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Studyof Unsharp Masking and Contrast Limited Adaptive Histogram Equalization on CT Images of Emphysema

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Abstract- Emphysema is a chronic pulmonary disease caused due to devastation of air sacs present inside the lungs. Emphysema symptoms can be slowed with medications but can't be cured. Accuracy of diagnosis is very limited and there are several factors behind its misdiagnosis. Poor textural quality is one of thesignificant factors behind poor diagnosis of emphysema. In this article, emphysema images textural quality is enhanced using UnsharpMasking and Contrast Limited Adaptive Histogram Equalization. Result alsosupports a significant increase in contrast improvement of emphysema images. This method potentially suppresses noise and enhances the image contrast as well.

Keywords:Contrast Limited Adaptive Histogram Equalization (CLAHE), Computer Tomography (CT),Contrast Enhancement(CE), Emphysema,UnsharpMasking(UM).

I. INTRODUCTION

Normal lung tissue looks like a new sponge. Emphysematous lung looks like an old used sponge, with large holes and a dramatic loss of "springy-ness" or elasticity. When the lung is stretched during inflation (inhalation), the nature of the stretched tissue wants to relax to its resting state. In emphysema, this elastic function is impaired, resulting in air trapping in the lungs. Emphysema destroys this spongy tissue of the lung and also severely affects the small blood vessels (capillaries of the lung) and airways that run throughout the lung. Thus, not only is airflow affected but so is blood flow. This has dramatic impact on the ability for the lung not only to empty its air sacs called alveoli (pleural for alveolus) but also for blood to flow through the lungs to receive oxygen.

Emphysema is detected from CT images based on the textural changes in the image [1-4].
Poor clarity of textural content is one of the major factors which preclude the diagnosis of the Emphysema from CT images [5]. Among the available state of art techniques, Robert's, Perwitt's, Sobel, Laplacian and Laplacian of Gaussian (LOG) [6-7] operators are discrete kernels for computing first or second derivatives of the image. Generally, they are used in edge detection and cannot be employed directly for improving the region-wise contrast or clarity of textural content.

Contrast Limited Adaptive Histogram Equalization (CLAHE) [8-11] is one among the most popular contrast enhancement schemes used in medical image processing. Open platform for bio-image informatics, 'icy' and open source raster graphics editors like, Imagej, ImageMagick etc. have CLAHE plug-in. CLAHE is useful for enhancing the contrast among distinct regions in the image. However, it does not have the ability to sharpen high frequency content of the image. Unsharp Masking (UM) [12-14] is one of the widely used sharpening techniques, capable of magnifying high frequency content of the image.UM is so popular that many commercial as well as open source raster graphics editor software like GNU Image Manipulation Program (GIMP), Imagej, Paint.NET, Corel® AfterShot™ Pro 3, Image Magick etc. have plug-in of UM in them.

It has already been pointed out that CLAHE can improve only region-wise contrast and cannot influence the local edge strength. Even though, UM is a tehnique particularly dedicated for image sharpening, it has some serious constraints as well. In UM, a fraction of the thresholded difference image formed between the original image and its Gaussian blurred version is added back to the original image to improve the sharpness. The thresholding causes discontinuity artefacts in the sharpened image. UM over-saturates the image. Moreover, UM has three arbitrarily defined parameters which are threshold, the fraction termed as 'amount' and the paramters of Gaussian kernel. Tuning multiple operational parameters together is cumbersome.Similar to UM, CLAHE also has multiple operational parameters like tile size, clip-limit, specifications of the expected histogrm etc. Hence, there is an immediate need for a noise robust and user friendly sharpening technique with less number of operational parameters, free from discontinuity and saturation artefacts.

II. REVIEW OF LITERATURE

A. State of art methods in literature

C. C. Pham and J. W. Jeon[15] used adaptive guided image filtering for the simultaneous denoising and sharpening. H. Ibrahim and N. S. Pik Kong [16] suggested that Sub-Regions Histogram Equalization is helpful for sharpening the images. Another method, Human visual system based unsharp masking [17] for the enhancement of mammographic images is simply a modified version of UM. A fuzzy model based method was adopted by F. Russo [18]. T. C. Aysal and K. E. Barner[19] made use of quadratic weighted median filters for edge enhancement of noisy images. Superposed vortex filter for directional edge enhancement in fingerprint images [20] and Non-linear polynomial filters for edge enhancement of mammogram lesions [21] are another two sharpening approaches available in literature, worth mentioning. Sharpening approaches in wavelet domain include, directionlet transform based sharpening of mammographic X-ray images [22], unidirectional and omnidirectional edge enhancement based on radial Hilbert transform of Gabor filter [23] and sharpening dermatological Color Images in the Wavelet Domain [24]. In the approach for dermatological images, the distribution of squared gradient magnitudes computedthrough anundecimated wavelet transform was modeled as a combinationof chi-squared and gamma distributions, and a posteriori probabilities where used to discriminate coefficients related to edgesfrom those related to noise or homogeneous regions at each scaleof the wavelet decomposition. Consistency across scales was used topreserve coefficients likely to be edge related in consecutive levelsof the wavelet decomposition, and local directional smoothing issued to reduce residual noise. Then, a nonlinear enhancementfunction was applied to wavelet coefficients, so that low-contrastedge-related wavelet coefficients are increased.

B. Lacuna drawn from the review

The major constraint associated with guided image filtering [15] is the need for a reliable ground truth. Sub-Regions Histogram Equalization [16] is mere an extension of global histogram equalization meant for limiting over-enhancement. The extensions of histogram equalization are helpful for improving the region-wise contrast. They do not have the ability to sharpen the edges selectively. No customized or dedicated method suitable for sharpening MRI is known to be available in literature. The modifications of UM [17] also are not free from discontinuity and saturation artefacts. The fuzzy model based approach [18] does not have appreciable noise suppression capability. Quadratic Weighted Median Filters [19] are computationally inefficient. Superposed vortex filter [20] and Non-linear polynomial filters [21] are also not free of computational overhead. Compared to fingerprint images MRI has very less Signal to Noise Ratio (SNR). The performance of the wavelet based approaches [22-24] purely depends on the selection of mother wavelet and the level of decomposition. It is very difficult to identify the wavelet sub-bands corresponding to noise. Perhaps noise may be present in multiple sub-bands. Hence it is quite tedious to extract a noise robust outcome from sharpening approaches in wavelet domain.

III. METHODOLOGY

The original CT images used in this research were downloaded from the web source http://image.diku.dk/emphysema_database/. Firstly the Contrast limited adaptive histogram equalization (CLAHE)is used to improve the contrast of the selected gray scale image. Later on unsharp masking is done to sharpen the image.

The conventions followed in UM and the steps involved in its computation are as follows; usually, the grey level at the edge pixels would be considerably greater than its neighbourhood average. Whereas, at homogenous regions the grey level value would be close to the neighbourhood average. At noisy pixels, the deviation of the grey level from the neighbourhood average is expected to be moderate. Consequently, in the difference image between the original image and its low-pass filtered version, obtained via neighbourhood averaging, edge pixels will have larger magnitude than the pixels from homogenous or noise affected regions. The difference image is usually considered as the high-pass filtered version of the original image. In UM, an arbitrary fraction of the difference image is added to the original image to improve its sharpness. The difference image,

$$\mathbf{D = X - (X{*}{*}H_G)} \qquad \mathbf{(1)}$$

Where, X is the original image and H_G is the Gaussian convolution mask. For ease of computation, (1) is usually realized as [8],

$$\mathbf{D=(X{*}{*}H_0) - (X{*}{*}H_G)= [H_0-H_G]{*}{*}X} \quad \mathbf{(2)}$$

The Gaussian kernel H_G is of the general form,

$$\mathbf{H_G(x,y)=\frac{1}{2\pi\sigma^2}e^{-\left(\frac{x^2+y^2}{2\sigma^2}\right)} \qquad -w\leq x\leq +w \ \ and \ -w\leq y\leq +w} \quad \mathbf{(3)}$$

There is practice of maintaining a formal relationship between the radius of the Gaussian kernel and its standard deviation σ. One of the typical form is σ = (w-1)/4. It can be noted that the standard deviation of the Gaussian increases in proportion to the radius of the kernel, in this case. With respect to the increasing radius of the kernel, the rate of decay of the Gaussian function with respect to the distance from the centre also increases so that the depth of smoothening increases drastically. The second convolution kernel H_0 is,

$$\mathbf{H_0(x,y)=\begin{cases}1 & x=0\ \&\ y=0\\ 0 & Otherwise\end{cases} \qquad -w\leq x\leq +w \ \ and \ -w\leq y\leq +w} \quad \mathbf{(4)}$$

In UM, to sharpen the image X, an arbitrary fraction of the difference image D ie. High-pass filtered version (1-2) is added to it. The fraction is generally referred as amount (λ). In some contexts it is also called as scale or gain as well.

$$Y=X^{**}H_0+\lambda([H_0-H_G]^{**}X)= X^{**}(H_0+\lambda[H_0-H_G]) \quad 0\leq\lambda\leq 1 \quad (5)$$

Adding a fraction of the difference image uniformly to the original image may amplify the noise contributed pixel intensity transitions. Based on the conventions that, in the difference image the edge pixels will have larger magnitude than the pixels from homogenous or noise affected regions, the difference image is thresholded with respect to an arbitrary threshold retaining the grey level magnitude at the edges intact. So that, after thresholding, the grey level magnitude in the difference image corresponding to homogenous and noise affected regions become zero. When the fraction of the thresholded difference image is added back to the original image, the edges in it become sharp and noisy as well as homogenous regions remain unaltered. The thresholded difference image,

$$D_T(m,n)=\begin{cases} D(m,n) & \text{if } |D(m,n)|\geq T \\ 0 & \text{Otherwise} \end{cases} \quad m=1,2,\ldots M \ \& \ m=1,2,3,.N \quad (6)$$

$$T=\alpha Max(|D|) \qquad 0\leq\alpha\leq 1 \qquad (7)$$

Where M and N are the number of rows and number of columns in the image.α is an arbitrary parameter termed as ‘threshold’ which limits the noise amplification. In effect, D_T comprises the differential edge strength between the original and smoothened image. The sharpened image thus become,

$$Y=X+\lambda D_T \quad (8)$$

The schematic of the UM is shown in fig. 1.

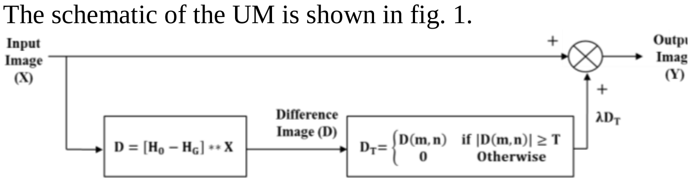


Figure. 1: The schematic of the steps involved in UM

IV. RESULTS OF UNSHARP MASKINGANDCLAHE

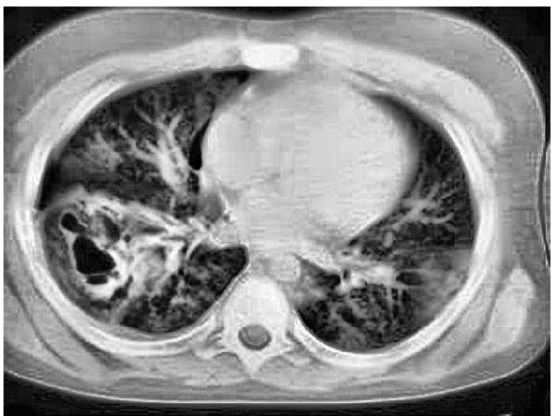
Output images obtained from CLAHE and UM for three different MR slices are shown in fig. 2 and fig. 3. In the output images of CLAHE, furnished in fig. 2(b) and fig. 3(b), it can be noticed that CLAHE is able to improve the region-wise contrast. It does not have the ability to selectively strengthen the textural content. CLAHE saturates the image and hampers its naturality. It undesirabily amplify noise as well. The amplification of background noise is particularly visible in the enhanced images.

Unlike CLAHE, UM is a technique specifically meant for image sharpening, rather than enhancing the inter-region contrast. In UM, a fraction of the thresholded difference image formed between the original image and its Gaussian blurred version is added back to the original image to improve the sharpness, as already mentioned. The thresholding causes sharp discontinuities in the sharpened image. Another issue associated with UM is that, the bright or well enhanced regions in the image become easily over-saturated. UM disturbs the naturality of the image and the relative strength of edges/textural content in it.

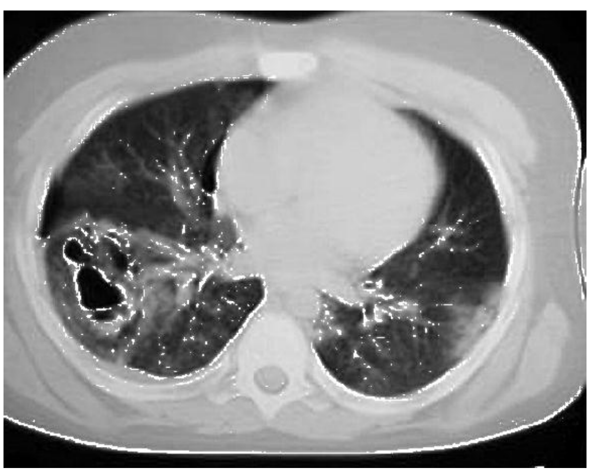
(a) (b)

(c)

Figure. 2: (a) Original CT slice 1 (b) Output of CLAHE (c) Output of Unsharp Masking



(a) (b)



(c)

Figure. 3: (a) Original CT slice 2 (b) Output of CLAHE (c) Output of Unsharp Masking

V. CONCLUSION

Results suggest that CLAHE and unsharp masking can sharpen the image along with enhancing the inter-region contrast. Such methods can be applicable for examining medical images.

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