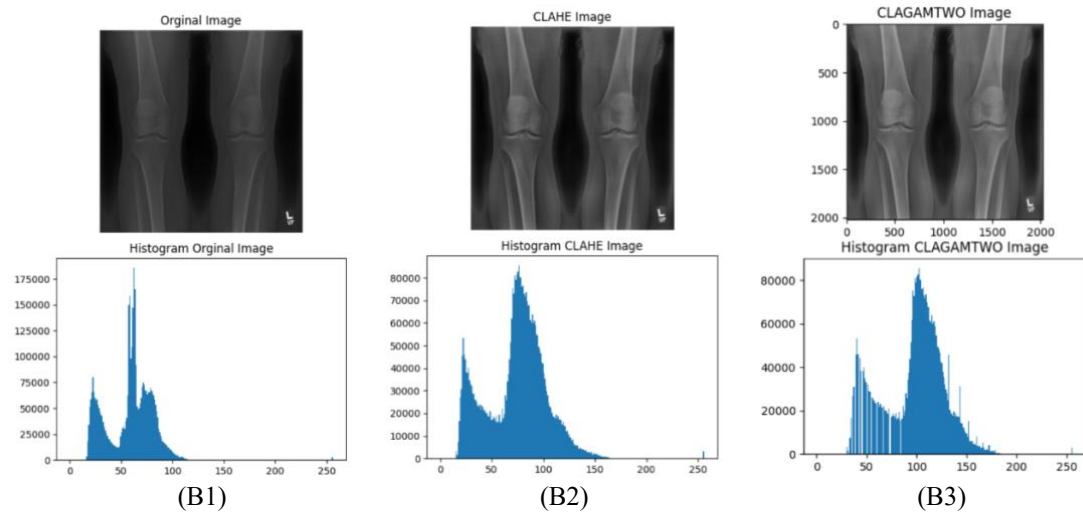


Fig. 3. Implementation of Knee Image: (B1) Original Image, (B2) CLAHE Image, (B3) CLAGAMTWO Image

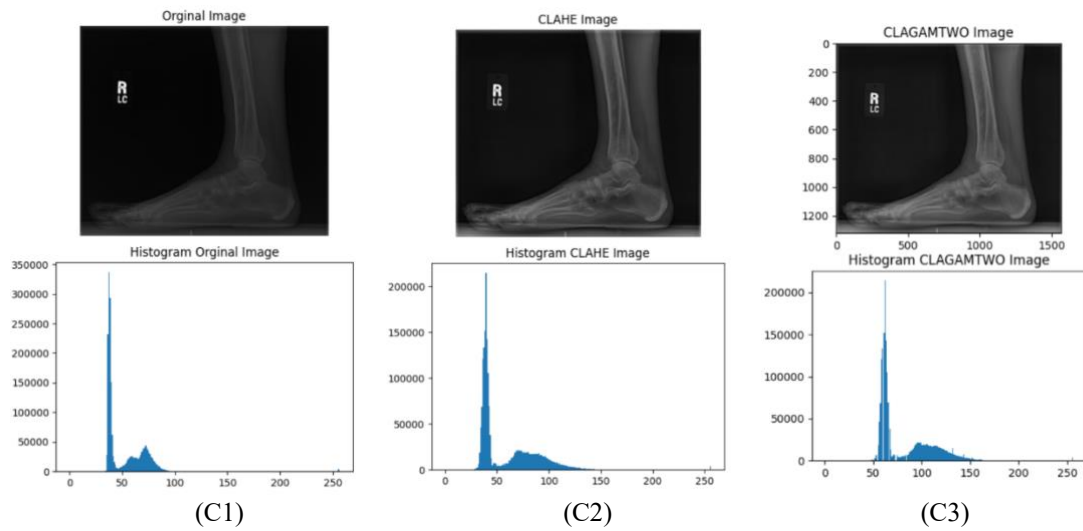


Fig. 4. Implementation of the Foot Image: (C1) Original Image, (C2) CLAHE Image, (C3) CLAGAMTWO Image

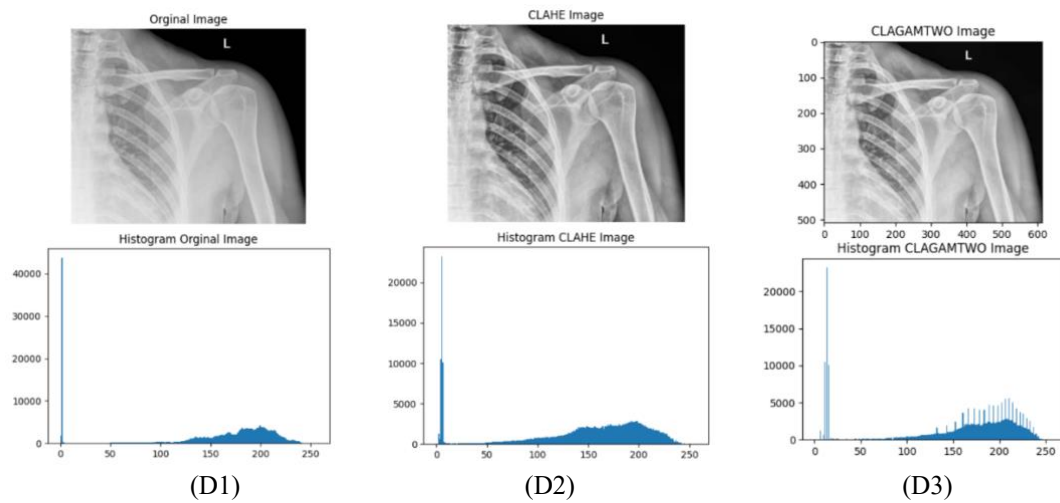


Fig. 5. Implementation of Shoulder Image: (D1) Original Image, (D2) CLAHE Image, (D3) CLAGAMTWO Image

It can be seen in the medical images in Figures 2, 3, 4, and 5 that CLAHE and CLAGAMTWO have been implemented. The images are divided into three different views for each image. Images A1, B1, C1, and D1 display the original image. Then, images A2, B2, C2, and D2 display images that have been implemented with CLAHE. Meanwhile, images A3, B3, C3, and D3 display images that have been implemented with CLAGAMTWO. At a glance, based on the images displayed, CLAHE displays a more contrasting image than CLAGAMTWO. Meanwhile, CLAGAMTWO has a softer contrast than CLAHE.

Based on Table 1, it can be seen that CLAHE is superior for the ENTROPY value of 7.154, while CLAGAMTWO is superior for the SSIM value of 0.944 and CNR of 1.820.

TABLE I. SSIM, CNR, AND ENTROPY MODEL EVALUATION RESULT TABLE

Image	Method	Model Evaluation		
		SSIM	CNR	ENTROPY
A	CLAHE	0.848	0.035	7.154
	CLAGAMTWO	0.862	0.613	6.941
B	CLAHE	0.926	0.710	6.684
	CLAGAMTWO	0.820	1.820	6.565
C	CLAHE	0.849	0.415	5.675
	CLAGAMTWO	0.944	1.692	5.661
D	CLAHE	0.805	0.138	7.151
	CLAGAMTWO	0.808	0.082	6.892

V. CONCLUSION

Based on the results and discussions that have been carried out, it can be concluded that the CLAHE and CLAGAMTWO methods have their respective advantages. CLAHE is superior in ENTROPY values, which indicates that the enhanced image has a higher level of complexity or diversity of information compared to CLAGAMTWO. Meanwhile, CLAGAMTWO is superior in SSIM and CNR values, which indicate that the enhanced image has a higher level of contrast clarity between dark and bright areas in an image, even though there is noise interference.

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