ORIGINAL ARTICLE

Stress Fracture Detection using Adaptive Histogram Equalization (Ahe) and Contrast Limited Adaptive Histogram Equalization (Clahe): A Comparative Study

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Abstract:

A lower extremity stress fracture is account about 80%-90% of all stress fractures and are standard among the person who involved in strength and substantial loading activities. Early detection and diagnosis manage to prevent further severe complication. However, initial plain radiography is unable to identify the presence of stress fracture approximately for an about up to six to ten weeks after the onset of the fracture; especially in the early stages without displacement of the bone fragment. The purpose of this paper is to discuss the enhancement of stress fracture detection of AP ankle digital X-ray by using image enhancement techniques. Two techniques are proposed in this paper, which is Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE). These study data images were retrieved from the online database. A total of 10 original images were retrieved, and 10 test images for each Set A and B are produced. The quantitative evaluation of this study was done, which is the structural similarity index measurement (SSIM) and peak noise to signal ratio (PSNR) in MATLAB software. AHE showed that it has better image enhancement and high image quality for SSIM and PSNR value compared to CLAHE. At $p>0.05$, there is a significant difference between SSIM and PSNR in AHE and CLAHE. From this study, it shows that the image enhancements techniques can be done as pre-processing steps to improve the enhancement of the stress fracture detection in digital AP ankle X-ray images.

Keywords: Stress fracture, adaptive histogram equalization (AHE), contrast limited adaptive histogram equalization (CLAHE), structural similarity index measurement (SSIM), peak signal-to-noise ratio (PSNR)

1. INTRODUCTION

Poor image contrast has become a common problem in radiography. It is due to limited exposure range owing to the varying thickness of the anatomy being examined. This eventually result in misinterpretation of the images. Study from Ghana had showed that the most common cause of poor image quality in radiography is due to inappropriate selection of exposure factors [1]. However, with recent development of image enhancement technique, poor image quality can be improved to meet proper diagnosis criteria [2]. The purpose of image enhancement is to enhance the detail or to improve the contrast of the low contrast images. Various image enhancement techniques such as noise reduction (filter), edge enhancement (Sobel edge detection) and contrast enhancement (histogram equalization; HE and adaptive histogram equalization; AHE) had been recommended [3] and widely used in image processing for human visual perception and computer vision [4].

The contrast enhancement plays an essential role in enhancing and providing better distinction of the anatomy of interest through an appropriate contrast appearance. As a result, the images with low contrast property can be enhanced for better visual interpretation.

Nowadays, the use of medical image processing allows doctors and other medical personnel to view fine details that are difficult to be interpreted or distinguish by using naked eyes. Usually, for nondisplaced fracture such as stress fracture, doctors may find it a bit difficult to be detected or may lead to the wrong diagnosis. However, with the used of medical image processing, it can assist the doctors and act as the second opinion [5].

The adaptive histogram equalization (AHE) contrast enhancement algorithm provides an excellent technique for contrast enhancement as it is effective, reproducible, and automatic operations that make it broadly applicable. AHE is distinct from standard histogram equalization (HE) where it computes a number of a histogram in adaptive method, each equivalent to a different segment of the image, and utilizes them to redistribute the values of the gray-levels of the [6].

Contrast limited adaptive histogram equalization (CLAHE); an improved version of AHE, manage to overcome problems possessed by AHE by limiting the over-amplification of noise in the image and resulting natural appearance of the images. CLAHE image is partition into many non-overlapping regions with almost equal in size, and then histogram equalization is applied to each the image, making equal distribution of gray-levels and improve visibility of the features. Thus, purpose of this study is to evaluate the ability of adaptive histogram equalization (AHE) and contrast limited adaptive histogram equalization (CLAHE) in detecting stress fracture.

2. MATERIALS AND METHODS

This is a retrospective secondary data analysis that performed to evaluate the enhancement of stress fracture detection by using adaptive histogram equalization (AHE) and contrast limited adaptive histogram equalization (CLAHE) with the application of median filter on anteroposterior (AP) ankle images. Ten (10) softcopy of the anteroposterior (AP) ankle images with stress fracture were retrieved from the free online database in PNG and JPG format.

2.1 Pre-processing

2.1.1 Noise addition

Poisson Noise was added to all ten (10) AP ankle images using MATLAB software.

2.1.2 Filter application

The Median filter was applied to all ten (10) AP ankle images using MATLAB software.

2.1.3 AHE and CLAHE application

Two sets; Set A and B, containing ten (10) AP ankle images each were produced. Images in Set A were applied with Adaptive Histogram Equalization (AHE), and images in Set B were applied with Contrast Limited Adaptive Histogram Equalization (CLAHE) using MATLAB software.

2.2 SSIM and PSNR quantitative evaluation

A total of twenty (20) images were produced and SSIM, and PSNR reading were done using MATLAB software.

3. RESULTS

In this study, independent sample t-test was used to compare the mean score between both image enhancement techniques, which are AHE and CLAHE techniques. The purpose of this study was to find the significant difference of mean score of SSIM and PSNR between AHE and CLAHE techniques in enhancing the detection of a stress fracture on AP ankle digital X-ray images. The independent sample t-test was conducted based on the quantitative measurement of SSIM and PSNR of both Set A and Set B images on MATLAB application. The alpha value for this experiment is set at α=0.05 with 95% CI.

3.1 Quantitative Evaluation between Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE) using SSIM

Table 1: The Independent sample t-test between AHE ("Test A") and CLAHE techniques ("Test B") for SSIM

	AHE (n=10) Mean (SD)	CLAHE (n=10) Mean (SD)	Mean Difference (95% CI)	t-stats (df)	P-value
SSIM	0.479 (0.065)	0.179 (0.0571)	0.299	10.914 (20)	0.00

From the finding, for Structural Similarity Index Measurement (SSIM), there is a significant difference ($p<0.05$) in image quality in AHE and CLAHE techniques with statistical analysis of [M = 0.479, (SD) = 0. 0653] and [M = 0.179, (SD) = 0.0571] respectively.

3.2 Quantitative Evaluation between Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE) using PSNR

Table 2: The Independent sample t-test between AHE ("Test A") and CLAHE techniques ("Test B") for SSIM

	AHE (n=10) Mean (SD)	CLAHE (n=10) Mean (SD)	Mean Difference (95 CI)	t-stats (df)	P-value
PSNR	18.888 (1.233)	9.155 (1.738)	9.733	14.444 (20)	0.00

From the result for Peak Signal-Noise-to Ratio (PSNR), there is a significant difference (p>0.05) in image quality in AHE and CLAHE techniques with statistical analysis of [M = 18.888, (SD) = 1.233] and [M = 9.155, (SD) = 1.738] respectively.

4. DISCUSSION

4.1 Evaluation of Independent Sample T-Test on Image Quality between different Image Enhancement Technique

From the result, it showed that there is a considerable difference overall image quality of both SSIM and PSNR between both image enhancement techniques. For overall image quality assessment, at α= 0.05 with 95% CI, with significant value (p<0.05), it is suggested that either one of the image enhancement technique tested are significant to be used to enhance the detection of a stress fracture on digital X-ray images. From the result, it shows that SSIM and PSNR of AHE have higher mean score compared to SSIM and PSNR of CLAHE to enhance the detection of stress fracture in digital X-ray images with M (SSIM) = 0.4785, M(PSNR)

= 18.888 and M (SSIM) = 0.1791, M(PSNR) = 9.155 respectively.

Previous study by Ahmed et al., the AHE produced images have higher SSIM values with lower entropy when comparing with HE and CLAHE. Besides, AHE produced maximum entropy values with better SNR values compared with other techniques. Furthermore, in some medical imaging applications, uniform re-distribution in CLAHE is not preferred as the corresponding values are evenly distributed over the entire dynamic range, which further amplifies the noise. However, in other studies by Pujiono et al., AHE useful for increasing local contrast but with a limitation that it over amplifies inhomogeneous noise regions of the image, but with the use of CLAHE has less noise, prevents brightness saturation and gives better results in local areas than other techniques like HE, AHE etc. [4].

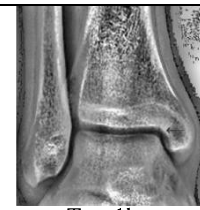
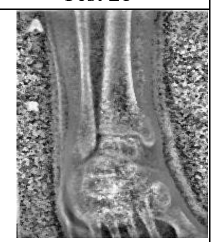
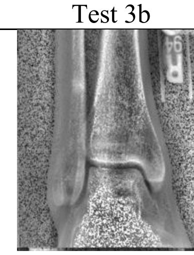
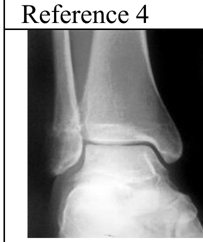
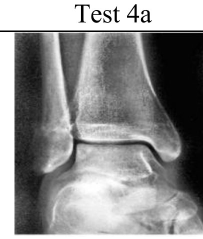
4.1 Image Enhancement by using Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE)

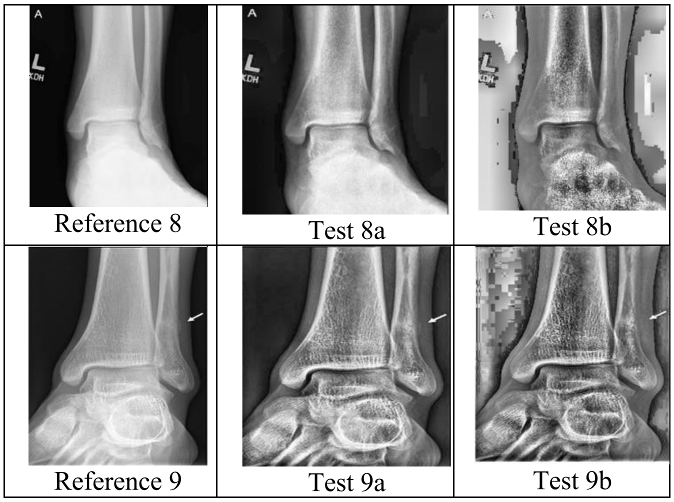
Image enhancement is among the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement techniques is to bring out detail that is obscured or simply to highlight certain features of interest in an image [10]. The adaptive histogram equalization (AHE) is a technique used to enhance the contrast in the images. It distinct from normal histogram equalization through computes a number of histograms in the adaptive method, each equivalent to a distinct segment of the image, and utilizes them to redistribute the values of the gray levels of the image [6]. A study was done by C. Rubini and

Pavitra et al., reveal that the Enhancement using AHE technique produces good results but with the ultimate enhancement of slight background noise present in the image. However, slow speed and the over enhancement of noise is produced in a relatively homogeneous region are the two problems of AHE [11].

In CLAHE proposed by Pizer etc. is a classic AHE-based image enhancement method, which first separates the image into numbers of continuous and non-overlapped sub-blocks, then enhances every sub-block individually and finally uses an interpolation operation to reduce the block artefacts [10]. The AHE is capable of attaining high contrast; however, the output image may be over enhanced [12]. A study was done by Ikhsan et al. to compare pre-processing method between Histogram Equalization (HE), Gamma Correction (GC) and Contrast Limited Adaptive Histogram Equalization (CLAHE) in vertebral bone segmentation found that GC achieved the best sensitivity while CLAHE obtains the best accuracy. Since accuracy measures correct detection, either positive or negative, it is the most suitable performance metric for the intended application. Thus, the most suitable algorithm for image enhancement is CLAHE [5].

Table 3: Reference and post-processing images for AHE and CLAHE

Reference Image	AHE	CLAHE
 Reference 1	 Test 1a	 Test 1b
 Reference 2	 Test 2a	 Test 2b
 Reference 3	 Test 3a	 Test 3b
 Reference 4	 Test 4a	 Test 4b
 Reference 5	 Test 5a	 Test 5b
 Reference 6	 Test 6a	 Test 6b
 Reference 7	 Test 7a	 Test 7b



Reference 8 | Test 8a | Test 8b
Reference 9 | Test 9a | Test 9b

In this study, based on Table 4.2.1, it is demonstrated that the quality of the test images degraded compared to original images. This is because further addition of noise to the image increases the image noise and the median filter that is used in this study cannot remove all the noise entirely. Moreover, in the AHE technique, the noise present is further amplified, thus reduce the image quality, SSIM and reduce the PSNR value compared to the original images. From the result, the image enhancement done by AHE showed higher SSIM and PSNR value compared to CLAHE. Even though the image quality is being degraded by AHE, it provides high contrast images and more significant enhancement of stress fracture detection compared to CLAHE. Besides, in CLAHE, the contrast limiting property is applied for each neighborhood from which the transformation function is derived. The contrast limiting property is controlled on the histogram equalization process. The neutrality of the original image is still preserved. However, this limiting property of CLAHE to enhance the contrast may not allow the observer to clearly depict the presence of some significant gray-scale contrast [4].

5. CONCLUSION

From this study, it shows that the image enhancements techniques can be done as pre-processing steps to improve the enhancement of the stress fracture detection in digital AP ankle X-ray images. Two types of images enhancement were proposed in this method which is AHE and CLAHE. From the result obtained in this study, from independent sample t- test showed there is a significant difference between the proposed methods. Since $p>0.05$, the null hypothesis which is Contrast Limited Adaptive Histogram Equalization (CLAHE) can improve the stress fracture detection; thus, the image will have higher SSIM and PSNR value was accepted where the means is treated as equal to the hypothesized population. It is also accepted that higher SSIM and PSNR value of the image enhancement techniques can be used to improve the stress fracture detection in digital AP ankle X- ray. From this study, the use of image enhancement process can be aided to enhance the stress fracture detection.

Future research can be done to improve this study but with an addition of other digital image processing algorithms such as segmentation. Furthermore, from this study, this can act as the alternative method that can be used by the doctors and radiologist for the detection of stress fracture without giving extra radiation to the patient and less waiting time.

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