A Comparison of Image Enhancement Methods for Lumbar Spine X-ray Image

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***Abstract*—A preprocessing technique is an essential in image processing. It enhances details of the image including edges before continuing further image processing. In this work, we compare three image enhancement methods for improving the contrast and details of the X-ray images that are needed for medical diagnosis subsequently. The image enhancement methods including Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE), Histogram Equalization (HE), and Contrast Limited Adaptive Histogram Equalization (CLAHE) were performed for purpose. Comparison of enhancing results are discussed. In this experiment, the results from the enhanced lumbar spine X-ray images show that the CLAHE technique is a technique that delivers excellent details and contrast among the other techniques.**

***Index Terms*—Image enhancement; Brightness Preserving Dynamic Histogram Equalization; Histogram Equalization; Contrast Limited Adaptive Histogram Equalization; X-ray image.**

I. INTRODUCTION

In the biomedical and medical fields has used x-ray image to diagnosis. The diagnosis of bone disease, the orthopedic medical or related doctor using x-ray image to analyze data and detail for abnormality identification [1]. Apart from x-ray also have several medical image modalities as a Computer Tomography, and a Magnetic Resonance Imaging. That used to identify severe bone disease and before the surgery. They can give the detail more is a ligament, tendon, and tissue but the examination is expensive [2]. Normally, x-ray images have characteristic are low intensity, high noise, and grayscale color, which data and detail may be distorted is affect the error in experiment [3].

Nowadays, image processing is a technique that manages and analyzes the information if image by a computer to processes. The processing there are several types of an image transformation, image description, image segmentation, face recognition, image filters, image enhancement, image restoration, and image compression [4]. For example, in the medical field have using the medical imaging to classify lumbar spine [5]. The system can identify the characteristic of lumbar spine. Most medical imaging analysis is often used in combination method to get results that help doctor's diagnosis those images faster [6]. In medical imaging, that requires a good quality image for using find the sharpen of detail and the extracted feature of an image, which is the importance of image processing for diagnosis [7]. The original x-ray image has the noise image. For help the segmentation image, it must be reduced noise and image enhancement [8]. Which is a challenge because x-ray image is low quality and limited information for feature extraction or segmentation.

The related research has enhancement x-ray image by using LabVIEW based on a fuzzy sure entropy was proposed [8]. At the Beginning, the x-ray images were the fuzzy c-partition to partitioned into two part as a bright part and dark part, and then corresponding involution fuzzy complements to compute the probability of the bright part and dark part. Then, attain optimal pair of the exhausted search approach for the maximum fuzzy sure entropy. the result has comparisons with four approaches: The Maximum Shannon Entropy Principle, the Median Filter (MF), the λ-enhancement method (λM), and the Maximized Parametric Index of Fuzziness (PIFM). The above method is tested on the "neck" and "hand" images that appears the method of paper is better than the λ-enhancement, the Median Filter, the Maximum Shannon Entropy Principle and the Maximum Shannon Entropy Principle.

As proposed and reported in [3], the analysis of vertebral bone image for segmentation using x-ray image enhancement methods was presented. There are three methods including Contrast Limited Adaptive Histogram Equalization (CLAHE), Grammar Correction (GC), and Histogram Equalization (HE). The comparison base on the output of before and after edge detection of image enhancement by the performance is quantified by specificity, the measurement of sensitivity, and accuracy of each method. In this paper, the result has shown CLAHE is the best accuracy and GC is the best sensitivity.

In [9], the x-ray image enhancement an efficient approach of detection the dental caries, based on the location of the lesion following by bottom-hat operation and morphological top-hat using the Contrast Limited Adaptive Histogram Equalization. Then using Homomorphic Filtering (HF) which reduces the noise and eliminates non-uniformity luminance distribution of the image. The comparison methods including: histogram equalization, following by morphological processing and noise suppression based on Wavelet packet transform (WPT); HF based on Fourier transform; CLAHE, MF, and HF based on Wavelet discrete transform (WDT), and CLAHE; Median Filter (MF); and the proposed method. The result of experimental have shown the images quality has better restoration of brightness level which the diagnostic has increase image information.

In this paper aims to compare the image enhancement result of x-ray image, so find out how to distribution feature extractions to efficiently by using a different preprocessing technique.

The rest of this paper is organized as follows. Section 2 provides the image enhancement techniques used in this study foundations. Section 3 present results from the studying enhancement methods and the discussion of the results is also given in this section. Lastly, conclusions are drawn in Section 4.

II. IMAGE ENHANCEMENT

Image enhancement is a process of highlighting or increasing the details of the image or adjust the contrast and intensity to increase the performance of image segmentation technique. Used samples of an x-ray image of the lumbar spine on the frontal and left side and collected from Mae Fah Luang University Hospital that provides a database of lumbar spine images.

The histogram is showing the distribution of image intensities. The image histogram is low spread has low contrast and histogram is high spread has high contrast. The height of the histogram graph represents the number of brightness value or tones. Each tone has a value from 0 - 255, with 0 is the darkest value and 255 is the brightness [3]. The suitable value of the histogram, In the middle of the graph, must be high value and the left and right side is the same height that appears similar to the dome.

Examples of the lumbar spine image is shown in Fig.1 this paper will compare the three exiting image enhancement methods including:

1) Histogram Equalization (HE)
2) Contrast Limited Adaptive Histogram Equalization (CLAHE)
3) Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE)

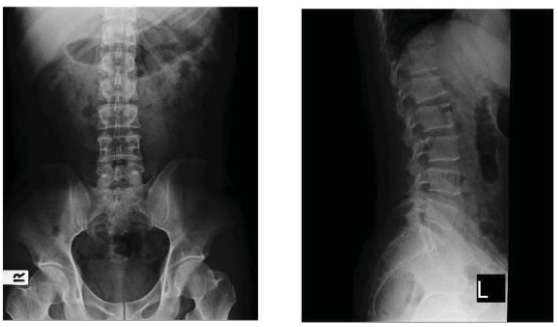

Fig. 1: Examples of lumbar spine images

A. Histogram

The original image and histogram of the image as shown in Fig.2 indicates that the histogram value is a slope from the left to the right side, which is closed to 0, so most of the image is darkest.

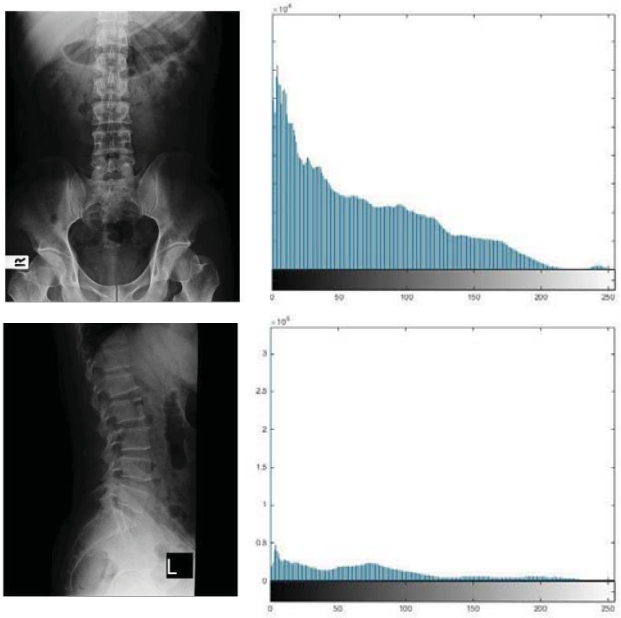

Fig. 2: Original lumbar spine x-ray images and their corresponding histograms.

B. Histogram Equalization (HE)

The most of using image contrast enhancement method is the Histogram Equalization by adjusting the each tile of histogram of the image. Histogram equalization using the histogram of the image to determine the intensity change function by making the probability density function of an intensity value of the image with spreading reduces the height of the histogram graph to flat with the equal distribution [10]. The histogram equalization enhances the contrast in an image, particularly in high-density areas in the histogram. So, that make histogram value is a uniform distribution [11]. The advantage of the HE is that it works automatically, without the need for parameter setting.

We see in Fig.3 that the results from Histogram Equalization method delivers brighter images than original ones shown in Fig.2; i.e., the lumbar spine can be seen more sharply. In addition, the obtained histograms value have the form of uniform distribution.

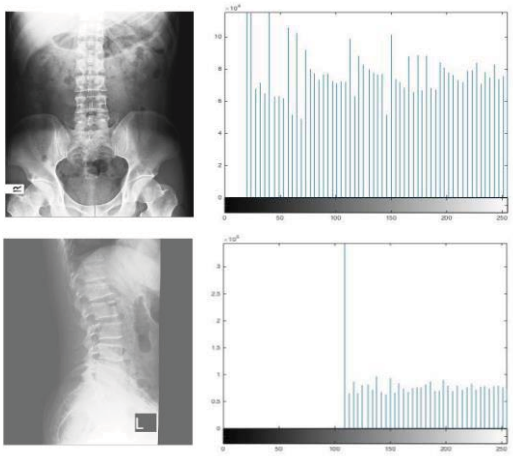

Fig. 3: Results from Histogram Equalization method

C. *Contrast Limited Adaptive Histogram Equalization (CLAHE)*

CLAHE is a procedure that is similar to the Histogram Equalization method, in which the ordinary histogram equalization uses single histogram for an entry image. But CLAHE uses a small area of the image called tiles it will equalization in the tiles. Then use a combination of neighborhood tiles to remove roughly added boundaries.

Contrast enhancement technique can adjust gray-level value, the process of CLAHE start with the image is divided into rectangular blocks of equal size and in each block is performed adjustment histogram. The main steps of a histogram adjustment have consists: the histogram creation, clipping, and redistribution. Then, cumulative distribution function (CDF) of the clipped histogram to the mapping function. Finally, remove possible block artifacts by the bilinear interpolation is randomize the color level to determine the origin pixel around the image as four points of the new pixel is considered between the block [12].

In Fig.4, the image is high contrast, more the details, and good white balance. The histogram value has distributed and histogram has an appropriate value.

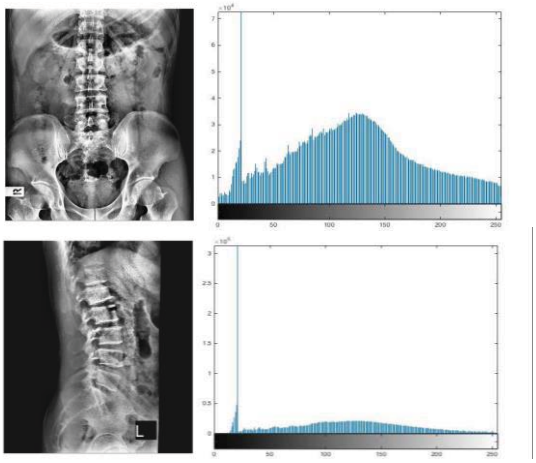

Fig. 4: Results from CLAHE method

D. *Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE)*

The Brightness Preserving Dynamic Fuzzy Histogram Equalization is the fuzzy domain that provides a technique for managing a better way in gray level instability and resulting of performance is better [13]. Used to enhancement abilities to adjust contrast and improve brightness preserving while simplifying calculations.

The first step is computation of fuzzy histogram. The fuzzy histogram is a fuzzy generalization of ordinary crisp histograms. That can be used to combine high performance statistics and high-performance computing. Then, partitioning of the histogram to better maintain the brightness of the image by increasing the sharpness. The partitioning according to the maximum histogram value that multiple sub histograms are performed at this stage. Then, dynamic histogram equalization of the sub-histograms consists of two steps are equalizing each sub-histogram and mapping partitions to a dynamic range, both methods is based on final number of pixels in the perform equalization has partitioning. Finally, normalization of image brightness, after adjusting the histogram, a different mean brightness will be used normalization to remove that the difference.

In Fig.5, it can be seen that the white part of the x-ray will increase more clearly to see the edge of bone but histogram value has the distribution is not different from the original image.

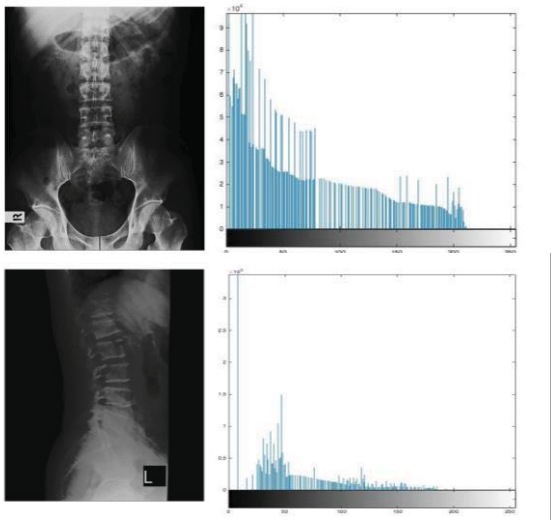

Fig. 5: Results from BPDFHE method

III. Result And Discussion

This paper selected three enhancement method are compared the Brightness Preserving Dynamic Histogram Equalization, the Contrast Limited Adaptive Histogram Equalization, and the Histogram Equalization and implemented on MATLAB. In order to tested on the lumbar spine image in frontal and beside.

The details of the original image are mostly dark. Therefore, the detail has rarely appeared and when compared

to HE, that shows more details than the original image. However, the pictures using the HE method show the same details which are clearer but less detailed. CLAHE method is very clear details and can be pulled structure detail in the dark. So, the details of the BPDFHE image not increase from the original because of too many the darker part. As compared to HE, CLAHE, and BPDFHE, the CLAHE shows more body structure detail.

The histogram of the original image has closely 0, so there is a lot of darkness. When using the HE method, the histogram is very distributed and the frequency of the histogram is reduced. The BPDFHE have the histogram value similar the origin image is just increase the distribution. The CLAHE method has a good histogram value, the middle value is high and the left and right values are the same high. The distribution of images is appropriate.

Table 1 has shown the result of the comparison of techniques by obtained from the formula applied in the MATLAB is I = sum(sum(image)). The HE is the most of all technique pixel value but is over brightness. The CLAHE is greater than origin image pixel value and less than HE value. So, the image has good white balance. And the last method, BPDFHE have less than original image pixel value is dark image. The CLAHE method provided the best image quality in comparison with HE and BPDFHE. So, the CLAHE method that clearly to see the structure, detail, and edge of lumbar spine image.

Seq.	Method	Pixel Value of Image 1	Pixel Value of Image 2
1	Original Image	211,174,409	301,612,082
2	HE	744,825,971	631,905,217
3	CLAHE	394,458,015	573,873,592
4	BPDFHE	210,320,663	301,720,658

Table 1: Comparison of techniques

IV. Conclusion

In conclusion, three selected enhancement methods are compared the Histogram Equalization, the Contrast Limited Adaptive Histogram Equalization, and Brightness Preserving Dynamic Histogram Equalization. The result shows that the CLAHE method can display detail and structure information more than the HE and BPDFHE method. Therefore, the appropriate process of enhancement is the CLAHE method. So, that can be developed in medical diagnosis.

Acknowledgment

The authors would like to thank Wiwat Chiewsilp, MD, School of medicine, for his support and encouragements. The publication of this work is funded by Mae Fah Luang University.

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