방사선기술과학 제44권 제5호 http://dx.doi.org/10.17946/JRST.2021.44.5.473
Journal of Radiological Science and Technology, 44(5), 473-480 ISSN 2384-1168(On-line) ISSN 2288-3509(Print)

<원저>

Comparison of Based on Histogram Equalization Techniques by Using Normalization in Thoracic Computed Tomography

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흉부 컴퓨터 단층 촬영에서 정규화를 사용한 다양한 히스토그램 평준화 기법을 비교

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Abstract This study was purpose to method that applies for improving the image quality in CT and X-ray scan, especially in the lung region. Also, we researched the parameters of the image before and after applying for Histogram Equalization (HE) such as mean, median values in the histogram. These techniques are mainly used for all type of medical images such as for Chest X-ray, Low-Dose Computed Tomography (CT). These are also used to intensify tiny anatomies like vessels, lung nodules, airways and pulmonary fissures. The proposed techniques consist of two main steps using the MATLAB software (R2021a). First, the technique should apply for the process of normalization for improving the basic image more correctly. In the next, the technique actively rearranges the intensity of the image contrast. Second, the Contrast Limited Adaptive Histogram Equalization (CLAHE) method was used for enhancing small details, textures and local contrast of the image. As a result, this paper shows the modern and improved techniques of HE and some advantages of the technique on the traditional HE. Therefore, this paper concludes that various techniques related to the HE can be helpful for many processes, especially image pre-processing for Machine Learning (ML), Deep Learning (DL).

Key Words: Medical Image Processing, Histogram Equalization, Contrast Limited Histogram Adaptive Equalization, CT, Thoracic Scout

중심 단어: 의료 영상 처리, 히스토그램 평준화, 대조도 제한 히스토그램 평준화, 컴퓨터 단층 촬영, 흉부 위치잡이 영상

Ⅰ. INTRODUCTION

In digital image processing, contrast enhancement technology is an important technology both Human and Computer vision. Histogram Equalization (HE) is one of the most effective and simple technologies for performing contrast enhancement[1, 2]. In contrast enhancement, this paper shows that the technique of the HE can reduce the number of gray levels by combining the gray levels of neighboring two or frequent more less at a gray level. Thus, the technique of the HE can stretch the brightness of high and low through the gray scale of high range. The resultant image then has a relatively more flatting histogram. This flattened histogram causes overall contrast enhancement of the input image[3, 4].

However, in the HE, any mechanism cannot control enhancement levels itself. This is because the output image has over the range of enhancement. The HE cannot

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Received 5 September 2021; Revised 3 October 2021; Accepted 21 October 2021
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be effectively performed when the input image contains the region that is substantially darker or brighter than other regions of the image. For getting over some limits mentioned the traditional method above and making it more variable, various techniques about contrast enhancement have been based on proposed methods by several groups' researchers. One of the most useful techniques is an Adaptive Histogram Equalization (AHE), which was advised by S. M. Pizer[5]. In this method, authors stated that each pixel could be mapped to intensity proportional to its rank in the pixels surrounding it. The AHE makes improved results in enhancing the signal component of the image. Nevertheless, in several cases, AHE tends to over-amplify noise in relatively homogeneous regions of an image. Noise enhancement can also make some artifacts in the output image. And those artifacts can decrease the expertise of the observer in confirming the important information contained the image. A variant of the AHE called Contrast Limited Adaptive Histogram Equalization (CLAHE) prevents this by limiting the amplification proposed by K. Zuiderveld, which has been a new and effective technique[6]. It has been made of dealing with these artifacts in the output image. Now, many users depend on the image technologies for getting an image acquisition that may have some types of inherent noise. This paper states that workers who use the medical devices can properly choose several filtering technologies for decreasing some noises and smoothing the out image. The quality of the image acquisition is attributed to the types of image enhancement technology that users used to more[7].

Finally, this paper discusses filtering and contrast enhancement technologies and then those technologies apply for various medical images[8]. The output images and image histograms to indicate the spectrum of the values at the pixel intensity are visually shown in figures below. This study was purpose to comparison of based on histogram equalization techniques by using normalization in thoracic Computed Tomography.

II. METHODOLOGY

The procedure with applying for equalization and normalization is described as below using the MATLAB software (R2021a). Enhancement of an image is occurring with using some technologies of histogram equalization. The flow of overall process is described in Fig. 1 and

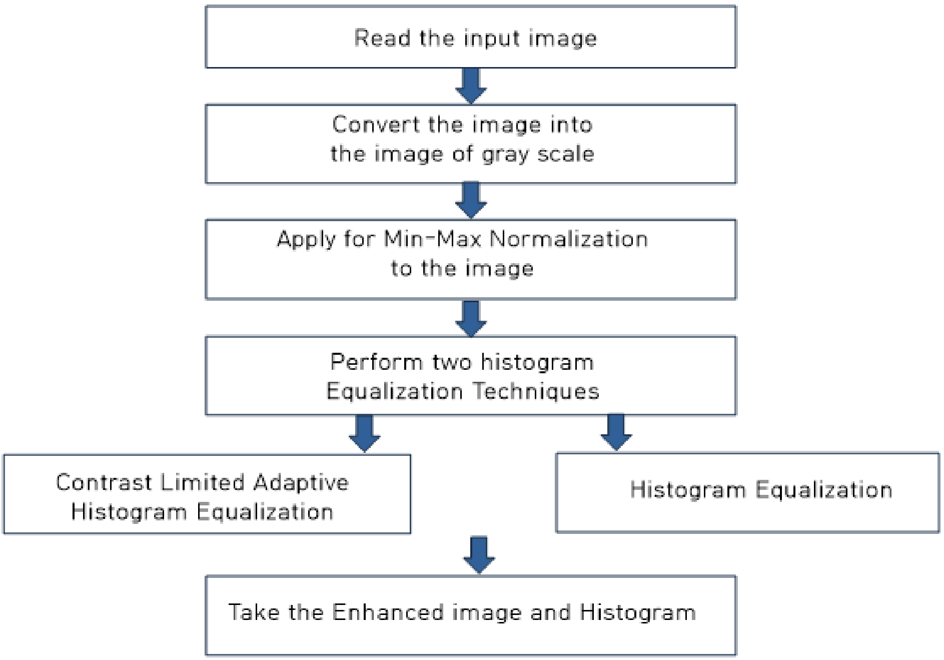

Fig. 1. Proposed algorithm for enhancement of medical images

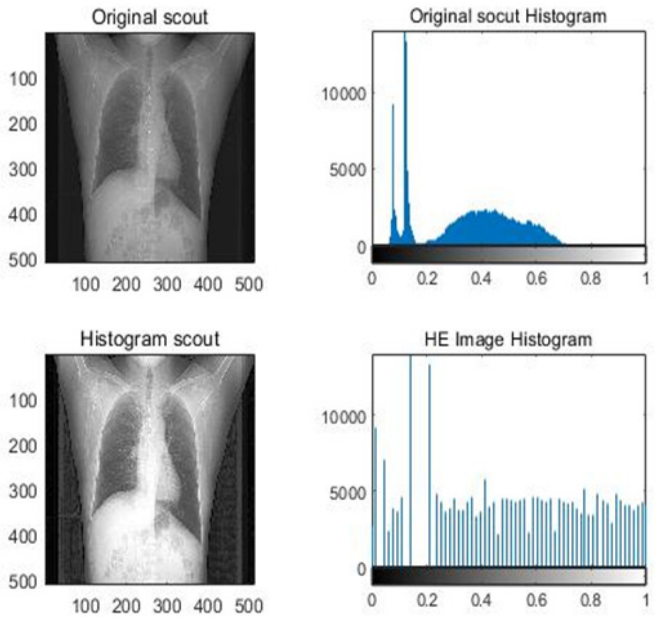

Fig. 2. Comparison of Initial and Final scout image with histogram after Histogram Equalization.

a scout image in CT is used as an input data.

And the configuration of the image is plotted in the histogram. The configuration is fundamentally the plot of intensity levels of pixels versus the number of pixels. The operation of the histogram is divided into two valuables of the input image, which are an image itself and the number of discrete instants. Although instants numbers are not entered in the parameters of the input image, the computing is performed with supposing the fundamental value. The mathematics operation is performed in the matrix of the image. Then, the operation will transform the matrix into the image with gray scale. And this computing assumes that the value in the black region of the image is a zero and white is a one. Then, the intensity value is modified consequently. The values in the field of the white and black will be measured maximum and minimum each. The intensive configuration in the histogram is subdivided for additional mortification. Next, the gray scale image is changed into an specific image with indexes. At the indexed image, the value is assigned in the input parameters of procedure that is predetermined by prior tasks. The indexed image is consisted of an array and color map. The image with indexes uses direct mapping the pixel value of the array to color map. The color map is also decided by the previous process. And then the image is changed the Probability Density Function (PDF) of the pixel and normalized. Next, the equalization of the pixels is performed with changing PDF to the Cumulative Density Function (CDF), converting multiplying maximum of range into the CDF value acquired. Then, the inverse of the CDF is computed and delivered with the matrix limits assigned through reshape operation and an object is generated as in[7, 8]. Then, the output values are acquired. The histogram of the image is much more stretched out. It improves the intensity levels and spatial density. The image conversion changed the blurred one to the proper and clear one. The equalized image shown in Fig. 2 seems to be brighter due to high levels of intensity, contrary to the original image.

1. DEFINITION SOME EQUATIONS

1) Probability Density Function (PDF)

A random variable χ with values in a measurable space $(\chi,\mathscr{A})$ (usually $\mathbb{R}n$ with the Borel sets as measurable subsets) has as probability distribution the measure $X*P$ on $(\chi,\mathscr{A})$: the density of χ with respect to a reference measure μ on $(\chi,\mathscr{A})$ is the Radon-Nikodym derivative:

$$F = \frac{dX \times P}{d\mu} \quad \text{Eq.1}$$

That is, $\mathscr{F}$ is any measurable function with the property that:

$$P_r[X \in A] = \int_{X^{-1}A} dP = \int_A F d\mu \quad \text{Eq.2}$$

For any measurable set $A \in \mathscr{A}$[9, 10].

2) Cumulative Density Function (CDF)

The cumulative distribution function of a real-valued random variable X is the function given by

$$F_x(x) = P(X \le x) \quad \text{Eq.3}$$

Where the right-hand side represents the probability that the random variable X takes on a value less than or equal to x. The probability that X lies in the semi-closed interval (a, b), where a 〈 b, is therefore,

$$P(a < X \le b) = F_x(b) - F_x(a) \quad \text{Eq.4}$$

In the definition above, the "less than or equal to" sign, "$\le$", is a convention, not a universally used one, but the distinction is important for discrete distributions. The proper use of tables of the binomial and Poisson distributions depends on this convention[11].

2. SCOUT IMAGE NORMALIZATION

Normalization is a procedure that changes range of the values with pixels intensity. And it is based on Beer's law. The purpose of active expansion with the gray scale in digital CT application is to generate an image with appropriate values for diagnosis in nature. It is described in the form as follow:

$$P_{Normalize} = \log\left(\frac{P_{Blank}}{P_{Raw}}\right) \quad \text{Eq.5}$$

Where $Pnormalization$ is a scout image normalized in CT, $Pblank$ is also a scout image with no object. And $Praw$ is a typical CT scout image.

3. HISTOGRAM EQUALIZATION TECHNIQUES

HE and their various techniques have been measured for contrast enhancement in several medical images. In this paper, it discusses several technologies when it comes to HE.

1) Histogram Equalization (HE)

The HE is a technology that adjusts the image intensity for improving contrast enhancement. An image with the histogram indicates mainly comparative frequency in occurrence of various gray levels in the images[12, 13].

$$P_n = \frac{no.of\,pixels\,with\,intensity\,n_k}{total\,no.of\,pixels\,n}, n = 0,1,...L-1 \quad \text{Eq.6}$$

Look at the input image with the gray scale at range from 0 to L-1. The PDF of the image can be calculated as follow:

$$P(r_k) = \frac{n_k}{n}, n = 0,1,...L-1 \quad \text{Eq.7}$$

Where $P(rk)$ is a gray level and nk is the number of pixels in the input image with gray level rk.

The HE method contains two important impediments affecting to efficiency of the method. The HE assigned a gray level to neighboring different two gray levels with other intensities. If most the images contain intrinsic gray levels, the HE of the image assigns gray levels with high intensity to that of gray levels and the output image can look like the blurred one, which is similar to the image with the low contrast. The HE can cause significant changes in the image with brightness that is getting the maximum values of image equally distributed.

2) Contrast Limited Adaptive Histogram Equalization (CLAHE)

This paper uses the CLAHE for sectional contrast enhancement that computes the region of different tiles of an image based on the histogram. Therefore, local features can be intensified even the region that is brighter or darker than most of the images. Thus, the CLAHE operation performs by limiting the amplitude of the histogram in the image[14, 15]. In addition, it also clips the amplitude of histogram as the green field in Fig. 3. And it causes some artifacts, which related to the noise shape, in the homogenous region of the image as shown in Fig. 3. The re-adjustment pushes up some bins through the clip limit again as the yellow region shaded in Fig. 3.

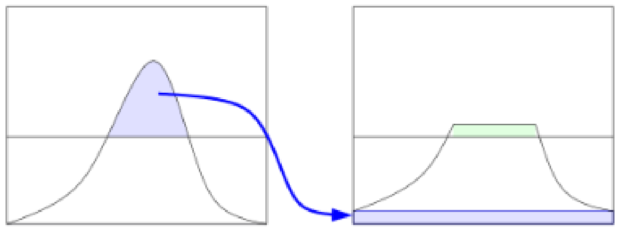

Fig. 3. Limits the amplification of histogram by clipping the histogram (Dashed line above)

The operation of the CLAHE can divide into two stages. To begin with, the image ought to be distributed some region that is not overlapped and almost equal sized. Secondly, each region of the histogram is computed. Then, the clip limit of cutting the histogram is obtained. In the next, each histogram is re-distributed in such a way that its height does not exceed the clip limit. The parameter of clip limit is acquired by β equation which can show in the form as follows:

$$\beta = \frac{M \times N}{L}\left(1 + \frac{\alpha}{100}(S_{\max} - 1)\right) \qquad \text{Eq.8}$$

Where β is a clip limit and $M \times N$ is the number of pixels in each region. And L is the number of gray scales and α is a clip element of range from 0 to 100. Last, $Smax$ is the maximum value of the probable slope. For instance, if α is zero from the equation (8) above, the clip limit is $M \times N / L$ as shown in Fig. 4, 5 [16].

Ⅲ. RESULT

For the statistical evaluation, the figure histogram is performed after conducting the procedure of the HE in MATLAB software. This paper considers some parameters forming statistical basis such as mean and median after applying the pre-processing operation. The study is relative typically. In other words, those factors were measured after the normalization and re-scaling operation. After then, the equalization operation could be processed with computing some statistical methods[7]. The range of mean and median is analyzed in the next process. In the figure with the first graph of the histogram has been shown as in Fig. 2, the figure is being produced at every instant and the range in the prior image has a lower gray scale. After applying for the HE, the latter image in Fig. 2 is improved. And the region, which is the lung hyper region like fissures, branches, nodules indicating as Fig. 2, tends to be brighter. The technique makes the CT medical checkup easier for diagnosis purpose. In the Fig. 2, this paper shows that the configuration of the latter histogram is much spread out. Plus, it is distinct that the configuration of the histogram is like an alliance of separate values. The histogram is a configuration of intensity versus number of pixels. Thus, the separate values are much higher in the Fig. 2 when comparing to the prior histogram. Because of the HE, detecting some fissures and demerits in the lung have gotten much easier as compared to the prior image[17, 18]. In both cases, the mean values after the scaling operation are 0.3994 and 0.5008 each. In both the figures of the histogram, having a look at the values of the median rendered the results that are 0.4364 and 0.4921 each(Table 1).

Therefore, this paper shows that users can confirm the resultant images through before and after applying for the operation of the HE to the input image. It is noticed that the prior one is like a blurred

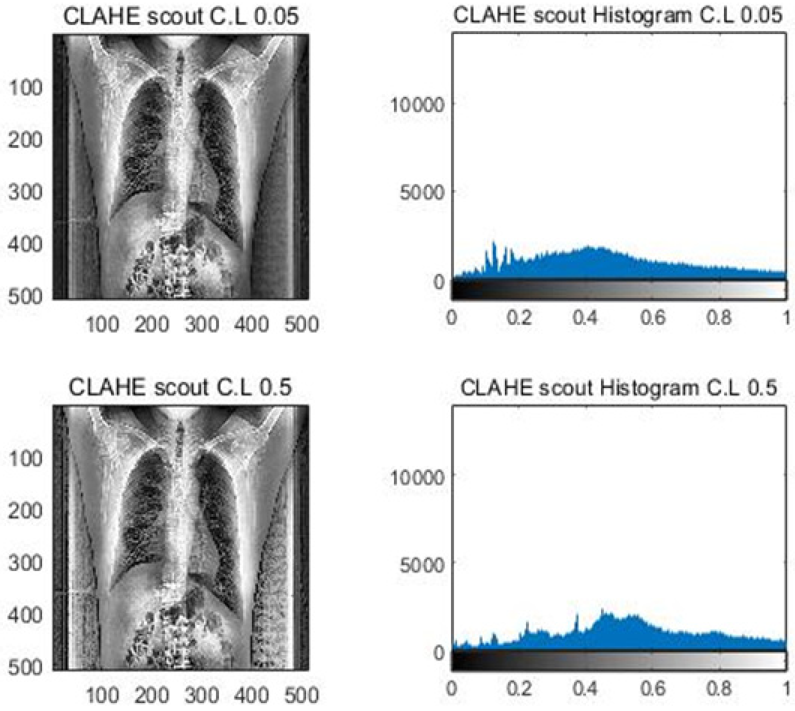

Fig. 4. Comparison of Initial and Final scout image with histogram after applying for CLAHE

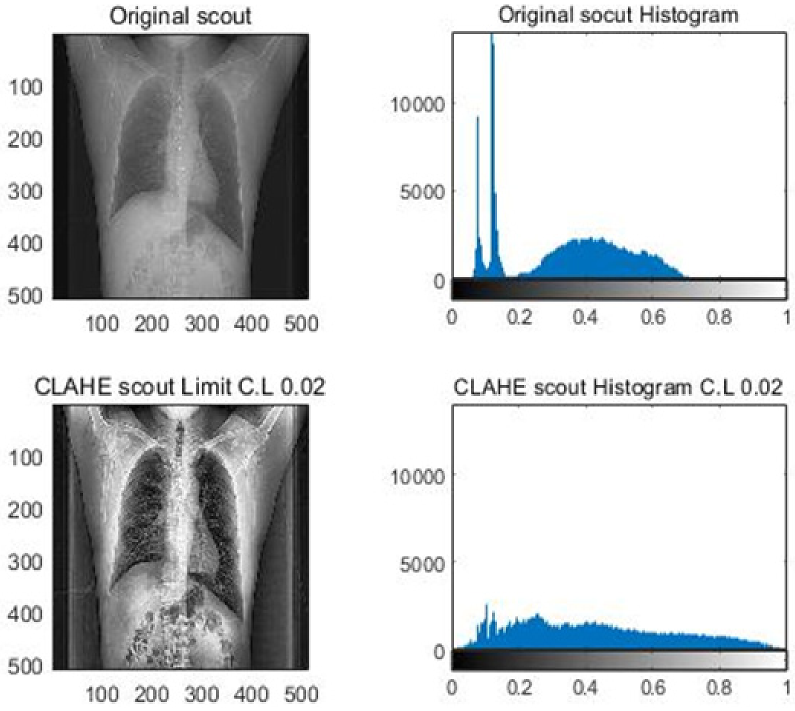

Fig. 5. Comparison of Initial and Final scout image with histogram after applying for CLAHE

image with the low contrast, and the histogram of the image does not be equally spread out over entire spectrum of the gray scale as shown in Fig. 2. For these reasons, mean and median values without applying for the HE are 0.3994 and 0.4364 each(Table 1).

After the operation of the HE, the histogram of the image in Fig. 2 is spread out over the whole range equally. Thus, number of pixels, which is positioned at each value

Table 1. Comparison of the values about the mean and median before and after applying for the Histogram Equalization

Technique	Mean		Median	
Histogram Equalization (HE)	Before	After	Before	After
	0.3944	0.5008	0.4364	0.4921

of the spectrum, increases as causing a higher contrast image than the before. As a result, the latter image is much lighter as described in Fig. 2. Likewise, the values of mean and median in the equalized histogram are 0.5008 and 0.4921 each(Table 1).

Ⅳ. DISCUSSION

In medical image processing, image analysis about the low contrast is a challenging issue[19,20]. Digital images of low contrast decrease the expertise of an observer, especially when analyzing the image. Image Enhancement is a method of converting the noised quality of an image into the advanced quality of an image. Thus, this paper is focused on analyzing image enhancement with by using various HE techniques such as HE, AHE, CLAHE, and so on. Thus, performs on a medical image, which is in the X-ray or CT device, through the MATLAB software. As compared to each histogram of the images, the results indicate that the quality of images after applying for the HE got higher contrast, contrary to the initial image with low contrast. The initial histogram of the images demonstrates that the number of pixels at the prior image is only positioned together partially without spreading out all ranges.

However, the traditional operation of the HE has been not dynamic gradually. And the operation is not considering the type of images as an input image. And the operation intensifies the all values of the gray scale without taking nothing into consideration. Accordingly, for solving these problems and improving the contrast depending on the types of the medical images, several modern technologies of the HE is needed to use such as Adaptive Histogram Equalization (AHE), Global Histogram Equalization (GHE), Dynamic Histogram Equalization (DHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE). Still these technologies cannot be used in the field of Customer Electronics and Medical Application. That is because these technologies can result in the undesirable output images under the critical clinical circumstance that the best result was expected all the time.

In short, the HE method is useful since the technique is much simple to conduct and fast to process. But the method of the HE generates numbers of demerits such as the output image is added some noise, enhancing the intensity of its background. And the signal got disarranged. The technique of the HE generates the enhanced resultant image and artifacts. This is because the HE spreads out the gray levels over the full range of the gray levels. Plus, many kinds of the HE is fundamental on the global methods. However, those global methods of processing medical images were insufficient to get over various problems entirely. Thus, many researchers should periodically propose some new techniques for processing medical images and workers ought to apply for the techniques situation.

Ⅴ. CONCLUSION

After applying for the operation of the HE, this paper obviously shows that the histogram gets spread out over on the spectrum of gray scale widely. And the HE can increase the pixels number at each spectrum resulting in improvement in contrast and brightness. Compared to the values of the mean and median in the histogram on the before and after image, this paper states that the values of the mean and median in the histogram of the latter image is higher than these in the histogram of the prior image. Therefore, this paper concludes that various techniques of the HE can be useful in many processes such as image pre-processing for ML, DL and distinguishing some fissures in the lung region.

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