Enhancement of radiographs using the HE and CLAHE techniques

تحسين صور الأشعة باستخدام تقنيات *HE*و*CLAHE*

Prof.Dr. Mohammed Abdo Ragheb Amasha
Dean of the Faculty of Specific Education
Computer Teacher Preparation Department
Faculty of Specific Education
Damietta University

_Dr._ Marwa Arif Tolba Ahmed Gaheen
Computer Teacher Preparation Department
Faculty of Specific Education
Damietta University

Asmaa Mohammed Mansour Mohammed Elmorsy
Computer Teacher Preparation Department
Faculty of Specific Education
Damietta University

المجلة العلمية لكلية التربية النوعية – جامعة دمياط

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Asmaa M. Mansour, Marwa A. Gaheen, Mohammed A. Amasha

Computer Teacher Preparation Department, Faculty of Specific Education, Damietta University

Abstract

Radiographs are essential information that doctors need to diagnose and treat patients appropriately. The diagnostic process depends mainly on the visual perception of the radiographs; therefore, the possibility of an error in the diagnostic process leads to a risk to the lives of the patients. Therefore, enhancing the visual quality of radiographs helps the doctor make the right decision in the diagnostic process, which results in saving the lives of patients. Histograms are common tools for improving radiographic quality. This paper provides on improving radiographs using histogram-based HE and CLAHE techniques. MATLAB software is used to analyze the performance of the optimization techniques for the radiographs. In addition to quantitatively comparing the results, we evaluate the effectiveness of the techniques as measured by three metrics: MSE, PSNR, and SSIM. The study results confirm that the techniques yielded good-looking images, particularly those produced by the CLAHE technique. Images generated using the HE technique are brighter, whereas CLAHE images have finer image details, making them superior for diagnostic purposes.

Keywords—*Radiographs; HE technique; CLAHE technique; Histogram; Image processing*

I. INTRODUCTION

Radiography plays a crucial role in producing a visual portrayal of the internal anatomy of the human body, representing a noteworthy advancement in the field of illness diagnosis . **Pashaei, E., & Pashaei, E. (2023), 1-24. Patel, S., Bharath, K. P., Balaji, S., & Muthu, R. K. (2020), 657-669**

There are various types of radiology, each with a specific goal and producing a radiograph with a different intensity distribution of pixels. Therefore, the radiographs resulting from each type of radiograph differ from each other . **El-Shafai, W., ., et al., (2023), 2905-2925**. Despite the continuous development of systems for obtaining radiographs, there are still some doubts about the representation of human parts. In the field of radiology, any error is unacceptable because it endangers the patient's condition. Furthermore, the quantity of image information, quality, and clarity are critical as an image can be considered of high quality if it highlights its key attributes (physical characteristics, form, material), and meets technical requirements (framing/margins, resolution, and correct file format).

Xiong et al., (2021) proposed an image enhancement algorithm for identifying corrosion regions and dealing with low contrast in shadow parts of a picture. The hue-saturation-intensity model is used in this approach to perform histogram equalization. Experimental results reveal that the suggested method considerably enhances overall brightness, increases contrast details in shadow areas, and improves the identification of corrosion areas in images. **Khan et al., (2020)** proposed an effective technique to enhance the contrast of medical images, which is (CLAHE) technique. The results of the experiment showed that the proposed technique, which is (CLAHE), works to improve the quality and contrast of the image to a good degree while maintaining image accuracy. **Bhairannawar (2018)** carried out a study in medical image enhancement using transformation (hue, saturation, value) of HSV space, and adaptive histogram equalization. It was observed that the proposed method performed the improvement process well in terms of signal-to-noise ratio (PSNR) as well as improved quality .**Patel, S., Bharath, K. P., Balaji, S., & Muthu, R. K. (2020), 657-669** carried out a study to demonstrate the significance of using histogram equalization techniques to improve MRI medical images. To improve a set of MRI medical images, the researchers used a number of histogram equalization techniques. The study found that the primary function of these techniques is to improve the brightness and contrast of the original image. As a result, these strategies can be used to improve medical imaging and aid diagnosis. Previous studies in the same field did not address the improvement of the four different types of radiology images (MRI, CT, Sonar, and X-ray) through the use of HE and CLAHE techniques.

Here lies the main research problem in the following question: What is the proposed model for improving different types of radiographs? To solve this problem, many approaches for improvement have been proposed by researchers. radiological images to improve the quality of image recognition because radiographs feature intricate structures and various modalities. Therefore, radiograph interpretation and processing require particular procedures to avoid data loss and restore image details **Patel, S., Bharath, K. P., Balaji, S., & Muthu, R. K. (2020), 657-669** . **Acharya, U. K., & Kumar,**

S. (2023) 25-45. The image histogram serves as a foundational element underpinning numerous spatial domain-processing techniques, offering valuable insights into image statistics and the potential for image enhancement. Its computation is amenable to both hardware and software implementations. Notably, histogram equalization (HE) is employed as a key technique in this context, facilitating the generation of images characterized by uniform intensity distributions across the entire image, thereby expanding the dynamic range and enhancing contrast **Surya, S., & Muthukumaravel, A. (2023). 57-76 . Saladi, S., et al., (2023). 285.** . It is worth noting that various histogram equalization approaches exist, including contrast limited adaptive histogram equalization **[Salem, N., Malik, H., & Shams, A. (2019). 300-311. Joseph, J., et al., (2017) , 489-497.**

The primary goal of this research is to improve the four different types of radiographs (MRI, CT, Sonar, and X-ray). By using HE and CLAHE techniques, and examines the response of each technique in terms of 40 radiographs using three metrics: (MSE, PSNR, and SSIM). To apply and evaluate the techniques, we used the MATLAB program.The following are the primary contributions of this study:

- Improving radiographs of different types of radiographs (MRI, CT, Sonar, and X-ray).
- Suggest two histogram techniques, HE and CLAHE, to improve radiographs.
- A comparison between the HE and CLAHE techniques to determine the best technique for improving radiographs.
- Evaluation of the proposed techniques using three metric parameters (MSE, PSNR, and SSIM)

The paper's remaining portions are as follows: Sect. 2 Materials and procedures are organized into five phases. The first phase is image reading, the second phase is converting RGB images to Grayscale images, and the third phase is concerned with image processing histograms, which clarify the relationship between the histogram and image contrast. This section contains two subsections. The first subsection discusses the HE technique, followed by the CLAHE technique. The fourth phase applies a median filter to the images produced by (HE and CLAHE) approaches, and the fifth phase evaluates the improved images using three metrics (MSE, PSNR, and SSIM). Sect. 3 covers the search experiment and its findings, as well as the dataset description and performance measures. Sect. 4 explains the conclusions, while Sect. 5 discusses future work.

II. MATERIALS AND PROCEDURES

This section delineates the procedures and steps that comprise the proposed approach. The suggested model is divided into six major phases, as shown in Fig. 1.

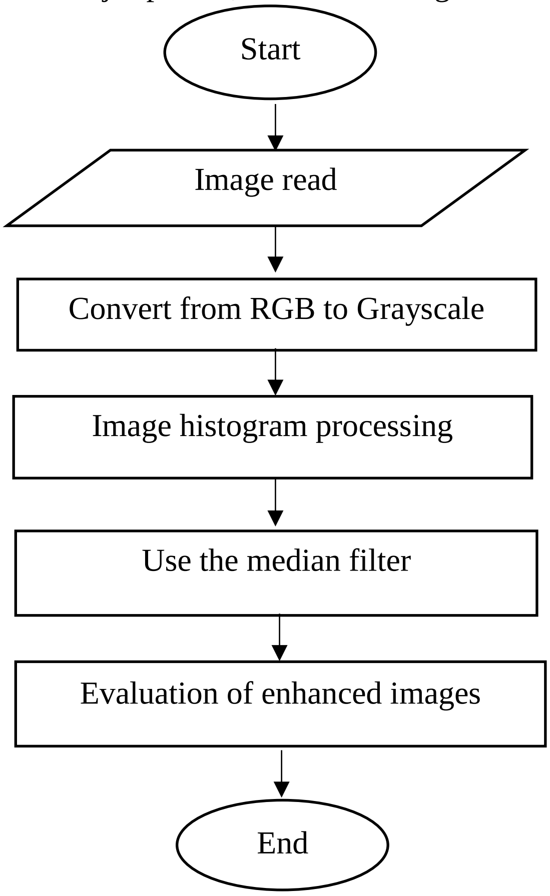


Fig. 1. Steps of the suggested model

II.I. Image Read

The first step, reading the image, is critical since without it, we will be unable to process the image. Therefore, the first stage in the image processing workflow is to download and read the image before processing it.

II.II. Convert from RGB to Grayscale

After reading the image, the radiograph's color scheme is transformed from RGB to Grayscale to produce a sharper and brighter image.

II.III. Image histogram processing

Radiographs help clinicians efficiently diagnose medical conditions . **Mousania, Y., Karimi, S., & Farmani, A. (2023). 105.**

because of their ability to produce a visual representation of a patient's interior anatomy. A two-dimensional monochrome digital image is a binary representation of a pixel matrix, where each pixel represents a different grey level **Salem, N., Malik, H., & Shams, A. (2019). 300-311.**An image histogram is a graphical depiction of a digital image's gray-value probability distribution **Salem, N., Malik, H., & Shams, A. (2019). 300-311**.Visualizing the histogram of an image allows one to observe the frequency with which different levels of gray appear in the image. Fig. 2. Shows a connection between the distribution of histograms and image contrast.

The histograms for dark images (the frequency) are on the left side, those for bright images (the frequency) are on the right side, and those for visually appealing images (the frequency) are uniformly distributed.

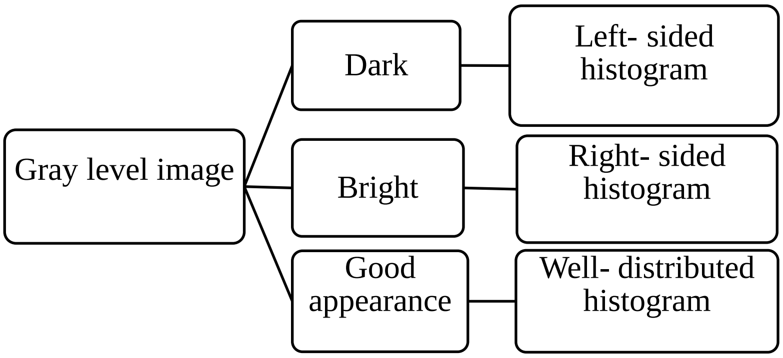


Fig. 2. Demonstrates the relationship between the histogram and the contrast of the image.

Medical images usually use 8-bit grayscale, with grayscale values varying from 0 (black) to 255 (white) **Saladi, S., et al., (2023). 285.**

Fig. 3 illustrates three images alongside their corresponding diagrams. On the left side are histograms representing the frequency distribution of dark images, whereas on the right side, histograms pertain to bright images, both reflecting their respective frequency distributions. In contrast, histograms for aesthetically pleasing images exhibit a uniform distribution of frequency values. Consequently, the brightness level and contrast quality of an image can be inferred from its histogram, where a predominantly even distribution suggests adequate contrast. Notably, a histogram that encompasses the entire spectrum of grayscale values signifies an image characterized by high contrast, where its features are distinctly discernible.

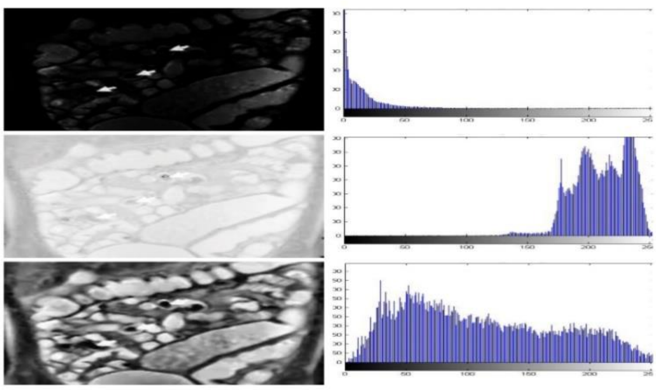


Fig. 3. Image histogram of dark images, brightimages, andgood contrast.

II.III.I. Histogram Equalization (HE)

Histogram equalization is a widely employed technique for enhancing the visual quality of low-resolution images, predicated on the manipulation of histograms. In the context of this study, histogram equalization (HE) was applied to reduce the brightness and contrast characteristics of input radiographic images by expanding the range of pixel values, a process designed to enhance the overall visual appeal and fidelity of the output image **Somasekar, J., et al., (2023) . Hossam, A., Fawzy, A., Elnaghi, B. E., & Magdy, A. (2022).338-355).**

Eq. (1) can be used to calculate the HE $Pn = \frac{No.of\ pixels\ with\ intensity\ (nk)}{total\ no.\ of\ pixels\ (n)}$ (1)

where n = 0, 1... L 1 denotes the gray-level value range. Let P(x) denote the probability density function (pdf) for image x (i, j) as follows:

$$P\ (x) = \frac{n^k}{n} \quad (2)$$

Where n^k where is the number of occurrences of level x^k In the input image x, and n denotes the total number of samples. P (x) is related to the histogram of the image. The cumulative density function C (a) is expressed as

$$C\ (a) = \sum_{j=0}^{k} P(xj) \quad (3)$$

The intensity values were mapped over the dynamic range $(x0, xL - 1)$ in the HE method by employing $C(a)$as a transformation function.

Eq. (4) defines $f\ (a)$,where the transform function is based on $C(a)$:

$$f\ (a) = x0 + (xL - 1 - x0)C(a) \quad (4)$$

As a result, Eq. (5) gives the output image

Y = Y (i, j):

$$Y = f(a) = \{f(x(i.j))\forall x(i.j) \in x\} \quad (5)$$

II.III.II. Contrast Limited Adaptive Histogram Equalization (CLAHE)

CLAHE is a well-known technique for enhancing low-contrast digital images. It has two differentiating features: histogram distribution is limited to avoid excessive augmentation of noisy areas, and equalization is hastened via interpolation.

The CLAHE method's performance is determined by the clip limit; the histograms of each non-overlapping section converge to a level lower than this value . **Haddadi, Y. R., & Mansouri, B. (2023)**. The clip limit β form is represented as

$$\beta = \frac{MN}{G}\{1 + \frac{\alpha}{100}(ASmax - 1)\} \quad (6)$$

M And N represent the number of pixels in each region, G is the number of grayscale levels, is the clip factor.

$ASmax$ is the maximum permitted slope. Therefore, estimating β is critical for achieving the best image quality. **Haddadi, Y. R., & Mansouri, B. (2023).**

II.IV. Median filter (MF)

The median filter is a digital filtering method that is nonlinear. The median filter reduces noise from the input of a picture or signal. In the Median Filter, a given pixel is replaced by the median value of its neighbours **Shah, A., et al., (2022),505-519** . The MF's image noise reduction skills are superb. After filtering, it keeps the edges while eliminating noise. **Yadav, G., Yadav, D. K., & Mouli, P. C. (2022).. 65-85**. Fig. 4 shows photos of the HE approach before and after applying a median filter. Figure 5 depicts the CLAHE method images before and after the application of a median filter.

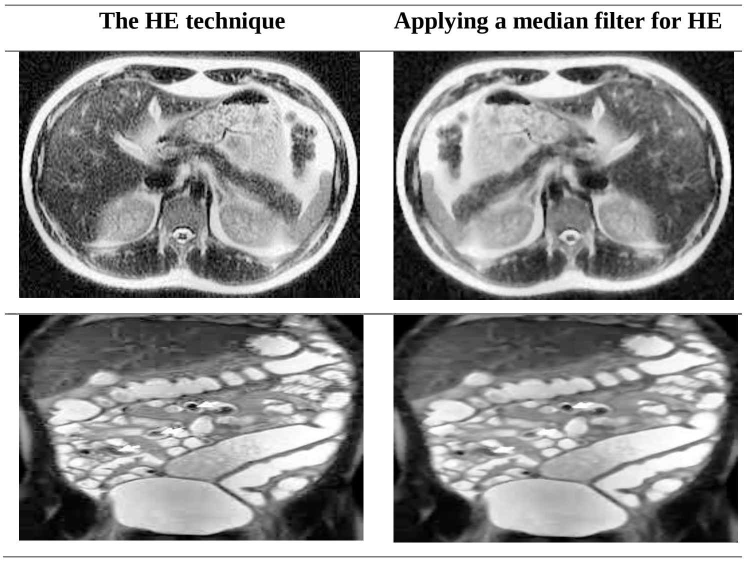


Fig. 4**.** Images of the HE technique before and after using the median filter

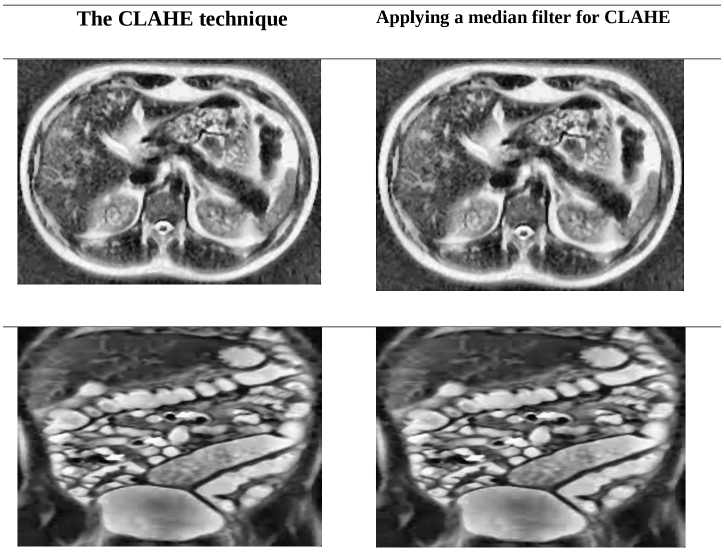


Fig. 5. Images of the CLAHE technique before and after using the median filter

II.V Evaluation of enhanced images

In this phase, the effectiveness of each histogram technique is verified using three measures (MSE, PSNR, and SSIM). Fig. 6 shows the steps for evaluating enhanced images.

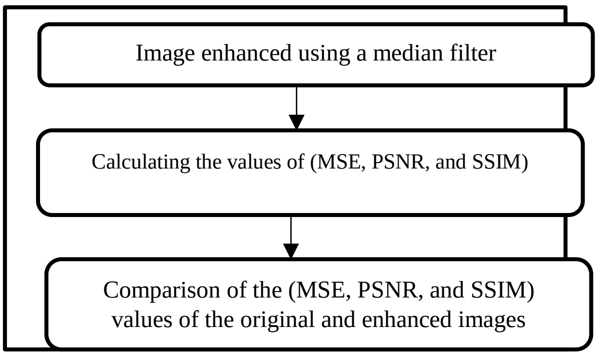


Fig. 6. Steps for evaluating enhanced images

III. EXPERIMENT AND RESULTS

This section assesses the performance of two histogram-based techniques (HE and CLAHE) for the enhancement of 40 radiographs, 10 MRI images, 10 CT images, 10 sonar images, and 10 X-ray images obtained from the anatomy course. The experiment was applied on "CPU Corei7" running with "Windows 7 32bit" and 2 GB RAM and Matlab 2013b. Fig. 7. Depicts the original images and their upgraded versions.A histogram of the original HE-enhanced and CLAHE-enhanced images is shown in Fig. 8.

III.I. Performance measures

Three metrics were calculated to assess the effectiveness of each histogram technique:

• MSE (Mean Square Error).
• Peak signal-to-noise ratio (PSNR).
• SSIM (Structural Similarity Index Measure).

III.I.I. Mean Square Error (MSE)

An estimator's mean squared error (MSE) is the average of the squared errors or the average squared difference between the estimated values and what is estimated. The MSE was determined by comparing the original image to a noisy (compressed) image. The MSE is always positive and never zero due to randomness. The MSE score with the lowest value implies the least amount of error [18]. The MSE was calculated using Eq. (7):

$$MSE = (M, N\ [I2\ (m, n) - I2\ (m, n)]M * N \quad (7)$$

- M Denotes the number of rows.
- N Denotes the columns in the images.

III.I.II. Peak signal-to-noise ratio (PSNR)

The peak signal-to-noise ratio (PSNR) is the ratio of the information's maximum possible power to the noise, which determines its quality . **Alhajlah, M. (2023). (3).** The PSNR can be calculated using Eq. (8):

$$PSNR = 20lg(MAX1) - 10lg(MSE) \quad (8)$$

- MSE Denotes the mean square error between images
- $MAX1$ Denotes the maximum possible pixel value in the images.

III.I.III. Structural Similarity Index Measure (SSIM)

The structural similarity index measure (SSIM) is a method for forecasting digital image quality and determining the similarity of two images. Image quality is measured or predicted using an uncompressed or distortion-free raw image as a reference [20]. The formula defines the SSIM calculation using Eq. (9):

$$SSIM(x, y) = \frac{(2\mu_x\ \mu_y + C1)(2\sigma_{xy} + C2)}{(\mu_x^2 + \mu_y^2 + C1)(\sigma_x^2 + \sigma_y^2 + C2)} \quad (9)$$

- μ_x And μ_y are the averages of the original and damaged grayscale images.
- σ_x^2 And σ_y^2 are the differences between the original and damaged grayscale images.
- σ_{xy} Represents the covariance between the original and damaged images (grayscale)
- C1 and C2 are constants used to ensure that the metric is a real number.

Tables 1, 2, and 3 present the outcomes of the three evaluation measures for each technique and image. Figure. 9. Shows the MSE, PSNR, and SSIM results.

The graphs clearly correspond; however, there is a discrepancy between stretching and filling. All data in the figures are represented using the (HE, CLAHE) techniques. A lot of contrast occurs near the edges in both methods; it is greatest in HE images; however, some characteristics are lost. Images by CLAHE There is less contrast than in HE, but there is greater detail.

The MSE values for each image are shown in Table (1). The results revealed a substantial difference in MSE values in optimized images for all techniques, with the greatest values in the HE technique in MRI 1 and X-ray 2 images and the highest values in the CLAHE technique in MRI 1 and X-ray 1 images. There is a slight difference in the MSE values for the remaining images.
Table 2 displays the PSNR values for all images, and the PSNR values in the CLAHE-enhanced images are the highest values of the HE-enhanced images among the six images. The images generated using the CLAHE technique have the best quality because they have the lowest MSE and maximum PSNR.

Table (3) displays the SSIM values for all images. Because the SSIM value range is limited to [0,1], all SSIM values for all enhanced images resulting from the two techniques are less than 0.85%, indicating that the original image and the enhanced image are completely different in their essential properties (brightness, contrast, and saturation). This shows that the enhancement techniques were beneficial and that the essential difference between the two images did not exceed the reasonable limit.

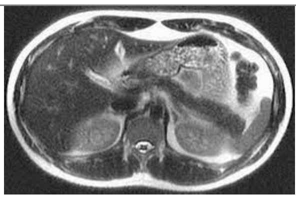
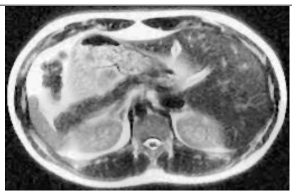
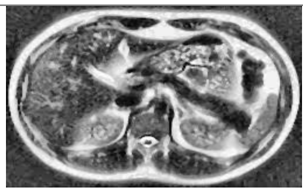
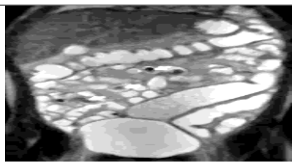
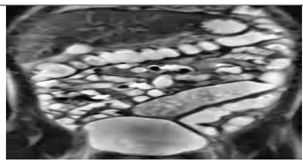
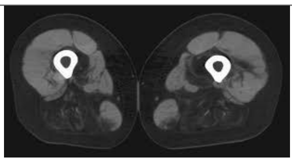
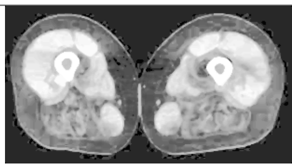
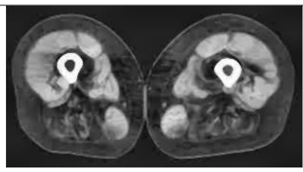
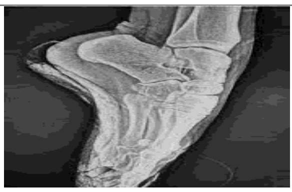
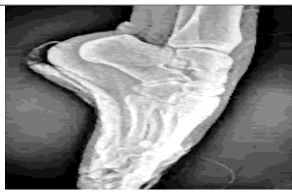
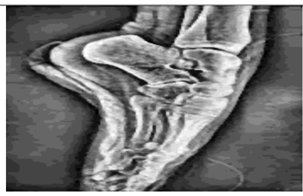
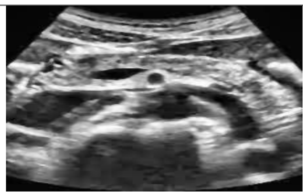
Image name	Original image	HE	CLAHE
MRI 1			
MRI 2			
CT 1			
CT 2			
Sonar 1			
Sonar 2			
X-ray 1			
X-ray 2			

Fig. . 7. A sample of original medical images, HE-enhanced images, and CLAHE-enhanced images in sequence

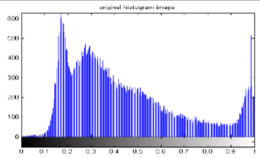
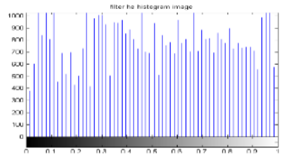
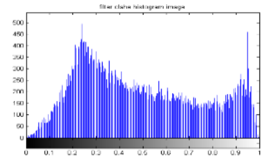
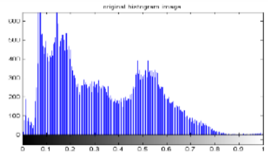
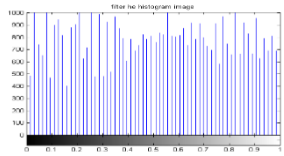
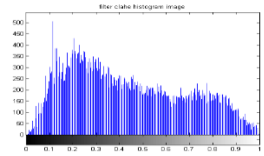
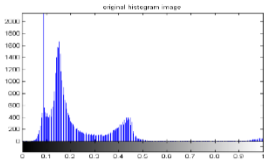
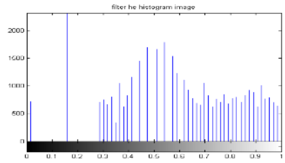
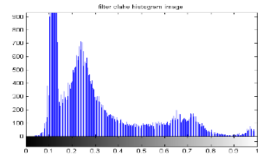
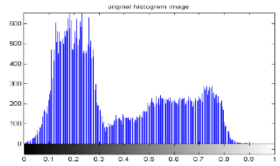
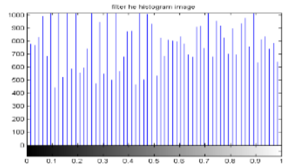
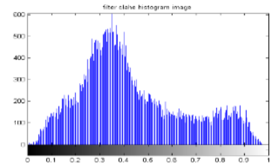
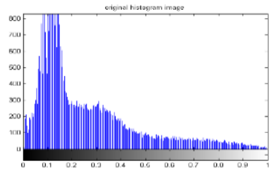
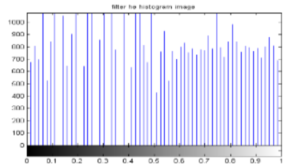
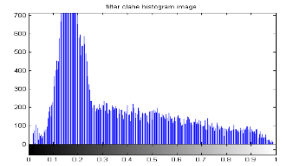
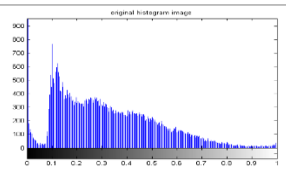
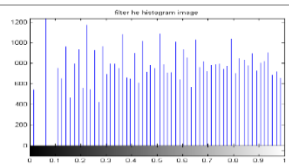
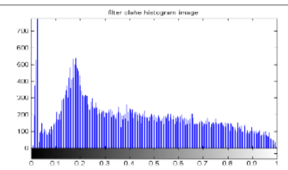
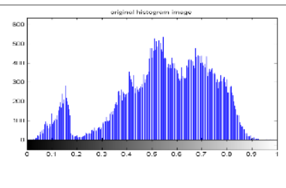
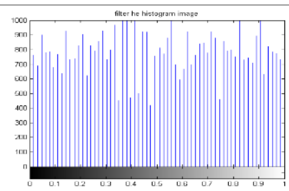
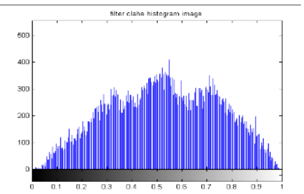
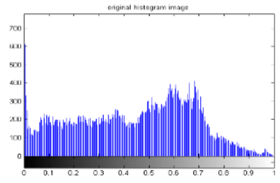
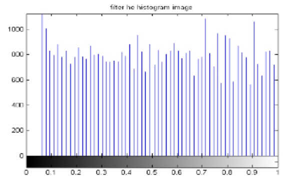
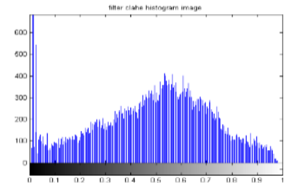
Image name	Original image	HE	CLAHE
MRI 1			
MRI 2			
CT 1			
CT 2			
Sonar 1			
Sonar 2			
X-ray 1			
X-ray 2			

Fig.8.Histogram of the eight original medical images, HE-enhanced images, and CLAHE-enhanced images in sequence

TAPLE 1. MSE of each technique for each medical image

The image's title	The HE technique	The CLAHE technique
MRI 1	815.9207	828.5454
MRI 2	2.7127 e+03	1.4370 e+03
CT 1	8.3512 e+03	1.1153 e+03
CT 2	1.5690 e+03	1.1737 e+03
Sonar 1	5.5626 e+03	1.1352 e+03
Sonar 2	3.5040 e+03	1.2626 e+03
X-ray 1	1.1067 e+03	988.4052
X-ray 2	991.3010	1.3297 e+03
Average	903.61085	908.4753

TAPLE 2. PSNR of each technique for each medical image

The image's title	The HE technique	The CLAHE technique
MRI 1	19.0143	18.9476
MRI 2	13.7968	16.5561
CT 1	8.9133	17.6567
CT 2	16.1745	17.4352
Sonar 1	10.6780	17.5802
Sonar 2	12.6852	17.1181
X-ray 1	17.6905	18.1815
X-ray 2	18.1687	16.8931
Average	14.6401625	17.5460625

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TAPLE 3. SSIM of each technique for each medical image

The image's title	The HE technique	The CLAHE technique
MRI 1	0.7768	0.7623
MRI 2	0.8024	0.7342
CT 1	0.5013	0.7756
CT 2	0.7637	0.7134
Sonar 1	0.5690	0.7229
Sonar 2	0.6866	0.7349
X-ray 1	0.7806	0.7360
X-ray 2	0.7885	0.6714
Average	0.7086125	0.7313375

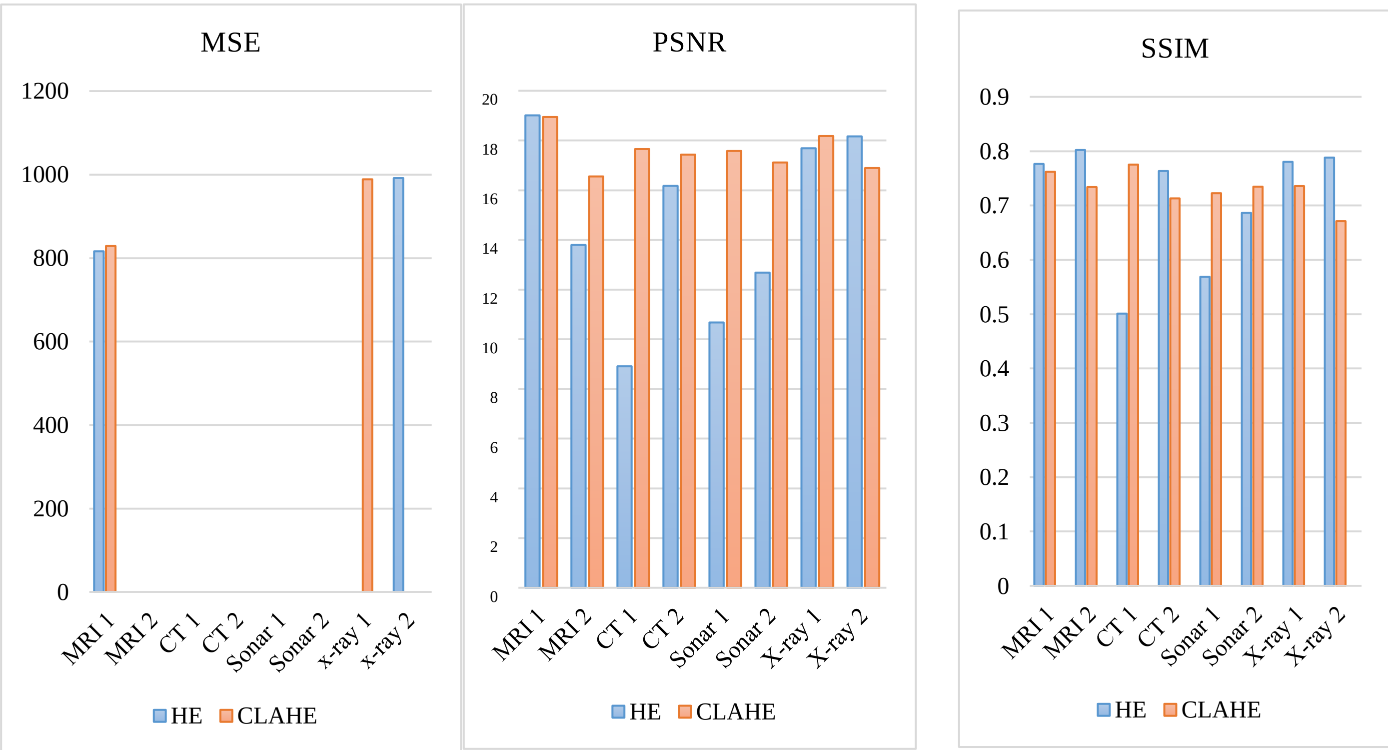

Fig. 9. MSE, PSNR, and SSIM; for each technique for every medical image.

IV. Conclusion and future work

This study provides a method for improving radiograph contrast using histogram techniques that maintains the improved image as the original image. The proposed method relies on extracting the frequencies and generating histograms of the gray values in the original image. The frequencies and histograms are then equalized. Then, new pixel values are calculated. To test the effectiveness of the proposed method, CLAHE and HE techniques were compared by applying the proposed techniques to 40 images of different types of radiographs (MRI, CT, Sonar, and X-ray). The response of each technique was examined using three measures (MSE, PSNR, and SSIM) to assess performance. The results demonstrated that the techniques yielded good-looking images, particularly those produced by the CLAHE technique. Images generated using the HE technique are brighter, whereas CLAHE images have finer image details, making them superior for diagnostic purposes. Although the quality measures are generally near values, the CLAHE technique is better.

In the future, many histogram techniques can also be used to improve the contrast of radiographs to address many of the problems that doctors and specialists face when examining radiographs. These techniques provide physicians and medical professionals with a tool to assist them in various medical specialties other than radiology. Exploring other image enhancement algorithms, testing existing algorithms with current research on different types of medical images

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تحسين صور الأشعة باستخدام تقنيات HE وCLAHE

المستخلص:

تعد صور الأشعة معلومات أساسية يحتاجها الأطباء لتشخيص وعلاج المرضى بشكل مناسب. تعتمد عملية التشخيص بشكل أساسي على الإدراك البصري لصور الأشعة؛ ولذلك فإن احتمال حدوث خطأ في عملية التشخيص يؤدي إلى خطر على حياة المرضى. وبالتالي فإن تعزيز الجودة البصرية لصور الأشعة يساعد الطبيب على اتخاذ القرار الصحيح في عملية التشخيص، مما يؤدي إلى إنقاذ حياة المرضى. تقنيات Histogramهي أدوات شائعة لتحسين جودة صور الأشعة. يهدف هذا البحث الي تحسين صور الأشعة باستخدام تقنيات HE وCLAHE القائمة على Histogram**.** يتم استخدام برنامج MATLAB لتحليل أداء تقنيات التحسين صور الأشعة. بالإضافة إلى مقارنة النتائج، يتم تقييم فعالية التقنيات المستخدمة من خلال ثلاثة مقاييس: MSE، PSNR، **و**SSIM. وتؤكد نتائج البحث أن التقنيات أنتجت صورا أفضل من الصور الأصلية، وخاصة تلك التي تنتجها تقنية CLAHE. تكون الصور التي يتم إنشاؤها باستخدام تقنية HE أكثر سطوعًا، في حين تحتوي صور CLAHE على تفاصيل أدق للصورة، مما يجعلها أفضل لأغراض التشخيص.

الكلمات الرئيسية: صور الأشعة، تقنية HE، تقنية CLAHE، Histogram، معالجة الصورة.