Enhancing the Contrast of CT Medical Images by Employing a Novel Image Size Dependent Normalization Technique

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Abstract

Employing an efficient contrast enhancement technique is considered as an essential step to improve the overall visual representation of clinical images, and as a consequence provides better diagnosis results. This paper employs an easy, fast and reliable technique to improve the contrast of different types of computed tomography (CT) medical images by applying the technique directly to the entire image and normalize it depending on its size in the spatial domain. The experiment is conducted on naturally degraded CT images collected from diverse medical imaging repositories. Likewise, a comparison is presented between the suggested approach and other popular contrast enhancement techniques. Besides, the accuracy is measured using the universal image quality index (UIQI) metric.

Keywords: *Computed tomography (CT) images, Contrast enhancement, CT degradations, Image size dependent normalization technique, Medical image processing*

1. Introduction

In the digital domain, images are sampled into small components named pixels. Digital images are handled as matrices. Each matrix contains the light intensity at each sampled point (pixel) [17]. Medical images are one of the forms of digital images. Medical imaging is an indispensable mean of diagnosing diseases that lead to a better patient's care and recovery. During the previous decades, vast improvements in information technology and medical devices have led to significant enhancements in the field of medical imaging. Computed tomography (CT) imaging is one of the areas that have seriously concerned lately [1]. CT medical images are affected by different types of degradations such as noise [2], blur [3] and contrast imperfections [4]. This paper handles the issue of enhancing the contrast of CT medical images only. Generally, the computed tomography (CT) medical images own a low contrast, and enhancing the intensity of CT images is a vital issue for humans. The contrast of any image is decided by its dynamic range, which is defined as the ratio between the brightest and the darkest pixel intensities. Many reasons led to imperfection in the contrast such as varying display devices, acquisition methods, transmission storage, restoration and enhancement algorithms [4, 5]. Improving the contrast of medical images would lead to better visual representation of the images, improved syndromes diagnosis, more accurate detection of diseases and as a consequence enhancing the contrast of the CT images will show smaller components and features of the medical image allowing the therapist to perform a healthier treatment for the patient. Enhancing the contrast of CT images is considered as a pre-processing step in many medical image processing applications. This paper is structured as the succeeding: Section 2 explains in details the proposed technique. Section 3 demonstrates the experimental results of applying the suggested technique to different medical images. Section 4 illustrates a comparison between the technique offered by this paper and other popular methods. Finally, the conclusion is highlighted in Section 5.

2. The Proposed Technique

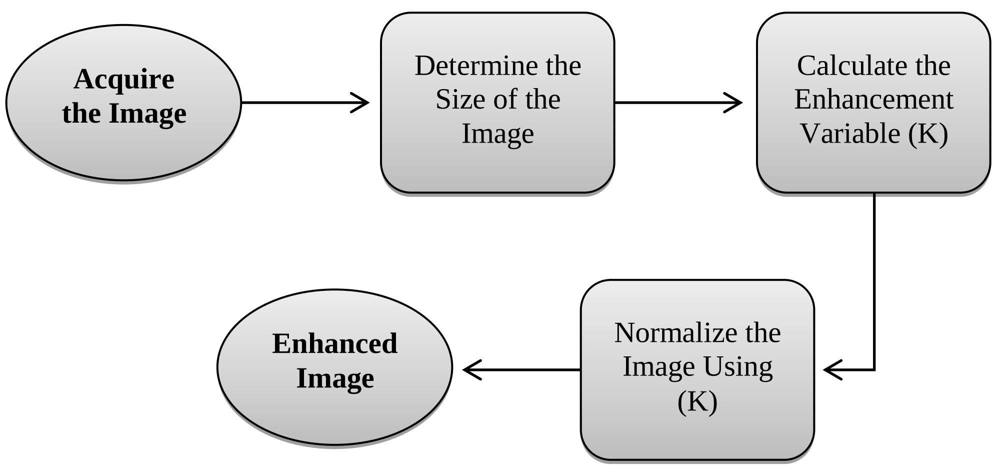
When enhancing the contrast of computed tomography (CT) medical images, two factors to complete the task must be considered, those are speed and efficiency. The proposed technique considers these two factors by supplying a fast processing with effective results. This technique has been utilized in the spatial domain. Moreover, it has been applied to the entire image directly instead of processing the image pixel by pixel. Normalizing the image based on its size takes the following course: first, the size of the processed image is determined. Then the enhancement variable (K) is computed using the subsequent equation:

$$K = \frac{\sum_{i=1}^{i} \sum_{j=1}^{j} x(i,j)}{m \times n}$$

Where (*x*) is the degraded image, the above equation sums all pixels values and divides them by the size of the image represented by (*m*) and (*n*). Finally, the image is enhanced using the following equation:

$$EI = \frac{[x - \min(x)] \times \mathrm{e}^{\mathrm{K}}}{[\max(x) - \min(x)]}$$

Where (*x*) is the degraded image, (*min*, *max*) are the minimum and maximum pixel values of the processed image, (K) is the enhancement variable, and (EI) is the contrast improved image. The following flow chart represents the enhancement methodology:



3. Experimental Results

The proposed technique applies to different types of CT medical images collected from various websites, medical imaging databases or papers across the internet. In this paper, three images will be demonstrated to verify the success of the proposed technique as in Figure 1. Later, the suggested technique will be compared to different well-known contrast enhancement methods. The comparison can be seen in the following section.

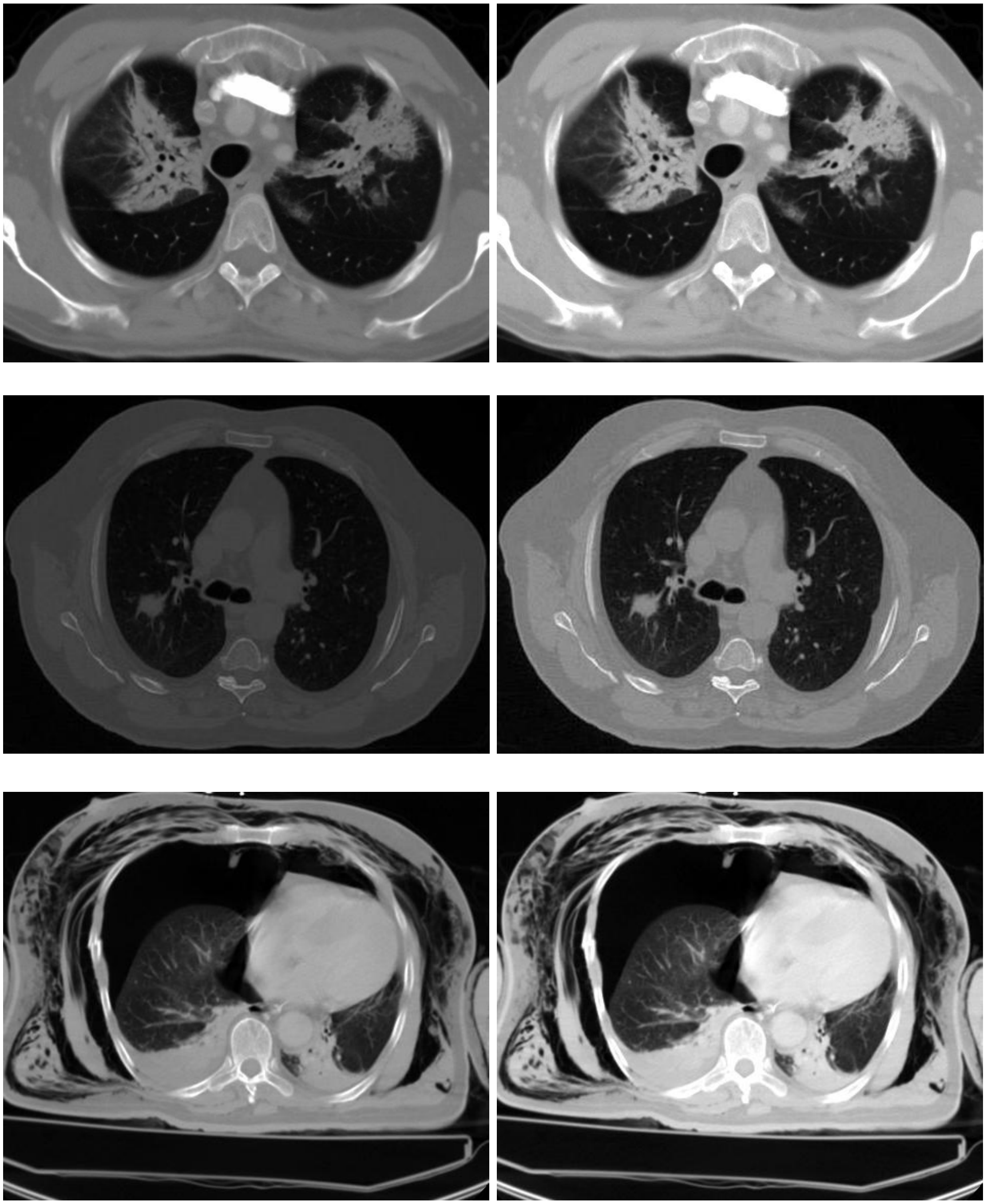


Figure 1. Images on the Left Column are the Degraded CT Images, on the Right Column are the Enhanced Images using the Proposed Technique

4. Comparison

The need to compare the proposed technique with different other common methods is highly required to determine its effectiveness. Therefore, varied techniques such as traditional histogram equalization [9], brightness preserving Bi-histogram equalization [6], equal area dualistic sub image histogram equalization [7], brightness preserving dynamic fuzzy histogram equalization [10, 11], sigmoid function [15], adaptive contrast enhancement and

Fourier domain based enhancement [8], have been chosen to be compared with the proposed technique. Measuring the accuracy of these methods is done by using the Universal Image Quality Index (UIQI). This metric was chosen due to its robustness. Likewise, the UIQI measures the distinction between the original, and the resulted images in terms of luminance, contrast, and structural comparisons [12, 13, 14]. Figure 2 illustrates the results of the comparison, while Table 1 shows the precision measurement using the UIQI metric.

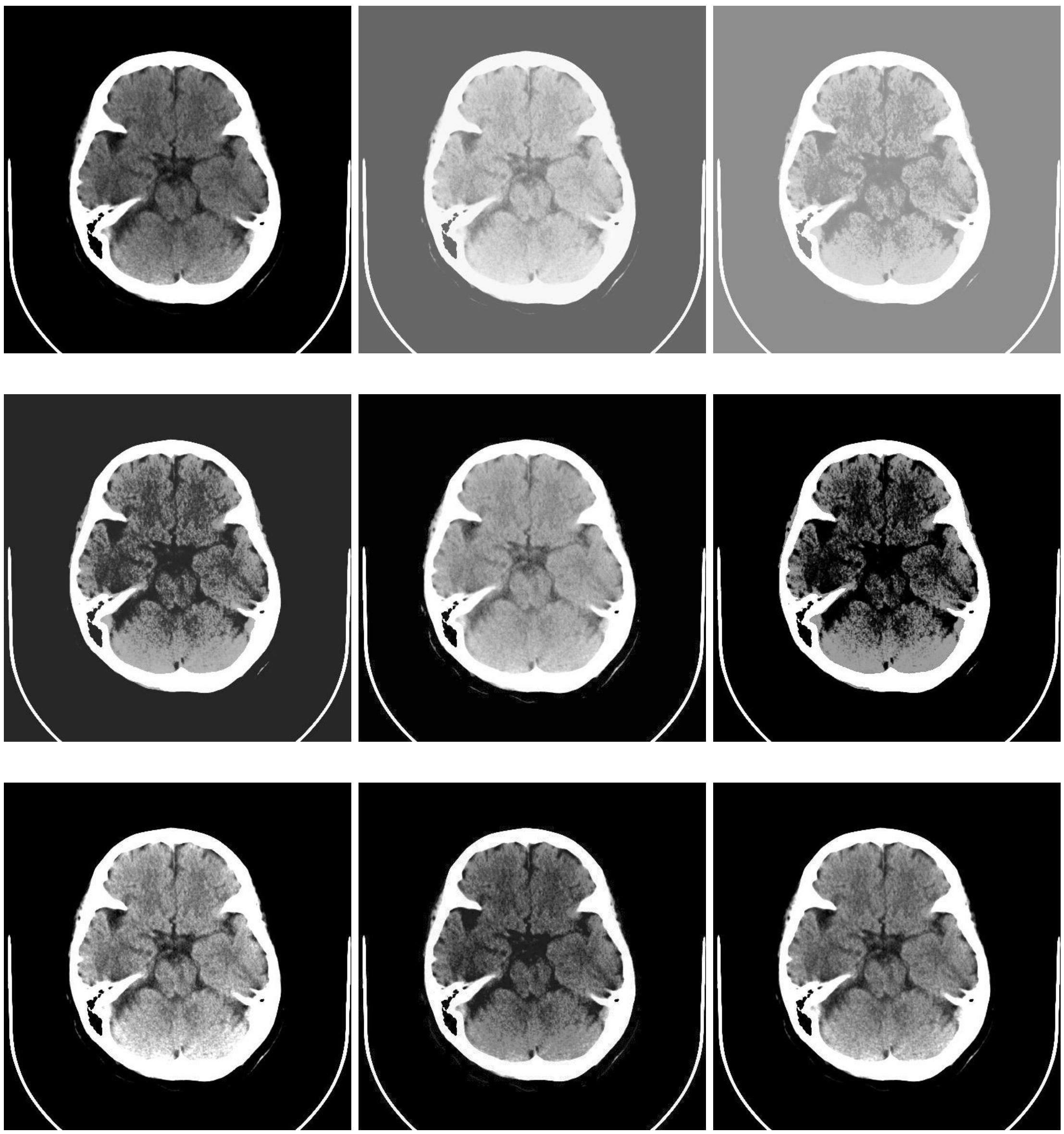


Figure 2. Images from left to right, top to bottom: Original image [16], Processed by a sigmoid function, Processed by histogram equalization, Processed by brightness preserving Bi-histogram equalization, Processed by Fourier domain based enhancement, Processed by equal area dualistic sub image histogram equalization, Processed by adaptive contrast enhancement, Processed by brightness preserving dynamic fuzzy histogram equalization, and Processed by the proposed technique.

Table 1. The Measured Accuracy Values of the Compared Methods

Methods	*(UIQI)*
Sigmoid Function	**0.2440**
Histogram equalization	**0.2625**
Brightness preserving Bi-histogram equalization	**0.3208**
Fourier domain based enhancement	**0.3264**
Equal area dualistic sub image histogram equalization	**0.7946**
Adaptive contrast enhancement	**0.8700**
Brightness preserving dynamic fuzzy histogram equalization	**0.8916**
Proposed technique	**0.9109**

5. Conclusion

As exhibited previously, the process of enhancing the contrast of CT images using a normalization technique that depends on the image size gave extremely convincing results. When measuring the accuracy with the UIQI metric, the suggested approach gave the highest result. This method is straightforward and fast due to several reasons, such as, it's applied directly to the entire image, not to every pixel of the processed image. It functions in the spatial domain. It contains a small number of mathematical operations. Fast implementation along with granting the processed image a reasonable intensity since it depends on the normalization technique not on a statistical redistribution of pixels values similar to histograms.

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